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AMAP Greenland and the Faroe Islands 1997-2001

Vol. 1: Human Health

Editors: B. Deutch & J.C. Hansen

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Contents

Preface

The present report, is one of five National Reports on AMAP activities in Greenland and The Faroe Islands during phase 2, 1997-2002, published by the Danish Environmental Protection Agency. The scope of the report is to provide the fully referenced, comprehensive, technical and scientifically presented assessment of available and validated data on the Human Health status in Greenland and the Faroe Islands relative to the AMAP phase 2 mandate. This report provides a more comprehensive and detailed presentation of data from the two areas than what was possible to include in the international report. The report is specifically addressed to scientists in Public Health, Environmental Medicine, and others with interest in the Arctic Environment.

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The Map of Greenland has kindly been made available by "Greenland Statistics".

Introduction

At the Rovaniemi Ministerial meeting in 1991 it was decided to implement a programme to monitor the levels and assess the effects of contaminants in all compartments of the Arctic environment. Accordingly, between 1991 and 1996 the Arctic Monitoring and Assessment Programme, AMAP was designed and implemented as AMAP phase I. The first international assessment report was subsequently published (AMAP 1998). To fulfil the international requirements a specific Greenland AMAP programme was implemented and a Greenland Faroe Islands assessment report was produced (Aarkrog et al. 1997). The accomplishments of AMAP phase I were fully recognized by the Ministers. As such it was determined that work should continue to fill gaps in the current understanding of transport processes, spatial and temporal trends, and possible effects of contaminants, and an AMAP phase II study was initiated.

Substantial new data have been collected during AMAP phase II both in Greenland, on the Faroe Islands and in the other Arctic regions. It was decided to make a second international AMAP assessment report, which will be published in September/October 2002 prior to the Ministerial meeting of the Arctic Council in October 2002. Furthermore, it was decided also to make an assessment of the Greenland and Faroe Islands AMAP data on the background of the studies carried out since AMAP phase I. A series of four reports will be published covering human health studies, environmental studies in Greenland and Faroe Islands, respectively, and the data collected. This report deals with the environmental studies carried out in Greenland during AMAP phase II, and is organized into environmental compartments (atmospheric, terrestrial, fresh water and marine environment). A section deals with so-called other contaminants defined as contaminants of which knowledge of levels in the Greenland environment is scarce because they have not been included in the basic monitoring studies or because the focus on their possible environmental impact is rather recent. One section deals with the effect studies on ringed seals and polar bears. Conclusions and recommandations are described in the individual sections, and summarized in the last section of the report.

The present report and a significant part of the studies described have been funded by the Danish Environmental Protection Agency as part of the environmental support program Dancea – Danish Cooperation for Environment in the Arctic. The authors are solely responsible for all results and conclusions presented in the report, and do not necessary reflect the position of the Danish Environmental Protection Agency.

1 Danish National Report Introduction

In the Phase 2 of AMAP the mandate of the Human Health Expert Group (HHEG) was extended from monitoring and assessment of human contaminant exposure to, in addition to assess effects of multiple environmental stressors. As a consequence the aim of the International Human Health Report has been to provide an overview of the combined effect of environmental and societal factors on human health. The scientific background to fulfil this task is not sufficient at present, however, the report is a step forward in the right direction The present national report follows the attempt from the international report to provide an integrated assessment of exposures to contaminants and measures of effect both at the epidemiological and the molecular level..

1.1 Major achievements in the International and Danish AMAP Human Health Programme during Phase 2.

The monitoring programmes have been extended to be almost circumpolar also on a regional basis and a considerable amount of new data on human exposure levels have been obtained including Greenland and The Faroe Islands. This has created a better basis for assessment of exposure levels regionally. Also dietary surveys have been extended and provided more detailed information on dietary habits, which in combination with more data on contaminant concentrations in food items has improved the possibilities to make realistic exposure estimates. The second major achievement has been the development and implementation of a human health effect programme. The programme is so far not implemented in all key sampling areas. In Greenland the effect programme has concentrated on biomarkers of effect at the molecular level while in the studies in the Faroe Islands programme the epidemiological approach has been prevailing. Both types of effect programmes should be continued and expanded in a continued and co-ordinated way. A third achievement has been the establishment of an analytical quality and control group to advise the HHEG. All laboratories producing data for the AMAP Human Health Assessment have to participate in the intercalibration programme run by the group.

1.2 New results.

1.2.1 Monitoring of exposure:

Monitoring of POPs (14 PCBs, 11 pesticides), heavy metals (mercury, cadmium and lead) and the essential micro nutrient selenium has continued. In addition also biochemical indicators of diet (plasma-fatty acids) and of smoking (plasma-cotinine) have been measured in some areas.
The extended data sets obtained during phase 2 have confirmed the results from phase 1 that in the Arctic traditional food is the main source of human exposure to most contaminants. In a number of communities in some areas of

the Arctic dietary intakes of PCBs chlordanes, and mercury exceed established national and international guidelines. So far it has not been possible to establish real time trends due to the short period of observation.

1.2.2 Effects of exposure:

At the epidemiological level there is evidence of subtle developmental effects in children following exposure to mercury and PCB´s due to their neurotoxic effects, also evidence of impaired immunodefence in children has appeared. Resent data, using serum samples from Greenland, have indicated that the concerted action of accumulated POPs in the samples excerts an inhibitory effect on the estrogen receptor in human cells.
The efforts to identify causal agents are complicated and confounded by new contaminants now being identified in the Arctic environment, but so far not included in the human monitoring programme.

1.3 The National Report.

The present report is a compilation of data generated in the programmes carried out under the AMAP Human Health Programme in Greenland and the Faroe Islands during the interim year 1997 and during the phase 2 of AMAP 1998 to 2002. As the activities are a continuation of the phase 1 programmes the results from this period are also to some extend incorporated for comparisons.
The programmes carried out in Greenland and in the Faroe Islands have not been co-ordinated consequently the two areas are reported separately.

