Chapter 7

Recent Dietary Studies in the Arctic

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Summary

Dietary surveys serve several purposes, namely to describe and analyze the food choice and nutritional adequacy of the diet and to assess the role of food components as sources/carriers of anthropogenic pollutants, including heavy metals, organochlorine (OC) compounds and radionuclides. Dietary surveys have been performed among Arctic populations as part of the AMAP Human Health Programme and as part of independent studies. A very large body of dietary information has been accumulated in Canada over the last twenty years, especially by the Centre for Indigenous Peoples' Nutrition and Environment (CINE).

This chapter focuses mainly on recent AMAP-related dietary studies, in particular where it has been possible to make comparisons between different geographic and ethnic groups. Despite very large variations, the general tendency is clearly that traditional/country food consumption is gradually decreasing as imported foods become more available and culturally acceptable to the Arctic peoples. This is most clearly shown by dietary indicators such as human blood lipid profiles of n-3 and n-6 polyunsaturated fatty acids; the n-3 : n-6 ratio is a strong marker of traditional food intake, mainly indicating the consumption of marine mammals, but also terrestrial fish and game. The high levels of n-3 fatty acids in traditional/country food are thought to provide some protection against cardiovascular disease and diabetes. On the other hand, human blood levels of marine-acquired n-3 fatty acids are strongly associated with levels of persistent organic pollutants (POPs), because the main dietary source of POPs is fat (blubber) from marine animals.

7.1. Positive effects of traditional foods

The traditional food of the Arctic indigenous peoples can be defined as consisting of specific compositions of local products gathered and prepared in certain ways that are thereby meant to fulfill the nutritional and cultural needs of the population group concerned (Kuhnlein and Receveur, 1996). Traditional/country foods include many Arctic animals and plants. Various species of fish are caught, including salmon and trout (*Salmo* spp.), whitefish (*Coregonus* spp.), burbot (*Lota lota*), and Arctic char (*Salvelinus alpinus*). In Arctic coastal communities, marine mammals, including various species of seal, bowhead whales (*Balaena mysticetus*), beluga (*Delphinapterus leucas*), walrus (*Odobenus rosmarus*), sea lion (*Eumetopias jubatus*), and polar bear (*Ursus maritimus*) are a valuable source of food. Both coastal and inland communities fish and hunt terrestrial animals with caribou/reindeer (*Rangifer tarandus*) forming a significant part of the diet. Although caribou/reindeer is the most important terrestrial mammal, moose (*Alces alces*), muskox (*Ovibos moschatus*), brown bear (*U. arctos*), black bear (*U. americanus*), Dall sheep (*Ovis canadensis dalli*), and a number of smaller animals are also caught. Berries, mushrooms, roots, and green plants are also gathered. In addition to their importance as a source of nutrition, traditional foods serve as a focus for cultural and social activities and help to maintain the social bonds within societies through the traditional sharing of the hunt/harvest and feasting together.

The indigenous peoples are well aware of the many benefits of traditional food systems, and as such these form integral parts of their holistic concept of health. Certain benefits are repeatedly emphasized in surveys regarding attitudes toward traditional foods: well-being, health, leisure, closeness to nature, spirituality, sharing, community spirit, pride and self-respect, economy, and the education of children (Van Oostdam *et al.*, 1999; Jensen *et al.*, 1997).

The traditional foods vary from community to community according to the availability of natural resources, climatic conditions and seasonal changes, but are particularly associated with the cultural traditions and associated technological skills which form the identity of the ethnic group concerned (Van Oostdam *et al.*, 1999). In Canada for example, Dene/Métis food is quite distinct from Inuit food, but both are generally referred to as 'country food' as opposed to 'market food' or imported food.

In Greenland, the traditional Inuit food 'Kalaalimernit' literally means 'little pieces of Greenlanders' as opposed to imported food 'Qallunaamernit' meaning 'little pieces of Danes'. Thus the traditional food of the Inuit is considered necessary as building blocks for a human being and as necessary for providing health, bodily warmth (to withstand the cold climate), strength and well-being in a way that imported food cannot.

7.1.1. General changes in food consumption in the various Arctic populations

Despite their awareness of the benefits of traditional food, during the last 50 years the energy content of the diet of indigenous peoples in most Arctic communities has increasingly been met by imported food products. For Baffin Island Inuit, market food now accounts for approximately 62% of the diet; for Sahtu Dene/Métis in the northwestern Canadian Arctic it is about 70%; in Fort Resolution in the North West Territories (NWT) 90% (Kim *et al.*, 1998); and for Greenland Inuit 75% to 80% (Pars, 2000). The percentage range is very large and in all cases dependent on location, road access, infrastructure, season, gender, and age group (Jensen *et al.*, 1997; Kim *et al.*, 1998; Kuhnlein, 1995; Kuhnlein *et al.*, 1995a,b, 1996; Kuhnlein and Receveur, 1996; Pars, 2000). The change can best be illustrated by examining the differences in intake of traditional food between older and younger generations. Three generations of adult women from Nuxalk, British Columbia, were interviewed about present and retrospective food use. Although outside the Arctic, their experience illustrates the steady decline throughout the twentieth century in the use of traditional plant food, such as berries, roots and greens, as well as a decline in the use of wildlife by indigenous peoples. The reasons given were the introduction of fishing- and game Acts, and their associated restrictions, better availability of market food, and increasing employment leaving less time for the traditional but time-consuming harvesting and hunting.

A 24-hour dietary recall survey of three generations of Baffin Island Inuit showed that traditional food accounted for an average of 30% to 40% of the daily energy intake, but was much less among younger people than older people. Among Baffin Island Inuit and NWT-Dene/Métis the average traditional food consumption varied from 200–300 g/day among the 13 to19 year age group, to 600–700 g/day among the 41 to 60 year age group (Kuhnlein *et al.*, 1996). As caribou is the main source of radiocaesium, whole body measurements of radiocaesium may be used to indicate caribou intake. Such a study on adults from the Baker Lake Area, NWT, indicated that caribou consumption had decreased from >250 g/day in 1967 to <70 g/day in 1989 (Jensen *et al.*, 1997).

Consumption of traditional Inuit food in Greenland (reported as monthly meals of seal, whale, wildfowl, and local fish) ranged from 20 meals/month among the 18 to 24 year age group to more than 40 meals/month among people over 60 years old (Bjerregaard *et al.*, 1997).

The same association between age and the intake of traditional foods was thus found in Canada and Greenland. Men generally consume traditional food more frequently than do women.

A decrease in the consumption of traditional food in the Russian Arctic, especially of reindeer meat, is less evident, despite the fact that since 1992 the quantity of market food transported to rural settlements and towns has increased considerably (Klopov, pers. comm., 2001). The continuing emphasis on traditional food relative to market food reflects tradition, low income, and the high price of imported foods. Consumption of reindeer meat by the indigenous peoples of the Taymir Peninsula is still about 400 g/day (Klopov, pers. comm., 2001). The non-indigenous peoples of Arctic Russia also eat local reindeer meat; approximately 80 to 200 g/day. The main reason for the majority of residents in the remote Russian Arctic relying on subsistence food, hunting, and fishing, is economic (Klopov, pers. comm., 2001).

7.2. Recent and ongoing dietary surveys in Arctic populations

7.2.1. Alaska

In 1987/1988, eleven indigenous communities in Alaska participated in a study of dietary intake. The study evaluated the nutritional contributions of various food items and listed some of the important sources of nutrition in traditional and imported foods (Egeland *et al.*, 1998a). More recently nutritional intake in a small number of Siberian Yupik in Alaska (29 men, 35 women) was investigated using a 91-item food frequency questionnaire (FFQ) (Nobman *et al.*, 1999). Marine mammal and fish intake, milk, syrup and pizza, and 27 different nutrients were correlated with cardiovascular risk indicators, such as the ratio between low density lipoprotein cholesterol (LDL-cholesterol) and high density lipoprotein cholesterol (HDL-cholesterol). Multiple linear regression analysis indicated a complicated situation in which the foods and nutrients that were significantly associated with LDL:HDL varied according to gender and age group.

The AMAP Human Health Monitoring Programme includes the Alaska Native cord blood monitoring programme. This aims to sample 20 to 25% of the pregnant women in the Arctic coastal and Bering Sea populations each year and will include dietary assessments, analysis of blood for POPs, heavy metals, and selenium (Se), and maternal urine analysis for radionuclides (AMAP, 2000).