1.3.1 Greenland.

The scope of the investigations in Greenland during the reporting period have been to provide an overview of geographical differences in human exposure, to perform estimates of dietary exposures to contaminants further to investigate the influence of life-style factors on body retention of persistent organic pollutants (POP´s), and to implement the Human Health Effect programme adopted by the international AMAP Human Health Group (HHEG). As a pilot study on spatial trends carried out in the interim year 1997 demonstrated the highest exposure levels to be found in the two East Greenland districts Ittoqqortoormiit and Tasilaq the main efforts has been to document the preliminary findings and to study biomarkers of effect in these highly exposed population groups.
During the phase 2 a more comprehensive data set on concentrations of contaminants in organs from a variety of animal species used as food has been available, this has, in connection with improved dietary surveys, made it possible to perform realistic estimates of dietary exposure with differentiation between species and various organs. These new data have improved the possibility for giving effective dietary advice considerably.
The Greenland part of the report is described in chapters 2-5.
Chapter 2 (P. Bjerregaard) gives a general overview of specific demographic characteristics and societal factors of importance for the interpretation of the monitoring data.
Chapter 3 (P. Johansen et al) describes the most recent data on contaminant concentrations in organs from the animal species used for food.

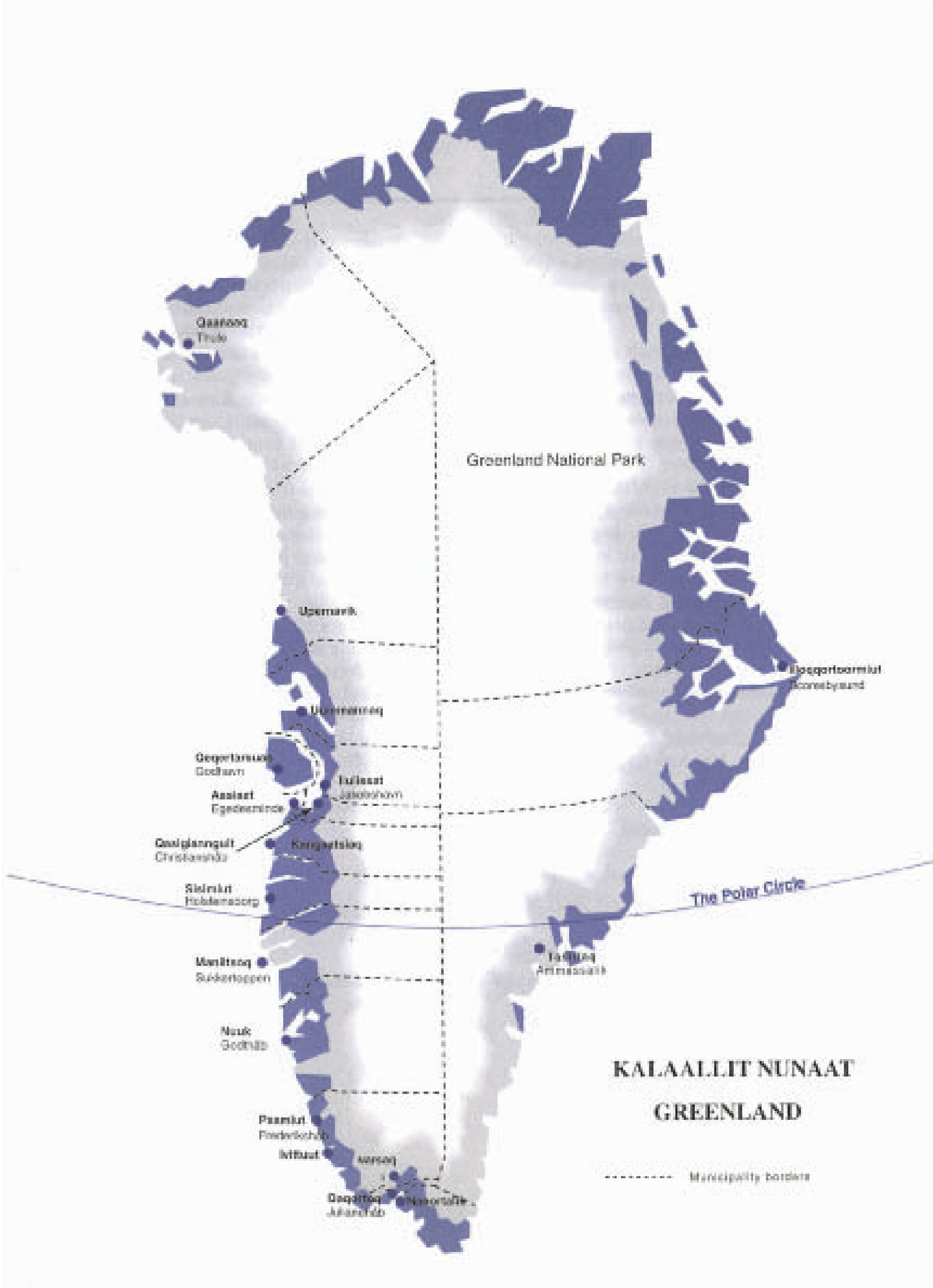
Chapter 4 (B. Deutch) describes the different monitoring programmes carried out in Greenland during the reporting period and the statistic-epidemiological assessment of the monitoring data.

1.3.2 The Faroe Islands.

The activities in the Faroe Island have concentrated mainly on kohord studies to evaluate mercury exposure in relation to consumption of pilot whale and to a lesser degree on POP exposure the results form the Faroe Islands are described in Chapter 6 (P: Weihe)

Chapter 7 (E. Bonefeld Jørgensen) describes the human health effect biomarker programme and the progress so far obtained.