7.2.2. Canada

Dietary assessments have been included in several surveys of indigenous peoples in Canada (Kim *et al.*, 1998; Kuhnlein, 1995; Kuhnlein and Receveur, 1996). Some studies focused directly on the amounts of anthropogenic substances in traditional food items while others presented comprehensive profiles of their nutritional components. Nutritional intakes and their distribution between traditional and market foods were determined for Inuit from the Baffin region based on data collected in 1987/1988 (Kuhnlein *et al.*, 1996). This study found marine mammals to represent 20 to 28% of the total energy intake, terrestrial animals 9%, fish 2%, and market foods 66%. A dietary survey of 16 Dene/Métis communities (Receveur *et al.*, 1997) and Inuit from the Baffin region (Kuhnlein, 1995; Kuhnlein and Receveur, 1996) concluded that their diets were deficient in calcium, vitamin A, and folic acid. Twelve years of data concerning the risks and benefits of food in Nunavik were integrated in the Arctic Environmental Protection Strategy Report (Dewailly, 1998). The report concluded that vitamin A intakes were insufficient due to seasonal variation in food availability; that iron deficiency was common among young women despite an apparently adequate iron intake, and that vitamin C intakes were only 25% of the recommended daily intake. The report also concluded that calcium intakes among Inuit were low, at around 50% of the recommended daily intake.

A recent survey has studied the traditional and market food intake of 426 Nunavik Inuit by 24-hour recall (Blanchet *et al.*, 2000). Habitual food intake over a year was studied in 246 women using an FFQ. Energy and nutritional profiles (only 10 different nutrients were considered) were calculated and the relative contributions of traditional and market foods were determined. Traditional food was identified as an important source of vitamin D, iron, Se, and phosphorus, and was the major source of the n-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Vitamin A and calcium were low in these diets. Market food was an important supplement for carbohydrates, and several other nutrients, such as vitamin A, calcium, and magnesium. The situation for vitamin C was not reported. In the same survey, the intake of fatty acids, plasma phospholipid fatty acids and cardiovascular risk indicators were measured and compared between sexes and two age groups (below and above 40 years old) (Dewailly *et al.*, 2001b). Men and women over 40 years old had a significantly higher intake of traditional foods and n-3 fatty acids than either men or women under 40 years old, corresponding to a higher relative concentration of EPA and DHA in plasma phospholipids. No correlation studies were reported between intake of fatty acids and their levels in blood.

Canada is currently implementing the AMAP Phase II Human Health Programme. Maternal blood contaminant monitoring has been completed or is underway in the Baffin, Kitikmeot, Kivalliq and Inuvik regions, and the results to date are reported in section 5.2.1.1. Dietary surveys have been completed in nineteen Inuit communities and the data are currently being analyzed (AMAP, 2000).

7.2.3. Greenland

The use of traditional food in Greenland has been examined in a countrywide study (n=1500) in which the results of different dietary survey methods (FFQs and semi-quantitative food frequency questionnaires; SQFFQs) were compared with the results of 48-hour and 24-hour recall (Pars, 2000). Within this wider investigation, a more in-depth study was carried out focusing on Disko Bay, with a sample size of 250 persons (Pars, 2000). To date, the information on intake of traditional food items (i.e., frequency and amount or weight) has been analyzed for different gender and age groups. As in most Arctic communities, the relative and absolute intake of traditional food increased with age and was higher in settlements than in towns. The AMAP Human Health Programme includes a small, 10-item, purely qualitative FFQ; the responses to which supported the general pattern of traditional food intake (Deutch, 1999, Deutch and Hansen, 2000). There was a reasonably good correlation between consumption of marine foods and blood mercury (Hg) levels (Pearson's bivariate correlation coefficient 0.417, $P<0.001$) and between marine food and n-3 fatty acids in plasma (0.42, $P<0.001$) or erythrocytes (0.39, $P<0.001$). In 1999/2000, more detailed dietary surveys were carried out in relation to the AMAP Human Health Effects Monitoring Programme. These included a 24-hour recall survey for 48 men from Uummannaq and an SQFFQ for 50 men and 50 women from Scoresbysund (Ittoqqortoormiit) and Ammassalik (Tassiilaq) (Deutch, in prep.).

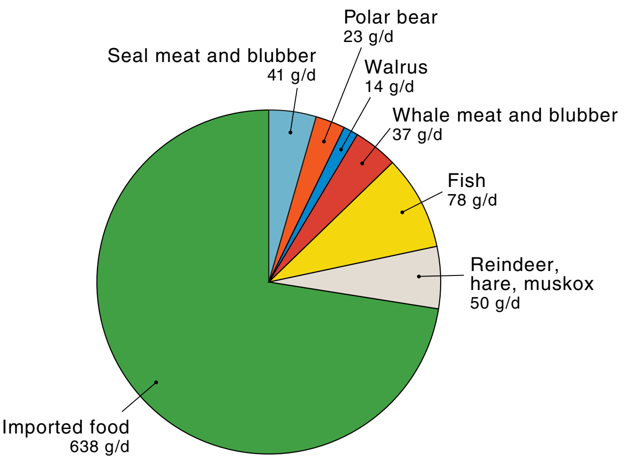

Figure 7·1. Estimated daily intake of traditional and imported foods in East Greenland in 2001 by semi-quantitative food frequency questionnaire (n=180).

Figure 7·1 illustrates the distribution of traditional and imported food intake in East Greenland and represents the outcome of a survey of 180 people (50 men and 40 women from both Tassiilaq and Ittoqqortoormiit). Traditional food represents 27% of the total solids intake, and is slightly but not significantly higher in Ittoqqortoormiit than in the more southern Tassiilaq. The intake of polar bear was higher in Ittoqqortoormiit, while fish intake was higher in Tassiilaq, which also had a more varied diet in terms of imported fruit and vegetables (Deutch, in prep.). There is currently no documented record of the dietary nutritional intake profile for the Greenland population. The data on which Figure 7·1 is based could be used to calculate nutritional intakes, however this has not been done to date.

Table 7·1. Dietary nutrient intake of pregnant women in the Faroe Islands and Finnish Lapland compared to the Nordic Nutrient Recommendations for pregnant women.

	Faroe Islands[1]	Finnish Lapland[2]	Nordic Nutrient Recommendations[3]
Sample size	150	127	
Total energy (kJ)	10200	7500	
Protein (E%)	14.7	16.3	15
Lipid (E%)	33	36	30
Carbohydrate (E%)	52	47.6	55–60
Saturated fat (E%)		16.2	10
Monounsaturated fat (E%)		11.1	10
Polyunsaturated fat (E%)		4.6	>3
Fiber (g/day)		19	
Retinol (equivalents/day)		878	800
Folic acid (µg/day)		260	400
Vitamin C (mg/day)		114	70
Vitamin D (ìg/day)		3.7	10
Vitamin E (mg/day)		7.4	10
Calcium (mg/day)		1170	900
Fe (mg/day)		10 + suppl.	10[4]
Zn (mg/day)		11.5	9
Se (mg/day)		68	55
Sum of n-3 fatty acids (E%)			0.5

E%: percentage of total energy intake.
[1]Weihe (pers. comm., 2002); [2]Mussalo and Soininen (pers. comm., 2002); [3]Nordisk Ministerråd (1996).
[4]Supplement recommended.

7.2.4. Faroe Islands and Iceland

An FFQ study of the adult population in the Faroe Islands showed an average daily consumption of 72 g fish, 12 g whale muscle, and 7 g blubber (Weihe *et al.*, 2000). A detailed dietary survey by FFQ and 24-hour recall was undertaken in 2001 for 150 pregnant women in accordance with the AMAP Human Health Effects Monitoring Programme. Table 7·1 shows a provisional calculation of mean nutritional intake values, for macronutrients only, based on three interviews, 24-hour recall, six food diaries per person, and using the Dankost Nutrient database (Weihe, pers. comm., 2002). The data are presented together with data for pregnant women in Finnish Lapland obtained by a comparable method (a food diary, and by using the Nutrica Nutrient database).

No recent dietary surveys have been reported for Iceland.

7.2.5. Northern Scandinavian Saami

7.2.5.1. Sweden

In 1987, food and nutritional intake were examined in a Swedish population (indigenous and non-indigenous) by repeated 24-hour recalls. The Saami had a high intake of protein and fat and a low intake of carbohydrates. Reindeer-breeding Saami had a lower than recommended intake of vitamin C (Becker, 1995). In 1990, the nutritional intake of a group of Saami was compared to that of the local Swedish population. The Saami carbohydrate intake had increased and had become more like that of the non-indigenous Swedish population, while their intake of certain minerals (Fe, zinc (Zn), and Se) and vitamin B-12 was also higher (Håglin, 1988, 1991).

7.2.5.2. Norway

In 1999, the dietary pattern of a group of Saami living in northern Norway (n=75) was compared to that of other Norwegians by dietary history interview. Their nutritional profiles were determined and the contributions made by various food items were calculated. The findings indicated that their diet was generally adequate except for folic acid for which their intake was too low. Calcium and iron intakes were slightly below recommendations for females. The diet of the Saami group was found to be changing towards a more typical Norwegian diet (Nilsen *et al.*, 1999). Reindeer accounted for 7% of their total energy intake, relative to 1.5% for the typical Norwegian diet; their intake of lean plus fatty fish was almost the same, representing approximately 12% of energy intake.