A general summary of conclusions and recommendations from the international assesment and specific conclusions and recommendations for Greenland and The Faroe Islands is given in Chapter 8.


Greenland National Park
Upernavik
Godhavn
Jakobshavn
Christianshåb
Sukkertoppen
Nuuk
Godthåb
Paamiut
Ivittuut
The Polar Circle
KALAALLIT NUNAAT
GREENLAND
Municipality borders

2 Sociocultural environment, lifestyle, and health in Greenland

By Peter Bjerregaard

The population of Greenland was 56,124 in 2000. Of these, 49,369 (88%) were born in Greenland, which is the official proxy measure for Greenlandic (Inuit) etnicity. However, in recent years an increasing number of ethnic Danes have been born in Greenland while a similarly increasing number of ethnic Greenlanders have been born in Denmark[1]. A study from the 1990s estimated that 97% of those born in Greenland considered themselves to be Greenlanders while 9% of those not born in Greenland considered themselves as Greenlanders and 17% as both Greenlander and Dane. The use of definition criteria (place of birth, identity or ethnicity of parents/grandparents) must be chosen according to the circumstances.

The population pyramid for the indigenous population is relatively broad based until the age group 30-34 (figure 2.1). Around 1970 the very high fertility rates decreased rapidly which, in combination with relatively few women of childbearing age resulted in small birth cohorts. After the dramatic decrease, the size of the birth cohorts increased steadily from 1974 to 1995 but is now once more on the decrease.

The population composition of the non-indigenous (Danish) population is very different. Men make up 70% of the non-indigenous population, and 79% of these are in the age group 25-59 compared with only 50% among the Greenlanders.

2.1 Settlement structure

The majority of the population (92%) lives on the South and central West coast; 6% live on the East coast, and 1.5% live in the extreme North (See map of Greenland, page 14). Furthermore, 81% live in small towns with population sizes ranging from 500 to 13,500, the remainder in villages with 50-500 inhabitants, and a few hundred people live scattered especially in the south. The non-indigenous population is concentrated in the towns.

The population is not scattered evenly all over the inhabited part of the country. Two thirds of the population live in four by Greenlandic standards relatively densely populated areas: 13,500 (24%) in the capital, Nuuk, 10,500 (19%) in the Disko Bay area, 8,000 (15%) in South Greenland, and 5,000 (9%) in Sisimiut on the central west coast.

Although Greenland is a very large island, 85% of its area is permanently covered with ice, and all settlements are situated on the coast, most often on the outer coast directly facing the open sea or very close. In the south there is some agriculture, but reindeer herding has never really been successful. A few mines have been open from time to time, and there are ongoing prospecting activities for hydrocarbons and minerals such as zinc, uranium, gold, and iron, but there are currently (2002) no active mines.

2.2 Language, culture and Economy

Greenlandic and Danish are both official languages of Greenland. Greenlandic is the mother tongue of the vast majority of the indigenous population, among whom 57% indicate to speak Danish reasonably well. Although Greenlandic is widespread as the first language, the presence of a large occupationally active contingent of Danes, who usually have no command of Greenlandic, has resulted in much of the administration taking place in Danish. Primary education takes place in Greenlandic but college and university level education takes place in Danish – and often outside Greenland. Thus a fluent command of Danish (and good command of English) are necessary in order to obtain a higher education.

The Danish/Norwegian colonization of West Greenland started in 1721, and what today is termed the traditional Greenlandic culture is a mixture of Inuit and European culture. The traditional occupation of the Greenlanders until the early 20th century was the hunting of marine mammals (seal, whales, walrus). During the 20th century hunting was increasingly supplanted by fishing, first from small dinghies but later from large sea-going vessels using the most modern equipment. The Greenlandic culture today is still very much centered around traditional Greenlandic food *(kalaalimernit)*, which is understood as the flesh and organs of marine mammals and fish often eaten raw, frozen or dried. Seal meat, for instance, is usually ascribed several positive physical as well as cultural qualities, and asking a person whether he or she likes seal meat is equivalent to asking whether he or she considers himself/herself to be a true Greenlander.

The economy of Greenland is based on transfer of funds from Denmark and on fishing, especially for shrimp. Until the beginning of the 20th century, seal hunting was the major trade in Greenland. After 1920, fishing and related industries became the main trades. After 1950, when Greenland opened up and was modernized, business and commerce changed. The service sector in particular has developed considerably. The educational level is high and the housing conditions have improved markedly but housing density is still much higher than, e.g. in Denmark.

Traditional sealing and whaling still plays an important role in the life of people especially in Northwest, North, and East Greenland although it is not the dominant industry in economic terms. Leisure time hunting and fishing is a very common activity.

2.3 Lifestyle

Information about the diet has been collected in several population surveys including a specific dietary survey. The consumption of marine mammals and fish is high but the young and the population in towns eat considerably less than the elderly and the population in the villages. Seal is the most often consumed traditional food item followed by fish. On average, 20% of the Greenlanders eat seal 4 times a week or more often while 17% eat fish similarly often. Traditional food is valued higher than imported food; the highest preference is given to muktuk (whale skin), dried cod, guillemot, and blackberries. Almost all value traditional food as important for health and less than one percent (in 1993-94) restricted their consumption of marine mammals or fish because of fear of contaminants.

A sedentary lifestyle is becoming increasingly common among the Greenlanders. In the villages, only 7% are self-reported sedentary while this increased to 23% among the well-educated residents of the capital, Nuuk. Overweight is an increasing problem among the Greenlanders; 35% and 33% of men and women, respectively, are overweight (BMI 25.0-29.9) and 16% and 22% are obese (BMI=> 30).