7.2.5.3. Finland

The Finnish National Public Health Institute has monitored adult health behavior (including dietary habits) since 1978 using annual postal surveys of 5000 persons. Since 1999, data have been gathered to investigate the variability in health characteristics between Finnish provinces (Nummela *et al.*, 2000). The surveys indicate that women in Lapland eat less bread than elsewhere in Finland, and that they prefer lighter food alternatives on bread. Also, that men in Lapland drink more fatty milk, and that both sexes eat fresh vegetables less often than in other parts of Finland. Healthy dietary habits were rarer in Lapland than elsewhere in Finland. Absence of teeth was common, perhaps because dental visits were rare.

During the period 1996 to 1998, as a part of the AMAP Phase I follow-up, 147 pregnant women from seven communities in the most northern and northeastern parts of Finnish Lapland completed a questionnaire concerning information on age, occupation, lifestyle, hobbies, parity, miscarriages, illnesses, use of medicines, and diet. These women completed an FFQ during their third trimester and 124 also kept a 7-day food diary. The nutritional intakes of these women were calculated using the Nutrica nutrient calculating program from the Finnish Social Insurance Institute. Mean nutritional intake values are shown in Table 7·1 and trace element and heavy metal intakes are shown in Table 7·2. The macronutrient distribution and the nutritional intakes for pregnant women in Finnish Lapland generally fall within the Nordic Nutrient Recommendations, although intakes for folic acid and vitamins D and E are slightly below recommendations. The results also indicated that dietary Hg intake was correlated with the Hg concentration in maternal whole blood ($r=0.293$, $P<0.01$) (Mussalo and Soininen, pers. comm., 2001).

Table 7·2. Estimated intake of trace elements and heavy metals by pregnant women in Finnish Lapland. Mussalo and Soininen (pers. comm., 2002).

	Finland[1]	
	mean	min – max
Iron, Fe (mg/day)	10.06	4.9 – 19.0
Manganese, Mn (mg/day)	4.92	1.8 – 10.4
Zinc, Zn (mg/day)	11.45	5.8 – 20.3
Copper, Cu (µg/day)	1187.31	598.7 – 2206.9
Cobalt, Co (µg/day)	13.36	6.6 – 31.9
Nickel, Ni (µg/day)	121.72	39.1 – 357.3
Chromium, Cr (µg/day)	23.5	9.0 – 59.1
Fluorine, F (µg/day)	385.77	173.6 – 777.2
Iodine, I (µg/day)	210.09	94.2 – 413.5
Selenium, Se (µg/day)	68.18	34.4 – 123.7
Arsenic, As (µg/day)	28.71	9.2 – 221.7
Aluminium, Al (mg/day)	4.29	2.3 – 7.8
Mercury, Hg (µg/day)	3.65	0.9 – 16.4
Cadmium, Cd (µg/day)	10.38	4.5 – 19.1
Lead, Pb (µg/day)	48.25	20.4 – 118.3

[1]sample size = 127.

In general there was very good agreement between the two methods used (i.e., FFQs and food diaries) so only food diary results are reported here. Protein accounted for 16.3% of the total energy intake and was higher than the recommended intake in Finland (i.e., 10–15%). Fat accounted for 36.0% of the total energy intake and was slightly higher than recommended (i.e., about 30%). Saturated fat accounted for 16.2% of the total energy intake and was considerably higher than the recommended intake of 10% in Finland. Essential polyunsaturated fatty acids accounted for 4.6% of the total energy intake, which is less than the recommended 5% for pregnant women in Finland (Finnish national recommendation), but more than the 3% Nordic Nutrient Recommendation. The energy intake from carbohydrates (47%) was also below the Finnish recommended level (55–60%). The estimated mean fiber intake was 19.3 g/day, which is below the minimum recommended intake (25–35 g/day), and 80% of the pregnant women had a fiber intake below the recommended minimum of 25 g/day. Reported alcohol use was very low, at below 1% of total energy intake.

The mean intakes of vitamins D and E, thiamin and folic acid were below recommended levels in Finland for pregnant women. Iron intake from the diet was 10.1 mg/day, which is below the recommendation for women (12–18 mg/day), but 40% of the women increased their intake using iron supplements. Relative to the values used by the Nutrica nutrient calculating program, the mean intake of heavy metals (Hg, lead (Pb) and cadmium (Cd)) among the pregnant women in the study were low, whereas the mean intakes of Zn, copper (Cu) and Se were above the requirement levels.

7.2.6. Russia

As part of a mother–infant study undertaken during AMAP Phase I, FFQs were used to obtain dietary information from obstetric patients in northern Siberia, including non-indigenous mothers (Norilsk, n=49; Salekhard, n=31; Dudinka, n=27) and indigenous mothers (Taymir, n=18; Yamal, n=12). For rural indigenous mothers the intake of reindeer meat was 320 g/day; ten times higher than for non-indigenous mothers in towns. Also, their fish intake was double and game intake 3 to 5 times higher (Klopov, pers. comm., 2000). In contrast to the situation in other Arctic populations, the blood levels of anthropogenic contaminants were lower among indigenous than non-indigenous mothers (Klopov, 1998; Klopov *et al.*, 1998; see also section 5.2.1.4.).

A more general dietary survey based on indigenous and non-indigenous men and women from the Taymir Peninsula, the rural areas of Khatangskiy and Ustj-Yeniseyskiy, and the towns of Dudinka and Norilsk (Klopov, pers. comm., 2001), confirmed the outcome of the study on the obstetric patients.

The results for the Ustj-Yeniseyskiy and Dudinka districts (Table 7·3) illustrate the differences between indigenous and non-indigenous peoples versus the trend between country and town. Indigenous populations in rural Ustj-Yeniseyskiy consume more reindeer and game and less vegetables and imported meat than the non-indigenous populations. This difference is also found in the more urban area of Dudinka. At the same time the rural populations consume more traditional food, especially reindeer, than the urban populations. In addition to the items listed both indigenous and non-indigenous peoples consume equal amounts, 40 to 50 g/day, of local 'treated' meat and 380 to 400 g/day of imported bread. The total food intake was lower in the urban population than in the rural areas, probably reflecting different levels of physical activity.

In a study of dietary habits among indigenous school children in 1997 the nutritional intake and energy values were calculated for children in boarding schools in the Taymir Peninsula (Volotchanka, n=63; Dudinka, n=155; Khatanga, n=130; and Norilsk, non-indigenous, n=360). The total energy intake, and the protein, iron, and Zn intakes were sufficient but the calcium, vitamin C, and iodine intakes were below recommended levels (Panin and Kiseleva, 1997).

Further health and dietary surveys were undertaken in Russia in 2001 as part of an ongoing project on 'Persistent Toxic Substances (PTS) and Food Security of Indigenous Peoples of the Russian North'.

7.3. Changes in dietary habits

7.3.1. Impact of changes in food consumption on other lifestyle factors

The hunting, gathering, production, and preparation of traditional food uses local knowledge and skills and can serve as a full-time occupation. A successful hunt or harvest brings respect from others and increases self-esteem (Van Oostdam *et al.*, 1999).

These activities also result in many types of natural physical activity and lead to the construction of tools, weapons, and traps; and the manufacture of specialized clothes for hunting. They also provide opportunities for the learning, development, and teaching of associated skills. The catch must also be transported and processed and the animal products shared. Because these activities require hard physical exercise that occurs outdoors at low temperatures, energy requirements are very high. As a local product economy is gradually replaced by wage earning in a market economy the strenuous physical activities associated with a subsistence diet are replaced by the considerably less energy consuming tasks of picking up food items at the local markets or supermarkets. Thus, the energy requirements of the population will in general decrease.

In 1936 the diet of a young male Inuit hunter in Ammassalik, Greenland was analyzed over a six-day period. The food intake averaged 2300 g traditional food per day, with the food comprising almost exclusively meat and fish and with an estimated energy content of 16 000 kJ/day (Hansen *et al.*, 1997). In 1994 to 1996, the average energy intake for 180 men in Disko Bay was estimated at 11 000 kJ/day (Pars, 2000). Thus, energy intakes (and requirements) appear to have decreased in Greenland by more than 40% since 1936.

Among the Dene and Métis in Canada a shift away from traditional food toward market food has been characterized by a significant increase in the absolute energy intake (Receveur *et al.*, 1997), which together with a more sedentary lifestyle can lead to obesity.

Traditional foods are often high in protein and very low in carbohydrates. The imported goods are often not sufficiently healthy alternatives to traditional foods, often being higher in fat content, sugar, and other 'empty calories', and low in nutritional value; a transition that has been termed 'cocacolonization', meaning a transition to a fast-food and soft-drink consuming society. Consequently the transition can lead to obesity and nutritional deficiencies and to increases in chronic diseases such as heart disease, osteoporosis, diabetes and cancer (see also chapter 3).

Table 7·3. Food intake in the Russian Arctic for indigenous (Nenets) and non-indigenous peoples (g/day per person). Source: Klopov, pers. comm., (2001).

	Reindeer	Fish (fresh or treated)	Game	Vegetables	Imported meats	Dairy	Total
Ustj-Yeniseyskiy district							
Indigenous, male, n=77	402	511	50	180	98	118	1798
Indigenous, female, n=91	380	484	45	156	86	113	1694
Non-indigenous, male, n=81	243	417	31	311	157	111	1734
Non-indigenous, female, n=98	210	255	24	270	113	98	1381
Dudinka area							
Indigenous, female, n=64	140	361	44	168	100	100	1228
Non-indigenous, female, n=87	80	217	35	382	215	130	1411

In remote communities in Alaska, Canada and Greenland (Egeland *et al.*, 1998a) the local stores have a limited supply of goods, and these are mainly preserved, canned, or dried foods with few fresh products, such as meat, dairy products, fruit, and vegetables. These foods are also comparatively expensive. Thus the replacement costs of subsidizing subsistence food with imported food may present considerable economic burdens on local indigenous groups in Canada, Alaska (Egeland *et al.*, 1998a), and Greenland (Hansen *et al.*, 1997).

Owing to different sampling and reporting methods, or simply to a lack of data, it is not, at present, possible to make direct comparisons between the prevailing dietary habits in the various Arctic regions and their variability over time, but the overall trend is clear: among all Arctic indigenous groups diets are gradually including more and more imported foods.

7.3.2. Impacts of changes in food consumption on nutritional intake

Traditional food systems have been developed through generations, relying on many different combinations of local products each with their own unique contribution to the integrated nutritional composition of the diet. Under normal circumstances (i.e., with the exception of starvation conditions), traditional diets are nutritionally sufficient to meet a broad range of dietary requirements. During the transition toward greater use of imported foods, specific items diminish in importance or disappear from the diet and are replaced by alternatives with a different nutritional composition. Also, local knowledge and skills associated with collection and preparation of traditional foods diminish and may be lost.

In many Arctic regions fish are caught locally and shared or sold in the local market. When fish are not available locally they are often not substituted in the diet by fish products purchased from supermarkets, since these may be too expensive. Instead, miscellaneous other products are used instead of fish, and thus an important source of calcium, vitamin D and iodine is consumed less often.

In Greenland, iodine intake (measured as µg urine-iodine/g creatinine) has dropped as the degree of imported food intake has increased. In the villages it is still sufficient but in the capital of Nuuk the intake is only 50% of that recommended (Andersen *et al.*, 2000). While iodine intake is normally sufficient among ethnic groups with a high intake of marine food, it may be a problem in ethnic groups that are more reliant on terrestrial foods. In the Yamal-Nenet Autonomous Okrug in northwestern Siberia, iodine deficiency goiter is highly prevalent (Luzina *et al.*, 1998) and iodine intake among boarding school children is below recommended levels.

Iron intake and iron status is considered good among both Dene and Inuit due to the high intake of haem iron from red meat; caribou, moose, beluga, seal, and walrus etc. (Jensen *et al.*, 1997). A recent comparative autopsy study of Greenland Inuit and Danes showed that older Inuit (>50 years old) in particular have a higher hepatic iron index than the Danes (Milman *et al.*, 2000). Trace mineral status, including iron, is also satisfactory in northern Norway, the Kola Peninsula and Arkhangelsk (Odland *et al.*, 1996).

7.3.3. Dietary changes and hygiene

As local knowledge about traditional food preparation diminishes or is lost, different hygiene issues arise concerning the prevention of parasitic diseases and food poisoning due to bacterial toxins.

Some traditional methods of preparing and preserving food by anaerobic fermentation procedures are potentially dangerous because toxin-producing *Clostridium perfringens* and *C. botulinum* grow under the same anaerobic conditions. *C. botulinum* poisonings are, however, very rare.

Many predatory animals, especially bears but also walrus, and some seals, dogs, and foxes, etc., can contain *Trichinella spiralis*. If the meat from these animals is very infected and not cooked for long enough, people eating the meat can acquire trichinosis (Hansen *et al.*, 1997).

Microorganisms associated with mass production have been introduced with imported foods, e.g., *Salmonella* sp., *Campylobacter* sp. and other zoonotic bacteria, and these can cause food-borne infections if proper hygiene procedures are not followed. As an example, Table 7·4 shows diagnosed bacterial food-borne diseases reported by the Danish Food Agency for Greenland in 1996 and Denmark in 1995 (only a small fraction of the total number of cases of diarrhea are usually diagnosed by positive cultivation of pathogens). The much higher incidence of food poisonings in Greenland suggests that the understanding of hygiene issues and the standard of hygiene practices are not appropriate for dealing with imported products.

7.3.4. Risk of imbalance of certain micronutrients in traditional foods

Despite a normally high iron intake among rural Arctic populations in Alaska (Yup'ik Eskimos), high levels of iron deficiency have been observed, and are thought to result from gastrointestinal bleeding caused by *Helicobacter pylori* infections (Yip *et al.*, 1997). Gastric biopsies revealed chronic active gastritis associated with *H. pylori* among 99% of the populations studied.

Table 7·4. Food poisoning and infections in Greenland (1996) and Denmark (1994–1995) diagnosed by positive cultivation of pathogens.

	Bacillus cerus	*Clostridium perfringens*	*Campylobacter* sp.	*Salmonella* sp.	Massive microbial contamination
Greenland, number of persons affected[1]	68	20	62	128	14
Greenland, cases/100000 capita	124	36	112	232	25
Denmark, number of persons affected[2]	18	30	2177	4307	5
Denmark, cases/100000 capita	0.33	0.54	39.6	78.3	0.9

[1]Hansen *et al.* (1997); [2]Danish Food Agency.

A screening for *Helicobacter* antibodies in Greenland showed a prevalence of about 40%, equivalent to that in Canadian Inuit populations (Koch *et al.*, 2000), although possible adverse effects on iron status have not been studied.

Calcium intake is traditionally low among the Inuit, who have a low intake of dairy products (and possible lactose intolerance) and, with the exception of fish bones and skin, their diets comprise few good sources of calcium (Jensen *et al.*, 1997). In this respect it is important to retain the consumption of locally caught fish as opposed to filets from the market. The low calcium intake may favor the uptake of other bivalent metals, such as Pb and Hg.

The Se level in traditional food is very high, with the main sources being muktuk (whale skin), and meat and liver from whales, seals, and seabirds. A dietary survey of 400 adults in Disko Bay (Greenland) in 1995/1996 resulted in an estimated Se intake of >600 µg/day, but the authors considered this an over-estimate (Johansen *et al.*, 2000). An AMAP study from 1997 (Deutch *et al.*, in prep., see section 5.3.1.2.), which included 96 pregnant women from Disko Bay, found an average whole blood Se concentration of 140 µg/L. In a 1986 survey, the range in whole blood Se levels among 95 Qaanaaq Inuit was 320 to 4400 µg/L, with the average concentration over ten times higher than among local Danes (Hansen, 2000). This means that the daily intakes in northern Greenland are substantially higher than the maximum safe daily intake of 500 µg recommended by Yang *et al.* (1989).

Selenium concentrations in reindeer/caribou meat are relatively high at 24 to 30 µg/100 g meat. Thus reindeer/caribou consumers have a reasonable Se intake, at least in Finland (see Table 7·8) (Näyha and Hassi, 1993).

The question of vitamin C intake and requirements among the Inuit are very complex and recommendations for western populations may not be applicable. Because of their high iron status and Se levels, the need for vitamin C as an antioxidant is normally filled and high intakes of the vitamin may even sometimes be harmful. However among young women in Nunavik with a vitamin C intake of only 25% of the recommended daily intake (RDI), iron deficiency anemia was common despite intakes of iron at the recommended level. Vitamin C also enhances the absorption of various other metals, including Hg, from the intestinal tract (Chapman and Chan, 2000).

There are few known sources of vitamin C in Arctic diets and the local supply, which depends on wild berries and plants, seaweed, raw seafood products, and the skin and liver of fish and seals, is seasonal. Historically, therefore, low vitamin C intake has been a matter of concern. However, use of local wild green leafy vegetables, fruits, and seaweed are not sufficiently documented (Kuhnlein and Receveur, 1996), and nutrition tables do not cover all products. In addition, fresh raw meat and fish are consumed by many Arctic groups and all fresh raw products, e.g., reindeer/caribou meat and organ meats, contain some vitamin C (Näyha and Hassi, 1993; Nummela *et al.*, 2000). Thus vitamin C intake is probably underestimated, and scurvy is not usually a problem among indigenous Arctic peoples.