The consumption of alcohol and tobacco has increased considerably during the lat 30-40 years but is now stagnant. The consumption of alcohol is now equivalent to ca. 13 litres of pure alcohol per year in the adult population, which is at the same (high) level as in Denmark. Alcohol is, however, often consumed in binges and the impact of alcohol on social and family life is marked. Among those born after 1960, more than 50% state that they experienced alcohol related problems in their parental home.

According to import statistics, the average consumption of cigarettes increased from 5 cigarettes per day in 1955-59 to 9 in 1990-94. Recent population surveys estimate the proportion of cigarette smokers to be 70-80% among both men and women compared with 40% in Denmark, but the proportions of heavy smokers are similar in the two countries. Young people start smoking very early, often well before the age of 15, and the lowest smoking prevalence is found among the elderly.

2.4 Disease pattern

The disease pattern in Greenland is primarily known from mortality statistics, statistics on notifiable diseases, and population surveys. Life expectancy at birth is considerably lower both among men (60.8 years) and women (67.5 years) than in, for instance Denmark (73.6 and 78.6 years). Infant mortality is high (18.3 per 1000 live births) compared with Denmark (4.2 per 1000) as well as Alaska Natives (8.7). The causes of death show a different pattern from that of many European countries. Mortality from acute infections is still relatively high but among the young the most frequent causes of death are suicides and accidents (67% of deaths among the 15-44 year old), while later in life cardiovascular diseases and cancer account for the majority of deaths (58% of deaths among those above 45 years of age). Lung cancer and other tobacco related diseases are common causes of death and ill-health. The general picture of mortality trends during the last 30 years is that of a slightly increasing total mortality caused by the combination of a substantial decrease in infant and child mortality from infections (diarrhoea, measles, hepatitis, meningitis, and acute respiratory infections), neonatal deaths and, also in adults, from accidents, but an increased mortality in adults from lung cancer, suicides and homicides. This mortality transition is in keeping with the change of the Greenlandic society from material poverty to a society with increased material wealth but characterized by substance abuse and lack of spiritual health.

During the 19^{th} and 20^{th} centuries tuberculosis was one of the most important diseases and causes of death in Greenland. The incidence decreased dramatically during the 1950s due to the combination of improved housing conditions, case finding and treatment, and BCG vaccination. In the early

1990s, however, the incidence of tuberculosis was still considerably higher in Greenland (89 per 100,000) compared with Denmark (8 per 100,000). Reactivation and spread of the disease occurs repeatedly, especially in remote communities with poor housing and sanitary conditions.

The general disease pattern is not as well described as the mortality. There is no computerized registration hospital diagnoses let alone of reasons for visits to the out-patient clinics. Information about the major health problems in Greenland must be pieced together from a few studies of contacts with the health care services, some studies on specific diseases, and a few population surveys.

Selfrated health status decreases with age, slowly until the age of 40-50, more rapidly afterwards. Women rate their health poorer then men, and there are pronounced socioeconomic differences. About 75% of adult Greenlanders have been bothered by one or more symptoms during the two weeks before participating in a health survey, most often by pain in the arms or legs, fatigue, headache, or common cold. Only few of these had contacted the health services. About 60% of adult Greenlanders state that they suffer from a longstanding illness, most often a musculoskeletal disease. While this self reported disease pattern is quite similar to what has been found in health interview surveys in Denmark, Greenlanders use prescription drugs considerably less often than the general population of Denmark.

2.5 Health care

Greenland is divided into 18 municipalities of varying size; 16 of these presently has a small hospital or health post manned by at least one physician, nurses, health aides etc. Queen Ingrid's Hospital in Nuuk is not only the hospital for the municipality but the central hospital for the whole country. It has 130 beds and specialists in general and orthopedic surgery, obstetrics and gynecology, internal medicine, psychiatry, dermatology, anesthesiology, radiology and dentistry. Specialists from Queen Ingrid's Hospital and from Denmark visit the health districts on "the Coast" regularly but usually not more than a couple of times each year. Patients with diseases that cannot be treated at Queen Ingrid's Hospital are transferred to Denmark.

Each town on "the Coast" has a small hospital staffed with 1-4 general practitioners. There is usually an out-patient clinic, emergency unit, maternity unit, operating theatre, x-ray facilities, a laboratory and a number of beds depending on the size of the municipality. There are also one or more dental clinics at the hospital or at the school. In villages with more than 300 inhabitants there is a nursing station, in smaller villages a health aide and in small villages with less than 70 inhabitants an untrained person authorized to dispense certain drugs after consultation with the physicians. The physicians visit the villages regularly but due to shortage of staff and poor weather conditions it is not always possible to make these visits as often as needed. Probably only few villages are visited on a monthly basis. Most health professionals in Greenland are Danes working on short time assignments i.e. a couple of months or a couple of years but quite a few have settled permanently in Greenland.

Notes
1. Place of birth refers to the place of residence of the mother. Children born at the Copenhagen University Hospital (Rigshospitalet) for medical reasons are thus registered as born in Greenland if the permanent address of the mother is in Greenland.

2.6 References

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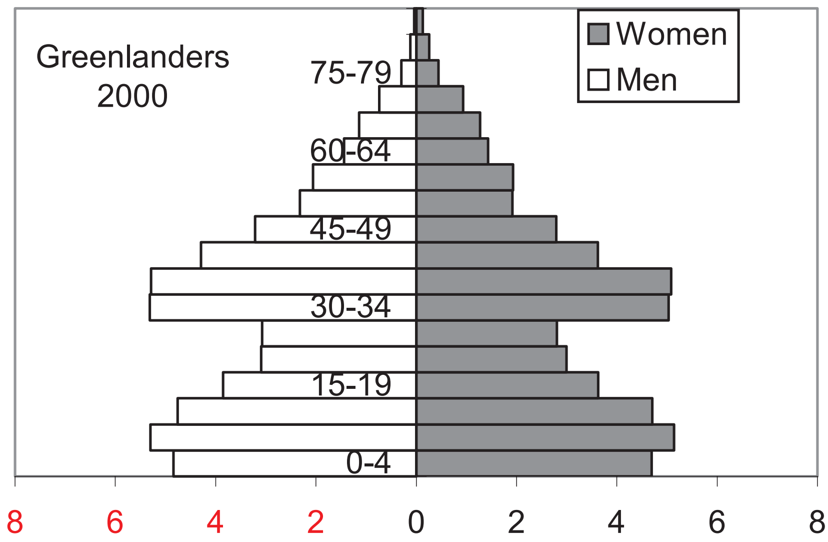
Figure 2.1 Population pyramid of the indigenous population of Greenland, 2000.



3 Contaminants in Subsistence Animals in Greenland

by

Poul Johansen , Derek Muir , Gert Asmund, and Rune Dietz

3.1 Introduction

In general people in Greenland are more exposed to contaminants from their diet than people in Europe and North America. The reason is that marine traditional food items (fish, seabirds, seals and whales) are much more important in Greenland, and at the same time that some of these food items have high levels of contaminants, i.e. metals like mercury and cadmium and organochlorines like PCBs. Within the Arctic, Greenlanders have the highest concentrations of mercury and PCBs (Hansen 1998).

Some knowledge of contaminant concentrations in the diet of Greenlanders has been available for some years, but a study to systematically survey the traditional diet was not initiated until 1999. This paper is based on results from the diet study and on data published elsewhere.

In the text, tables and figures, the names of the species are called by their English name solely, but to facilitate the understanding their Latin, Danish and Greenland names are shown in Appendix 3.1.

3.2 Methods

3.2.1 Sampling

The methods of sampling and analysis of contaminants in the diet study is described in the second volume af this report (Riget et al. 2003), in which the results are also presented more detailed than here. The purpose of this document is to assess contaminant levels in the diet in relation to human exposure. The focus in the diet study has been on Southwest Greenland, which is the most densely populated part of Greenland. Almost all samples are from this region, between Paamiut in the south to Qeqertarsuaq in the north. Many samples were collected in important areas and seasons for hunting. For examples samples from seabirds were obtained from hunting during winter in Nuuk as the most important region for hunting seabirds when they winter off Southwest Greenland. In this way samples are considered representative of the hunt and thereby of the human exposure to contaminants in the tissue and species in question.

All metal and organochlorine levels are presented on a wet wt basis with arithmetic means and standard deviations shown. This has been chosen, because the arithmetic mean will represent the average human exposure to the contaminant in question from the diet (Johansen et al. 2000), provided that the meal is selected irrespective of age, sex and region. In some cases these factors are known to affect contaminant levels, for example cadmium levels are known to increase with the age of seabirds and seals (Dietz et al. 1996). Also PCB and DDT levels are higher in male ringed seals than in females and higher in East Greenland than in West Greenland (Table 3.1 and 3.2).

3.3 Results

3.3.1 Metals

Below we will compare the metal levels with Danish standard limits for heavy metals in food (Anon. 1995). These regulations are not in force in Greenland, but the limits may be used as a reference point in assessing the levels found in Greenland food items. We also discuss the human intake of the metals and compare these to the PTWI (Provisional Tolerable Weekly Intake) set by FAO/WHO and shown in Table 3.3.

Table 3.4 lists levels of lead, cadmium, mercury and selenium in marine, freshwater and terrestrial species from Greenland. These were extracted from a Greenland contaminant database (Dietz et al. 1996, Dietz et al 1997, Riget et al. 2000) and from the diet study initiated in 1999. Data from all regions in Greenland are included, but only for datasets with at least 4 individuals analyzed.

3.3.1.1 Lead

Mean lead concentrations range from below 0.01 µg/g wet weight in marine fish meat to 0.337 µg/g in caribou liver (Table 3.4). From the same species levels are higher in liver (and kidney) than in meat. However, all lead concentrations may be considered low and are lower than the Danish standard limits for heavy metals in food ranging from 0.3 to 1 µg/g wet weight (Dietz et al. 1996).

In a study in West Greenland, the mean human intake of lead from marine food is estimated to 15 µg per person per week (Johansen et al. 2000), which is well below the PTWI as may be seen in Table 3.3.

However, the use of lead shot in Greenland may increase human lead intake considerably. In a study of breast meat of thick-billed murre (*Uria lomvia*) killed with lead shot, the mean lead concentration was 0.22 µg/g and it was estimated that eating one bird would result in an intake of 50 µg lead (Johansen et al. 2001). Later however, we have found that the actual lead intake by eating birds hunted with lead shot is significantly higher. By analyzing whole breasts, the mean lead concentration was 0.73 µg/g in murres and 6.1 µg/g in common eiders (Johansen et al. 2002). This implies that only one eider meal will result in a lead intake close to the PTWI. For murre the lead intake from one meal will be about 10% of the PTWI. We conclude that birds hunted with lead shot are a significant lead source, probably the most important, in the diet of many people in Greenland.

From a study among Baffin Island Inuit (Chan et al. 1995) a mean weekly intake of lead by adults may be calculated to 469 µg for women and 595 µg for men. This is much higher than the Greenland estimate, mainly because lead levels reported in local food in the Baffin Island study are significantly higher than in the Greenland study.

WHO (1995) has estimated that lead intake for adults worldwide range from 105 to 2212 μg per week. In Canada the dietary intake of lead may be calculated to 168 μg per week for a 60-kg person (Health and Welfare Canada 1989). This is almost similar to the estimated intake in Denmark of 162 μg per week (Anon. 1995). In Denmark cereals, vegetables, fruit and beverages are the dominant lead sources in the food.