7.3.5. Long-chain fatty acids

For diets in which the food mainly originates from the hunting of wildlife and the gathering of wild plants, dietary composition in terms of fatty acids differs from that of diets based mainly on modern industrially produced foods. In general, the saturated fat content of traditional foods is less, and the n-3 : n-6 polyunsaturated fatty acid ratios are higher. This is particularly the case for marine wildlife in which n-3 fatty acids are biomagnified and/or elongated through the complex food webs from microalgae to zooplankton, invertebrates, fishes, marine mammals and birds. The same is true for terrestrial plants: mosses, lichens, herbs, and berries (Simopolous, 1991); as well as for the secondary producers: hare, deer, caribou/reindeer, muskox, etc. In all cases the fat composition depends on the particular food chain, and food chains can now be manipulated. For example, fish are mostly wild, however fish farming is increasing, and research indicates that farmed fish have lower n-3 : n-6 ratios than the same species living wild. In modern agricultural practice livestock are fed n-6 rich grain instead of grass, and the popular n-6 rich vegetable oils comprise a high percentage of fats, cooking oils, and other industrial products. It has been proposed that humans have evolved on a diet close to the diet of hunters and gatherers and that dietary recommendations should aim at this 'Paleolithic diet'. Thus, in addition to reducing the dietary fat content they should attempt to balance the relative fat content, in particular the n-3 : n-6 ratio. It must be emphasized that DHA (an n-3 fatty acid) is essential for fetal retinal- and neuro-development and that low birth weight, birth length and head circumference are significantly correlated with low levels of maternal and cord plasma arachidonic acid (AA) and DHA (Crawford *et al.*, 1989).

Emphasis on addressing the relative fat content, in particular the n-3:n-6 ratio, rather than focusing entirely on reducing dietary fat content is in accordance with the many beneficial effects of n-3 fatty acids reported in relation to the development of chronic diseases. Nevertheless, susceptibility to chronic diseases such as coronary heart disease, hypertension, and diabetes, is to some extent determined genetically, e.g., through the response to dietary fats, and so different populations should not simply copy each other's dietary recommendations.

Recent reviews of epidemiological and experimental studies (Bjerregaard *et al.*, 2000; Connor and Connor, 1997; Simopolous, 1999) show that the n-3 fatty acids in the marine diet have important biological effects on several pathways leading to atherosclerosis. Experimental studies show that n-3 fatty acids have antithrombotic and antiarrhythmic vascular effects etc., and modify the serum lipid pattern toward that associated with lowered cardiovascular risk, in both the normal population and in coronary heart disease patients, thereby lowering coronary heart disease mortality.

A few studies have analyzed this phenomenon within Arctic populations. During 1993/1994 a random sample of Greenlanders (n=259) participated in a health study (Bjerregaard *et al.*, 1997, 2000). Multiple linear regression analysis showed a significant inverse correlation between several cardiovascular risk factors and plasma n-3 : n-6 ratios, total Hg levels (as a dietary marker), and seal consumption. The pattern for serum lipids was the same as that for the effects found in intervention studies using fish or seal oil in other populations, namely that n-3 significantly lowered VLDL (very low density lipoprotein) and triglyceride levels, increased HDL levels and had little effect on LDL and total cholesterol levels (Bonefeld-Jørgensen *et al.*, 2001b; Connor and Connor, 1997; Deutch *et al.*, 2000).

The diet of Yup'ik living in southwestern Alaska is based on fish and marine mammals and their EPA:AA plasma ratios are 9 to 14 times higher than in non-indigenous Alaskan adults (Ebbeson *et al.*, 1999). Based on the outcome of an FFQ for Siberian Yupik in Alaska (n=64), dietary nutritional intakes were correlated with cardiovascular risk factors. The HDL levels were higher and the triglyceride levels lower than in the general North American Caucasian population (Nobman *et al.*, 1999), however, within the population sample studied, beneficial effects of n-3 could not be demonstrated. Adipose fat and plasma lipid profiles of polyunsaturated fatty acids indicate that the diets of Alaskan Natives are already more 'Americanized', with considerably lower n-3 levels than the Inuit population of Greenland (Deutch *et al.*, 2000; Ebbeson *et al.*, 1999; Pedersen, 2000). Their diets are basically similar to those of north Europeans (Danes) and non-indigenous Canadians (see Tables 7·5 and 7·6).

Prevalence of diabetes was relatively low among the Alaskan Yup'ik and Canadian NWT/Nunavut Inuit compared to other Natives in North America (Young *et al.*, 1992). This could be explained by lower fasting insulin and lower insulin resistance. However, the prevalence of diabetes has increased over the last 30 years (see chapter 3). Insulin resistance increases with increasing obesity (Schraer *et al.*, 1998). The reasons for the rapidly increasing prevalence of non-insulin demanding diabetes mellitus and impaired glucose tolerance among Alaskan Yup'ik is only partly understood, but there is some evidence to suggest that they are associated with a lower intake of fish and marine mammals, lower plasma n-3 levels and higher levels of saturated fat (Ebbeson *et al.*, 1999). In the Greenland health study, fasting blood glucose was significantly correlated with the plasma n-3:n-6 ratio and the intake of seal (Bjerregaard *et al.*, 2000). While n-3 polyunsaturated fatty acids may protect against thrombogenesis and diabetes, very high levels (as occur in Greenlanders) may be a risk factor for hemorrhagic strokes (Pedersen *et al.*, 1999). Canadian standardized mortality statistics indicate 70 and 34 deaths per 100 000 person-years due to cerebrovascular events among Nunavik Inuit and Quebec citizens, respectively, and 96 and 246 deaths per 100 000 person-years, respectively, due to ischemic heart disease plus myocardial infarction (Dewailly, 1998). Thus the benefits of an n-3 rich diet appear to be greater than the risks, but this may depend on the level of n-3 intake. The incidences of diabetes and cardiovascular disease in northern areas are confounded by other dietary factors, drinking water composition, lifestyle, latitude/climate, and genetics; and thorough consideration of all these factors is a vast area of research, beyond the scope of this report.

Although single food items have been analyzed for fatty acid content (Kuhnlein *et al.*, 1991), for most Arctic populations there are no studies providing comprehensive information about the total dietary content of n-3 and n-6 fatty acids except for Canadian Sahtu Dene/Métis (Kuhnlein, 1997; Kuhnlein *et al.*, 1995b).

Several studies have indicated that adipose fat and blood levels of fatty acids are good biomarkers of the dietary polyunsaturated fatty acids and good indicators of the intake of marine mammals and fish (correlation coefficients: 0.4–0.5) (Andersen *et al.*, 1999; Marckman *et al.*, 1995; Willet, 1998). Adipose tissue polyunsaturated fatty acids show good correlation with long-term dietary intake. Plasma fatty acids occur in different lipid fractions and with different half-lives; total plasma fatty

Table 7·5. Polyunsaturated fatty acid profiles for subcutaneous adipose tissue from recent population studies. Fatty acids are expressed as a percentage of total lipid content.

	18:2, n-6 linoleic acid	20:4, n-6 AA	20:5, n-3 EPA	22:6, n-3 DHA	Σ n-3 fatty acids	Σ n-6 fatty acids	n-3:n-6 ratio
Greenland[1], n=99	7.57	0.14	0.2	0.56	1.74	7.71	0.23
Denmark[2], n=77	11.88	0.3	0.06	0.16	1.18	12.7	0.09
Alaskan natives [1], n=129	12.27	0.16	0.11	0.3	1.28	12.5	0.10
Alaskan non-natives[1], n=115	13.06	0.2	0.05	0.13	0.95	13.3	0.07

[1]Pedersen (1999); [2]Deutch *et al.* (2000a).

Table 7·6. Polyunsaturated fatty acid profiles for blood lipids (phospholipids) from recent population studies. Fatty acids are expressed as a percentage of total lipid content.

	18:2, n-6 linoleic acid	20:4, n-6 AA	20:5, n-3 EPA	22:6, n-3 DHA	Σ n-3 fatty acids	Σ n-6 fatty acids	n-3:n-6 ratio
Inuit, Nuuk[1], n=15	14	5.24	4.9	7.89	14.6	21.4	0.68
Inuit, Uummanaq[2], n=48	14.2	4.68	5.5	5.89	13.4	21.5	0.62
Alaska, Yup'iks[3], n=436	24.8	5.4	5.05	4.3	15.3	36.4	0.42
Inuit, Canada[4], n=426	19	6.22	3.01	4.95	9.7	28.4	0.34
Indigenous, Koryaks, Russia[5,6], n=74	28.6	6.13	0.98	1.92	3.7	36.2	0.10
Indigenous, Koryaks, Russia[3,7], n=57	23.6	3.32	4.67	3.24	9	28.3	0.32
Denmark[8], n=42	29.9	6.3	0.82	2.53	4.5	36.2	0.13
Canada (general population), n=16	18.4	10	1.3	4.23	6.9	32.7	0.21

[1]Stark *et al.* (1999); [2]Deutch *et al.* (2002); [3]Ebbeson *et al.* (1999); [4]Dewailly *et al.* (2001b); [5]Klopov, pers. comm. (2001); [6]reindeer breeders; [7]coastal population; [8]Deutch *et al.* (2000a).

acids represent intake within the last few weeks, whereas erythrocyte or phospholipid fatty acids represent intake within the last month or so.

A recent dietary study of 426 Nunavik Inuit (Dewailly *et al.*, 2001b), based on 24-hour recall and using measurements of plasma phospholipid fatty acids and several cardiovascular risk indicators (total-cholesterol, LDL, HDL, and triglycerides), showed that plasma n-3 was negatively correlated with the cholesterol:HDL ratio and with the triglycerides:HDL ratio. These risk factors were low among the study group. Plasma n-3 fatty acids were positively correlated with plasma glucose but there was no significant association with plasma insulin or with diastolic and systolic blood pressure. However, Dewailly *et al.* (2001b) do not report the correlation factors between individual fatty acid intakes, plasma fatty acids, and the various cardiovascular risk factors.

7.3.6. Genetic aspects of metabolism

In addition to reflecting dietary composition, the fatty acid profiles of adipose tissue and blood lipids in Tables 7·5 and 7·6 depend on the ability to elongate and desaturate dietary fatty acids such as linoleic and linolenic acids. Linoleic acid levels are high in almost all types of diet since linoleic acid is ubiquitous. Among Caucasian populations linoleic acid is a major substrate for the formation of the essential fatty acid AA by elongation and desaturation.

Both AA and DHA are essential for the development of the fetal brain and visual function (Innis, 2000), and selective partitioning appears to exist between the developing fetus and its mother, namely a magnification of the two essential fatty acids from maternal to cord blood (see Figure 7·2). Furthermore, within the fetus DHA is selectively partitioned between the liver and brain (Crawford *et al.*, 1989).

The ratio between linoleic acid and AA in plasma phospholipids or erythrocytes is much higher among the Inuit of Chukotka, Alaska, Canada and Greenland, than among Caucasians. This indicates that the desaturation of linoleic acid is not optimal, with possible inhibition of the metabolic pathway regulated by δ-5 and δ-6 desaturases (Young *et al.*, 1999), and that AA is supplied directly by the diet from the same sources which supply EPA. It is thus fortunate that AA is high in traditional diets consisting of mammals and fish (see Table 7·6). This highlights the importance of retaining these diets to supply the essential fatty acids for fetal development.

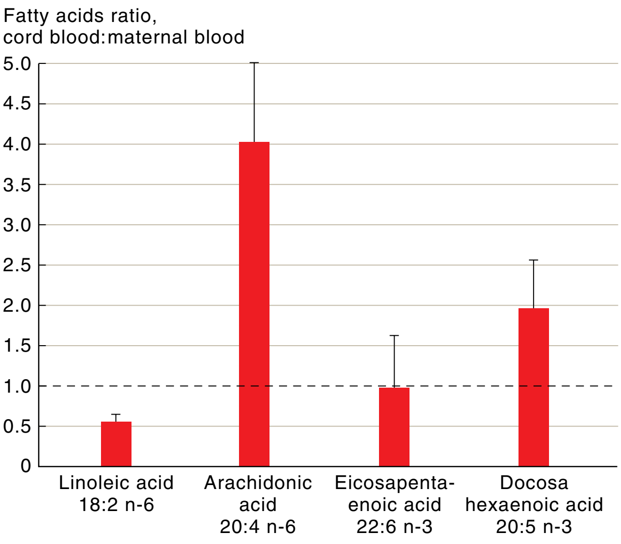

Figure 7·2. Selective partitioning of essential fatty acids from maternal to cord blood. The ratio of essential fatty acids in cord blood: maternal blood is based on 50 mother–infant pairs from the Disko Bay area in 1996 to 1997.

7.4. Traditional food as a source of anthropogenic substances

It has been known for more than twenty years that a range of anthropogenic substances bioaccumulate and biomagnify in the higher trophic levels with older and more predatory fish, mammals and birds containing the highest concentrations. These animals comprise the bulk of the traditional diet of Inuit and other indigenous peoples of the Arctic. A substantial amount of literature highlights an association between a diet high in traditional food and high body burdens of anthropogenic substances (AMAP, 1998), such as POPs and heavy metals. Epidemiological investigations, especially regarding exposure parameters, are best supported by long-term diet surveys. However, almost all dietary surveys concern present daily intakes using methods such as 24-hour recall or food diaries covering a number of days, although some do attempt to cover longer periods, e.g., for up to a year, through retrospective FFQs. If their purpose is to estimate exposure from persistent OCs or metals then it is generally assumed that present day dietary intakes are the same, or similar to the long-term intake, which may not actually be the case. For example some individuals may have changed their dietary habits in response to contaminant information and also most diets exhibit day-to-day and seasonal variations (Willett, 1998). In Arctic areas, seasonal variations may be more extreme because of the influence of climatic conditions, supply problems, and extent of hunting and gathering seasons. In Greenland, for example, seal consumption is constant throughout the year, but the consumption of other species such as walrus and birds varies seasonally. The same is true for consumption of whales, with baleen whales (e.g., bowhead whale) more commonly taken in the fall and toothed whales (e.g., beluga, narwhal) in the spring (Pars, 2000). Thus associations between reported dietary intakes and human blood levels of contaminants should be accepted with caution unless supported by other techniques such as biomarkers.

7.4.1. Heavy metals

Contaminant databases for wildlife have recently been established for several Arctic areas: Canada (Berti *et al.*, 1998; Chan, 1998; Kim *et al.*, 1998) and Greenland (Dietz *et al.*, 1996; Johansen *et al.*, 2000). Such data may be combined with dietary survey data, concerning relative and absolute intakes of traditional food, to estimate the average habitual intake of heavy metals or other contaminants and to indicate the major sources of intake. Heavy metal concentrations in wildlife products vary widely between species, and for the same species by geographical location (Egeland *et al.*, 1998a), as well as by age, gender and size of the animal, tissue or organs.

In general, fish liver and liver and kidney of large marine and terrestrial mammals contain higher metal concentrations than muscle (meat). Caribou/reindeer and moose liver contains very high concentrations of Pb, Cd, and Hg; seal and toothed whale liver and kidney contain very high concentrations of Cd and Hg (resulting in an 'allowable lifetime weekly intake' (ALWI) of 40 to 140 g of the food source for Cd) (Egeland *et al.*, 1998a). However, most of the Hg in liver is not methylated and has low bioavailability (Egeland *et al.*, 1998a). Thus seal meat and toothed whale meat are the most important sources of Hg. Marine birds and bird liver can be important sources of Pb (Berti *et al.*, 1998; Chan, 1998; Johansen *et al.*, 2000).

Tables (7·7 and 7·8) show estimates of dietary exposure to heavy metals from traditional food for indigenous peoples in Greenland and Canada. These estimates are based on the contribution from traditional food items only and do not include the contribution from market food. Since traditional food represents 20% to 30% of the total energy intake, market food (from Denmark or Canada) adds to the total contaminant burden, most significantly for Pb.

In Greenland, contamination of waterfowl by lead shot is considered the most important single dietary source of Pb. The intake of one murre (*Uria* spp.) boiled in soup could yield as much as 50 µg of Pb (Johansen *et al.*, 2000).

In Finland the nutritional and trace element intakes of 147 pregnant Lappish (Saami) women were estimated by FFQ and a 7-day food diary. The results of the two methods showed good agreement. Table 7·1 shows the food diary results together with comparable data for pregnant women in the Faroe Islands. A Nutrica database was used to estimate daily trace element intakes (see Table 7·2). The estimated weekly mean intakes in Finland were: Pb 337 µg, Cd 73 µg, Hg 26 µg, and Se 476 µg (Mussalo and Soininen, pers. comm., 2002). These are shown in Table 7·8 together with the estimated heavy metal intakes in other Arctic/ Nordic and Canadian populations.

All populations have additional Cd exposure from smoking (Egeland *et al.*, 1998a) and there are particularly high rates of smoking among the Inuit (Bjerregaard *et al.*, 1997).

The total Hg intake of 850 µg estimated for Greenland and Canadian Inuit includes a contribution of about 500 µg from seal and whale liver. However, in fatty tissue such as liver, inorganic Hg makes up than 90% of the total Hg (Egeland *et al.*, 1998a). The bioavailability of inorganic Hg, which is Se-bound, is low and the estimated exposure should be modified accordingly (Hansen, 1990), resulting in an estimate closer to 450 µg. Other dietary components (e.g., calcium, Se and fatty acids) interact with the uptake, metabolism, and probably the toxicity of Hg and *vice versa*. Thus to evaluate the possible health impacts of Hg many factors must be considered (Chapman and Chan, 2000).

Table 7·7. Estimated heavy metal intakes (µg/person/week) from marine food in the Disko Bay region, West Greenland 1995–96 (Johansen *et al.*, 2000).