3.3.1.2 Cadmium

The mean cadmium concentration range from below 0.01 μg/g wet wt in berries and meat from fish and terrestrial mammals to 70.4 μg/g in ringed seal kidney. In the same species levels are lowest in the meat, higher in the liver and highest in the kidney (Table 3.4). Cadmium levels are generally higher in the marine than in the terrestrial environment. In terrestrial species high cadmium levels are only found in ptarmigan (liver) and hare (kidney). Figure 3.1-3.3 compare the mean cadmium concentrations found in Greenland with the Danish food standard limits (FSL). In meat (Fig. 3.1) levels are below the FSL, except for ptarmigan, narwhal, common eider, ringed seal, king eider and kittiwake with mean levels up to about 5 times the FSL. But in liver (Fig. 3.2) and kidney (Fig 3.3) most levels exceed the FSL, up to about 70 times the FSL. In liver only terrestrial mammals, Atlantic cod, Arctic char, Atlantic salmon and Greenland cod have cadmium levels below the FSL, and in kidney this is only the case for sheep, caribou and musk-ox. In fat, blubber and muktuk cadmium levels are very low.

The mean human intake of cadmium from marine food in West Greenland has been estimated to 1004 μg per person per week, which is about twice the PTWI (Johansen et al. 2000). Seal liver is the dominant source for cadmium intake from local marine food in Greenland, but seal meat and seabird liver is also important. Other sources (fish meat and liver, whale meat, liver and skin and seabird meat) each are below 10% of the total estimated intake and thus of minor importance.
In the Canadian Eastern Arctic the mean cadmium intake by Inuit has been calculated to 1008 μg for women and 1183 μg for men (Johansen et al. 2000, based on a study by Chan et al. 1995). These figures are very close to the Greenland estimate (1004 μg) and significantly above the PTWI.

In Canada the dietary intake of cadmium may be calculated to 88 μg per week for a 60-kg person (Heath and Welfare Canada 1989). This is close to the estimated intake in Denmark: 102 μg per week with cereals, vegetables, meat and plucks and beverages as the main sources (Anon. 1995). As may be seen the mean cadmium intake in Greenland from local marine food is about 10 times higher than in Canada and Denmark.

3.3.1.3 Mercury

The mean mercury concentration range from below 0.01 μg/g wet weight in meat from all terrestrial species except caribou to 18.1 μg/g in polar bear kidney (Table 3.4). Except for fish, the mercury concentration is higher in liver than in meat of the same species, and levels are generally higher in the marine than in the terrestrial environment.

In Figure 3.4-3.6 the mean mercury concentrations are compared to the Danish food standard limits (FSL). Except for caribou liver, no mercury levels exceed the FSL in any tissue of the terrestrial species, whereas in marine species mercury levels exceed the FSL in most cases. The mercury concentration is only below the FSL in mussels, crustacean, fish meat and fish liver. In fat and blubber from mammals and in muktuk from minke whale mercury levels are below the FSL for meat, whereas levels in muktuk from toothed whales exceed this limit.

The mean human intake of total mercury from marine food in West Greenland has been estimated to 846 μg per person per week, which is almost 3 times the PTWI (Johansen et al. 2000). Seal liver is the dominant source and seal meat is important for mercury intake from the local diet in Greenland. Other sources (fish meat and liver, whale meat, liver and skin and seabird meat) each are below 10% of the total estimated intake and thus of minor importance. In the Canadian Eastern Arctic the mean mercury intake by Inuit has been calculated to 854 μg for women and 1162 μg for men (Johansen et al. 2000, based on a study by Chan et al. 1995). These figures are very close to the Greenland estimate (1004 μg) and significantly above the PTWI.

In Denmark the intake of total mercury from food is much lower than in Greenland. It has been estimated to 35 μg per person per week with fish as the most important source (Anon. 1995).

3.3.1.4 Selenium

The mean selenium concentration range from less than 0.3 μg/g-wet wt in berries and meat from most terrestrial mammals to 16.9 μg/g in whale skin (Table 3.4, Figure 3.7-3.9). In the same species the concentration is higher in the liver than in the meat. Selenium levels are higher in the marine than in the terrestrial environment, as is also seen for mercury.

Selenium is an essential trace mineral and has experimentally been shown to reduce the toxic response in the nervous system associated with exposure to mercury (WHO 1990), but the efficacy of selenium as an antidote against mercury toxicity in humans is controversial (Magos 1991). It is however notable that in all tissues of Greenland animal groups with high mercury levels (e.g. marine mammals and seabirds) selenium is present in substantial surplus to mercury on a molar basis, indicating an association between mercury and selenium (Dietz et al. 1996).

A PTWI for selenium has not been set. Yang et al. (1989) suggested 400 μg per day as the maximum daily safe intake, equaling 2800 μg per week. Whale skin is the dominant selenium source in Greenland food, constituting more than 80% of the calculated intake (Johansen et al. 2000). From this source alone the selenium intake is above the limit suggested. The calculated intake from whale skin in Greenland however may be somewhat overestimated. Next to whale skin, the most important selenium sources in Greenland are seal liver and meat from seals and seabirds. The total selenium intake is estimated to 4569 μg per person per week.

In Denmark the selenium intake from food has been estimated to 343 μg per week with meat, plucks, fish, egg, milk, cheese and cereals as the most important sources (Anon. 1995), which is much lower than the intake in Greenland. The Danish intake is close to the recommended intake from food of 350 μg per week in Denmark (Anon. 1995).

3.3.2 Organochlorines (OCs)

Prior to 1999 only few analyses for organochlorines had been conducted in Greenland. We have not included these in this paper, because only few are important to human diet, and because some of the older data cannot be compared to the data obtained in the diet study initiated in 1999. In this study chemical groups analyzed include PCBs (sum of 104 congeners; ΣPCB), DDTs (sum of 6 DDT-related compounds; ΣDDT), chlordane, toxaphene (total and selected congeners), HCH, chlorbenzenes, mirex, octachlorostyrene, and endosulfan. A subset of the samples is also analyzed for coplanar PCBs, BPDE, CDPE, SCCP and TBT.