	Pb	Cd	Hg	Se
Fish meat	1.7	26	24	34
Fish liver	0.5	63	1	75
Seal meat	6.2	62	147	129
Seal liver	2.0	693	507	212
Whale meat	1.7	7	52	36
Whale liver	0.03	7	6	6
Whale skin	0.8	11	60	3833
Bird meat	1.1	34	29	152
Bird liver	0.6	101	20	92
Total	15	1004	846	4569

7.4.2. Persistent organic pollutants

Diet is the main source of human exposure to organic xenobiotic compounds, chemicals foreign to the biosphere, although their transport to the Arctic is mainly via winds and water currents. These lipophilic chemicals accumulate in the fatty tissues of all biota, they accumulate with age due to their slow metabolism, and some are biomagnified in food chains. They are therefore prevalent in large Arctic mammals, especially those at the top of the food chains, and are concentrated in their fatty tissues and organs, such as blubber, liver, brain, and kidney. Almost without exception, OC levels are lower in the terrestrial environment than the marine environment due to the longer food chains and higher fat content of marine mammals and large fish. But birds, especially bird liver, can contain high concentrations of OCs due to their high metabolic rate. Analyses of the OC content in a growing list of wildlife species have been published

Table 7·8. Provisional tolerable weekly intake of heavy metals and the estimated weekly intake of heavy metals from traditional food (µg/week) for a 60 kg person. The data are based on wildlife contaminant databases for Greenland Inuit and Canadian Arctic populations and estimated daily food intakes. The Finnish data are based on a dietary survey and calculated heavy metal data from the Nutrica database.

	Pb	Cd	Hg	Se
PTWI (World Health Organization unless otherwise indicated)	1500	420	200	2800[1] 4000 (Canada) 2400 (United States)
Greenland, Inuit[2]	15	1000	850	4500
Canada, Inuit[2]	470	1000	850	
Canada, Dene/Métis[3,4,5]	<42	32 (240[6])	42	
Denmark, general population[2]	162	100	35	340
Canada, general population[2]	168	88		
Finland, Saami[7]	337	73	26	476

[1]Yang *et al.* (1989); [2]Johansen *et al.* (2000); [3]Berti *et al.* (1998); [4]Chan (1998); [5]Kim *et al.* (1998); [6]traditional food + market food + smoking; [7]Mussalo and Soininen (pers. comm., 2002).

Table 7·9. Estimated daily intake of OCs by Inuit in towns and villages in south-western Greenland. Estimates based on a semi-quantitative food frequency questionnaire for 410 adults with traditional food intakes (Pars, 2000) and contaminant concentrations in Greenland species (Johansen *et al.*, 2000). Canadian TDI guideline values are given for comparison (Berti *et al.*, 1998).

	Chlordanes	ΣDDT	HCHs	HCB	ΣPCB_{10}
18–24 years, n=50 ng/day	9190	24765	5998	1759	21270
35–59 years, n=175 ng/day	11553	27095	6026	1737	22159
All, n=410 ng/day	9920	23992	5446	1578	19862
All, n=410, µg/kg/day	0.165	0.399	0.09	0.026	0.331
Canadian TDI, µg /kg/day	0.05	20	0.3	0.27	1 (Arochlor) 0.3 ΣPCB_{14}

for Canada (Berti *et al.*, 1998; Kuhnlein and Receveur, 1996) and West Greenland (Johansen *et al.*, 2000). Berti *et al.* (1998) combined a regionally adjusted contaminant database with a nutritional database and dietary survey based on 24-hour recall for 1012 Dene/Métis and compared the 99th percentile values with the present Canadian guideline values. Only chlordane and toxaphene intakes approached the guideline values, with three and five people, respectively, exceeding the guideline values. For the estimated intakes of all other OCs the 99th percentiles are below 20% of the guideline values. Compared with the Inuit, however, the Dene/Métis are not consuming such large quantities of marine foodstuffs.

Johansen (in prep.) presents concentrations of polychlorinated biphenyls (PCBs) and DDT on a 5-decade logarithmic scale, on which the lowest concentrations occur in Arctic hare (*Lepus arcticus*) muscle and liver and the highest in ringed seal (*Phoca hispida*) and minke whale (*Balaenoptera acutorostrata*) blubber. In general, the prevalence of the various OCs in the environment strongly coincides although there may be minor differences from tissue to tissue. The distribution pattern is also similar to that of total Hg.

Table 7·9 shows the estimated dietary POP exposure for a 60 kg person from towns and villages of south western Greenland (Disko Bay). The estimate was derived using:

1. estimated dietary intakes in g/day of 25 different local traditional food items (for which contaminant levels are available) yielding a total intake of 200 g traditional food per day (Pars, 2000); and
2. POP concentrations in Greenland animal species determined by Johansen (in prep.).

Contaminant levels have not been analyzed in reindeer, and have only been determined in one species of saltwater fish from West Greenland (Aarkrog *et al.*, 1997). Also, only one whale species, minke whale, has been included, even though the concentrations of contaminants in toothed whales, e.g., beluga and narwhal (*Monodon monoceros*) are known to be higher (Kuhnlein and Receveur, 1996). Whale blubber was analyzed but not whale meat. The contaminant level in whale meat was estimated for the calculations based on the relative fat content of whale meat and was estimated to be 10% of the content in whale blubber.

The estimated contaminant intakes from the traditional food for Greenland Inuit are slightly lower but of the same order of magnitude as for Baffin Inuit (Kuhnlein, 1995; Kuhnlein and Receveur, 1996), but are higher than for Sahtu Dene/Métis by factors of 10 to 20 (Berti *et al.*, 1998). Traditional food intake in Greenland varies by district and is lower on the southwest coast than on the east and northwest coasts. This is consistent with measured blood levels of POPs in younger men and women from seven districts in Greenland (Deutch and Hansen, 2000; and section 5.2.1.2).

The estimated contributions from various traditional food items to daily β-HCH, total chlordanes, hexachlorobenzene (HCB), ΣPCB_{10}, and DDT exposure are shown in Figure 7·3. These data are based on relatively few species. However, the relative contributions from seal blubber and meat are so predominant that the missing food items can be considered of minor importance.

Seal is the most important source of dietary POP exposure because it is the most common traditional food item and its intake is greater than that of whale products. Traditional food intake in rural communities (30%)

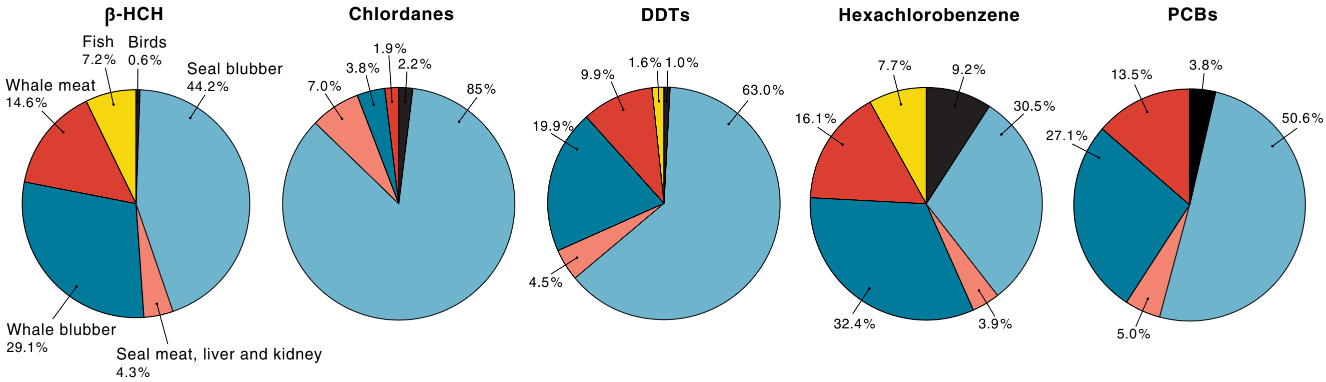

Figure 7·3. The contribution of different traditional foods to dietary exposure to organochlorines in southwestern Greenland. Relative OC contributions from different food groups are based on estimates of daily food intake by Pars (2000) multiplied by contaminant levels reported by Johansen *et al.* (2000). The relative contributions from terrestrial animals are not shown but are below 0.5%.

Table 7·10. Average concentration of OCs (ng/g) in 0–3 year old male ringed seal blubber from four districts in Greenland (AMAP, 1997).

	ΣPCB	ΣDDT	ΣHCH	HCB
Avernarsuaq, NW Greenland	505	4218	1636	116
Qeqertarsuaq, Disko Bay, W Greenland	275	4408	1256	116
Nanortalik, S Greenland	573	7464	1182	141
Ittoqqortoormiit, NE Greenland	706	9649	1805	163

is greater than in towns (19%), especially regarding seal. However, whale intake is higher in towns and accounts for some of the difference in exposure to POPs. Traditional food accounts for 22% of the total energy intake. The remaining 78%, from imported food, also adds to the total contaminant burden (Pars, 2000). This additional contribution has not been measured directly, but based on human blood levels of PCBs and DDT in northern Europe and Canada it is estimated at 25% to 35% (AMAP, 1998). This implies that previous estimates (based on traditional food alone) are too optimistic and should be at least 25% to 35% higher. The mean intakes of chlordanes and PCBs already exceed the Canadian guideline values and the mean β-HCH intakes represent one third. This means that a large proportion of people exceed the guideline intake values as supported by measured blood levels of contaminants from another study (Deutch and Hansen, 2000). Organochlorine concentrations were analyzed in several marine animals from four locations in Greenland, Table 7·10 (Aarkrog *et al.* 1997). The data for ringed seals clearly illustrate the general geographical distribution of pollutants. Blood levels of OCs measured in 1997 in a small geographical survey (Deutch and Hansen, 2000) follow approximately the same pattern. The urban population in southwest Greenland has the lowest pollution burden and Ittoqqortoormiit in the northeast the highest, with >60% of men exceeding the Canadian PCB guideline level for action (100 µg PCB-Arochlor 1260 per liter plasma).

The estimated PCB intake of Inuit in southwestern Greenland exceeds the TDI value (Table 7·9). If seal blubber were the only source of PCB (and compared to the TDI value it is the most critical), the daily intake of ringed seal blubber should not exceed 300 g in Disko Bay or 100 g in Ittoqqortoormiit. However, seal blubber contributes about 50% of the PCB intake, which changes these limits to 150 g and 50 g respectively. In Disko Bay the average daily intake of seal blubber is about 30 g (Pars, 2000).

Taking another example, locally grown and produced farm products were collected in Arkhangelsk, northern Russia, in 2000 and analyzed for pesticides and PCBs. All the grain- and vegetable products had very low concentrations of POPs, except for HCH which was high. The meat and fats from farm animals had considerably higher concentrations and were 3 to 10 times higher than the corresponding levels in Norway (Polder *et al.*, 2002b). This applied particularly to pig meat and fat, for which the DDT concentrations were 10 and 130 ng/g respectively. A 60 kg person consuming a pork chop per day (170 g meat and 30 g fat) would consume 0.1 µg DDT/kg/day, however this is still only 25% of the estimated intake in Greenland (Table 7·9).

7.4.3. Dietary intakes, anthropogenic blood levels and dietary indicators

A correlation between the intake of traditional food items measured by dietary surveys and blood levels of xenobiotic substances has been demonstrated on a group and population basis for heavy metals (Hansen, 1990) and OCs (Van Oostdam *et al.*, 1999). However, to describe and analyze dietary risk behavior in more detail it would be extremely useful to be able to demonstrate this correlation at the level of an individual. This is obviously more difficult to achieve owing to the large day-to-day variation concerning dietary behavior and to the seasonal variation in traditional food availability. Also, individuals may accumulate contaminants at different rates owing to genetic causes and other lifestyle factors modifying their metabolism.

Organochlorine compounds are metabolized by a number of enzymes: CYP1A1, CYP1A2, phenobarbital-CYP, etc., which are part of the P-450 cytochrome oxidase system (Lagueux *et al.*, 1999). Different OCs are metabolized by the same enzyme systems and may compete or interact with each other in terms of uptake and excretion. These same enzymes metabolize nicotine and its breakdown products, which may also influence enzyme expression. Tobacco smoking has been correlated with higher OC levels in plasma (Deutch, 1999; Deutch and Hansen, 1999, 2000). In residents of Nunavik, northern Quebec, with a high marine food intake and OC exposure, CYP1A1 activity in placenta tissue was

Table 7·11. Correlations between reported monthly intake of marine food items (based on a food frequency questionnaire), plasma phospholipid n-3:n-6 ratios, whole blood Hg (µg/L) and lipid adjusted plasma PCB levels (µg/kg lipid) in male Inuit hunters from Uummanaq, northwest Greenland, n=48 (bivariate Pearson correlation coefficients) (Deutch *et al.*, 2002).

	Marine food intake	n-3 : n-6 ratio	Whole blood Hg	Plasma PCB
Marine food intake		0.39**	0.26 ns	0.22 ns
n-3 : n-6 ratio	0.39**		0.72**	0.63**
Whole blood Hg	0.26 ns	0.72**		0.65**
Plasma PCB	0.22 ns	0.63**	0.65**	

ns: not significant; **P* < 0.05; ** *P* < 0.01; *** *P* ≤ 0.001.

statistically correlated with DDE, PCB congeners and HCB levels, as well as with levels of smoking (Lagueux *et al.*, 1999). Therefore, to identify individuals at risk of high OC burden is a multi-factorial issue, and is not just a question of diet.

Thus, although it is well documented that marine mammals in the traditional diet contain high levels of OCs (AMAP, 1998; Chan, 1998; Johansen *et al.*, 2000; Kuhnlein, 1995; Kuhnlein and Receveur, 1996) at the present time it is only possible to demonstrate:

1. the overall correlation between self-reported high intakes of traditional food and selected dietary biomarkers such as blood Hg (Bjerregaard and Hansen, 2000; Deutch, 1999) or n-3 fatty acids in plasma, phospholipids, erythrocytes or adipose tissue (Bjerregaard *et al.*, 2001; Deutch and Hansen, 1999, 2000); and
2. the correlation between these dietary indicators (fatty acids, blood Hg levels etc.) and OC levels.

In the Canadian reports (Chan, 1998; Kuhnlein, 1995; Kuhnlein and Receveur, 1996) the question of direct associations between self-reported marine food intake and blood levels of OCs is not considered. In other reports such associations are described as being weak or non-significant (Bjerregaard and Hansen, 2000; Deutch, 1999; Deutch and Hansen, 1999, 2000; see also Table 7·11).

7.5. Conclusions and recommendations

Within the last five years most countries have performed one or more dietary surveys among their Arctic indigenous populations. However, these have been undertaken for different reasons, with different target groups, and using different sampling and reporting methods. It is difficult to make direct comparisons between dietary survey data obtained by different methods, e.g., interviews versus recording or food frequency questionnaires. Also, some studies report results as intake frequency or weight of listed food items whereas others calculate nutritional profiles. Some dietary surveys report traditional food intake only, whereas others consider total diet. Therefore, in most cases, only qualitative comparisons can be made between countries, or between ethnic groups within countries. This should be considered when planning sampling methods for future dietary surveys and when considering more standardized means of reporting. The aim should at least be to report both daily intakes, e.g., g/day (rather than portions), and daily nutritional intakes in absolute and relative units, e.g., per 10000 kJ.

The diet of Arctic indigenous peoples includes traditional food and imported (market) foods. Although varying by country, location, gender, and age group, traditional food currently yields 10% to 40% of the total energy intake; a considerably smaller percentage than 30 to 40 years ago. Traditional foods are the main sources of protein, fat, most minerals (iron, Zn, Se, iodine), vitamin D, and particularly the essential long-chain n-3 fatty acids, which supply some protection toward heart disease and diabetes. The ratio between n-3 and n-6 fatty acids in human lipid fractions serves as an indicator of the relative intake of traditional food.

Imported foods are the main sources of carbohydrate, water-soluble vitamins, vitamin A, and calcium. Composite diets are sufficient in terms of most nutritional requirements. However, those elements of most importance in relation to meeting required intakes in Arctic populations are vitamin A, vitamin C, and folic acid due to the low intake of vegetables, and calcium due to the low intake of milk products. The iodine intake of inland indigenous populations is sometimes below recommended levels.

Analyses of food items of animal origin have provided ample proof that traditional food is a major source of heavy metals (Hg, Cd and sometimes Pb) and persistent organic substances. Exposure estimates of heavy metals calculated from dietary intake data show good correlation with human tissue concentrations. Dietary exposure estimates of POPs have so far only been compared with human body burdens of POPs on a population basis. Correlations between estimates of individual dietary intakes and individual blood levels of xenobiotic substances are not yet available. However, several studies show very significant positive associations between n-3 fatty acids in human lipid fractions and blood levels of both Hg and POPs, which makes a connection between intake of marine mammal fat (e.g., blubber) and organic pollutants highly probable. It is also evident that POP concentrations in animal fat vary with the age, gender and geographical location of the animals.

Uptake, metabolism, and excretion of OCs are influenced, among others, by genetic factors. Tissue levels are influenced by various lifestyle factors such as smoking (Deutch, 1999; Deutch and Hansen, 1999, 2000; Lagueux *et al.*, 1999) and body mass index (Deutch *et al.*, 2002). Therefore, identification of individuals at risk of accumulating high POP burdens is not just a question of dietary exposure but also a more complex question of interacting genetic and biochemical factors. These should receive more attention in future studies.