The analytical results for major organochlorines found in species analyzed so far are shown in Table 3.5-3.6. Figure 3.10-3.12 presents the results for ΣPCBs, Figure 3.13-3.15 for ΣDDTs and Figure 3.16 for toxaphene.

Almost without exception OC levels are lower in the terrestrial than in the marine environment. The highest OC concentrations are found in fat tissues of marine mammals, whereas fat of terrestrial mammals has low concentrations. Otherwise there are no systematic variations in OC concentrations in different tissues. In some mammal and bird species concentrations are highest in the liver, but in other species it is opposite.

In a recent study OC data have also become available for fat from polar bear sampled 1999-2001 in Ittoqqortormiit, East Greenland. The ΣPCB concentration in these were the highest observed in recent Greenland samples with a mean level of 5708 µg/g wet weight in 9 females and 5892 µg/g in 10 males (Riget et al. 2003).

Mean concentrations of ΣPCB10 in ringed seal blubber were very similar to levels reported by Cleeman et al. (2000) for West Greenland (Qeqertarsuaq). Levels of ΣPCBs (and ΣPCB10) in ringed seal blubber were also similar to results from E. Baffin Island (Pangnirtung) but lower than reported in N. Quebec, Labrador or Ittoqqortormiit (Muir et al. 1999; AMAP 1998). Mean levels of ΣPCBs (and/or ΣPCB10) in kittiwake liver were similar to reports for Svalbard but lower than found at Bear Island and in Franz Josef Land. Mean levels of ΣPCBs in common eider were similar to reports for Svalbard. Musk-ox liver from Banks Island in the western Canadian arctic had similar levels of ΣPCB10 to those found in Greenland animals (AMAP 1998). There were few other data with which to compare the results from Greenland with the same species in other locations in the Arctic.

At this stage data are too incomplete for comprehensive calculations of human intakes of OCs in Greenland, but provisional estimates can be made. Calculations have been done for the Baffin Island community of Broughton Island (Qikiqtarjuaq) by Kuhnlein et al (1995, cited from Jensen et al. 1997), who also have compared the intakes to Tolerable Daily Intakes (TDI) of OCs. They conclude that the mean intake value of DDTs is well below the TDI (a factor of about 100) and that the mean intake values of chlorbenzenes, HCH, dieldrin and PCB are within a factor of 10 of the TDI for these contaminants. However for chlordane and toxaphene, the mean intakes exceed the TDI by nearly ten-fold. TDIs are calculated by dividing the NOAEL (no observed adverse effect level) from laboratory animal bioassays by an appropriate uncertainty factor to take into account the range of susceptibility of the human population (Calabrese 1985). The Canadian TDI's for chlordane (sum of oxychlordane, cis- and trans-chlordane and cis- and trans-nonachlor) of 0.05 µg kg bw^{-1} d^{-1} and toxaphene (quantified with the technical toxaphene standard) of 0.2 µg kg bw^{-1} d^{-1} are low reflecting a high uncertainty factor (1000) compared to PCBs (100) (Gilman et al. 1997). Future research may lower this uncertainty factor for chlordane and toxaphene. Also changes in methods of analysis of toxaphene involving the use of individual congeners rather than an estimate based on the total mixture, is showing that toxaphene levels are much lower than reported if quantified with the technical material (deGeus et al. 1999).

This study has developed data on OC concentrations in a wide range of important species in Greenland. There are very limited or no previous data for OCs in many of these species in the circumpolar Arctic.

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Table 3.1. Organochlorines in ringed seal blubber from East and West Greenland in 1994, arithmetic means ± SD in µg/kg wet weight (Cleemann et al. 2000). PCB10 is the sum of congeners (28, 31, 52, 101, 105, 118, 138, 153, 156 and 180). DDT is the sum of pp DDE, pp DDD and ppDDT.

	Sex and number of samples	PCB10	DDT
West Greenland	Females (33)	345 ± 198	488 ± 285
	Males (40)	501 ± 298	651 ± 404
East Greenland	Females (11)	813 ± 294	1134 ± 464
	Males (14)	1178 ± 964	1609 ± 1375

Table 3.2. Organochlorines in ringed seal tissues from East and West Greenland in 1999, arithmetic means ± SD in µg/kg wet weight (this study).

		East Greenland	West Greenland
Blubber	PCB10	551 ± 380	284 ± 131
	DDT	632 ± 319	430 ± 201
Liver	PCB10	33,8 ± 32,0	8,51 ± 1,49
	DDT	25,7 ± 26,6	7,97 ± 2,80
Muscle	PCB10	79,1 ± 95,1	11,9 ± 15,2
	DDT	65,6 ± 70,0	13,5 ± 20,1

Table 3.3. Provisional Tolerable Weekly Intake (PTWI) of lead, cadmium and mercury.

	µg per kg body weight per week	µg for a 60-kg person per week	Reference
Lead	25	1500	FAO/WHO, 1993, 2000
Cadmium	7	420	FAO/WHO, 1989
Mercury	5	300	FAO/WHO, 1972
Methyl-mercury	3.3		FAO/WHO, 2000

Table 3.4. Pb, Cd, Hg and Se concentrations (μg/g wet wt) in West Greenland species. In cases where no standard deviation is given, the mean is below the detection limit or is a mean of 2 or more datasets. Hg is total Hg.

		Tissue	N	Pb mean	Pb sd	Cd mean	Cd Sd	Hg mean	Hg sd	Se mean	Se sd
Terrestrial	Crowberry	berry	5			0.004	0.006	<0.002	-	<0.05	-
	Arctic blueberry	berry	5			0.028	0.007	<0.001	-	<0.03	-
	Ptarmigan	meat	5			0.116	0.150	<0.002	-	0.169	0.068
		liver	5			5.20	4.14	0.026	0.008	0.246	0.080
	Arctic hare	meat	5			0.005	0.003	<0.002	-	<0.05	-
		liver	5			0.186	0.021	0.029	0.010	0.102	0.046
		kidney	5			3.81	1.71	0.052	0.007	0.841	0.174
	Caribou	meat	>100	0.011	0.039	0.003	0.004	0.014	0.013	0.103	0.014
		liver	>100	0.337	0.463	0.418	0.366	0.152	0.177	0.264	0.242
		kidney	5			0.276	0.117	0.038	0.008	0.563	0.065
		fat	5			0.003	0.002	<0.003	-	<0.2	-
	Musk-ox	meat	9			0.002	0.004	0.002	0.001	<0.05	-
		liver	5			0.051	0.007	0.023	0.004	0.062	0.044
		kidney	5			0.284	0.202	0.072	0.025	0.757	0.246
		fat	5			<0.005	-	<0.005	-	<0.2	-
	Sheep	meat	10			<0.002	-	<0.002	-	<0.05	-
		liver	5			0.108	0.059	0.005	0.001	0.098	0.054
		kidney	5			0.200	0.081	0.012	0.011	0.707	0.165
		fat	5			<0.005	-	<0.005	-	<0.05	-
Marine invertebrates	Deep sea shrimp	meat	>6	0.038	0.019	0.019	0.014	0.050	0.016	0.142	0.014
	Queen crab	meat	10			0.035	0.032	0.096	0.066	0.599	0.157
		”liver”	5			5.06	1.71	0.074	0.023	3.27	1.15
	Blue mussel	soft parts	15	0.127	0.034	0.720	0.250	0.016	0.001	0.900	0.023
	Iceland scallop	soft parts	>10	0.130	0.025	3.21	0.10	0.020	0.005	0.470	0.057
		meat	8			2.04	0.648	0.022	0.002	0.128	0.010
Marine fish	Arctic char	meat	72					0.043	0.004		
		liver	4			0.092	0.035	0.018	0.004	1.48	0.291
	Atlantic salmon	meat	20			0.003	0.001	0.040	0.010	0.269	0.030
		liver	10			0.190	0.040	0.043	0.006	7.93	1.27
	Capelin	meat	20			0.003	0.001	0.009	0.002	0.163	0.021
		whole	10					0.007	0.002	0.131	0.014

	Atlantic cod	meat	9			<0.001	-	0.014	0.001	0.293	0.018
		liver	5			0.050	0.024	0.007	0.002	0.779	0.146
	Greenland cod	meat	5	<0.01	-	<0.015	-	0.020	0.010	0.209	0.023
		liver	>5			0.357	-	0.023	-	1.47	-
	Redfish	meat	>5			<0.015	-	0.037	-	0.27	-
		liver	>5			0.96	-	0.028	-	3.04	-
	Spotted wolfish	meat	>5	<0.01	-	<0.015	-				
		liver	>5	0.015	-	2.69	-				
	Greenland halibut	meat	>5	<0.01	-	<0.015	-	0.154	0.134	0.313	0.116
		liver	>5			1.45	-	0.151	0.151	1.49	0.759
Seabirds	Thick-billed murre	meat	20			0.089	0.119	0.076	0.021	0.538	0.230
		liver	10			4.99	3.96	0.227	0.085	1.07	0.108
	Common eider	meat	>10	<0.018	-	0.163	-	0.151	-	1.10	-
		liver	>10	0.060	-	2.99	-	0.891	-	7.10	-
	King eider	meat	>10			0.486	-	0.113	-	0.81	
		liver	>10			4.58	-	0.515	-	9.56	
	Kittiwake	meat	>10			0.523	-	0.180	-	3.31	
		liver	>10			8.17	-	0.708	-	11.1	-
Seals	Ringed seal	meat	>20	<0.015	-	0.196	-	0.221	-	0.295	-
		liver	>50	0.023	-	13.3	-	2.47	-	2.08	-
		kidney	>50			70.4	-	0.82	-	2.65	-
		blubber	10			0.011	0.007	<0.005	-	<0.2	-
	Harp seal	meat	>10			0.072	-	0.210	-	0.44	-
		liver	>10			3.04	-	2.29	-	1.62	
		kidney	>10			21.6	-	0.41	-		
	Hooded seal	meat	>10			0.072	-	0.487	-		
		liver	>10			10.4	-				
		kidney	>10			41.8	-				
Whales	Minke whale	meat	82			0.009	0.007	0.092	0.055	0.194	0.060
		liver	73			1.04	0.734	0.288	0.293	1.38	0.605
		kidney	75			4.20	2.68	0.222	0.181	1.22	0.262
		blubber	6			0.006	0.004	0.011	0.017	0.143	0.064
		muktuk	4			0.007	0.003	0.031	0.021	6.28	3.73
	Beluga	meat	>10			0.032	-	0.790	-	0.147	-
		liver	>10			2.70	-	7.38	-	7.01	-
		blubber	5			<0.005	-	0.020	0.016	0.100	0.040
		muktuk	5			0.009	0.009	0.291	0.159	5.67	2.27
	Narwhal	meat	>10			0.156	-	0.549	-	0.084	-

		liver	>10			9.22	-	4.05	-	3.35	-
		blubber	5			0.010	0.005	0.017	0.007	0.059	0.007
		muktuk	5			0.019	0.015	0.431	0.146	5.26	0.93
	Harbor porpoise	meat	77			0.078	0.069	0.554	0.221	0.58	0.24
		liver	44			4.29	2.87	6.23	5.34	3.29	2.04
		kidney	26			18.5	14.1	1.03	0.458	6.22	2.39
		muktuk	34			<0.02	-	0.558	0.272	35.3	16.9
	Polar bear	meat	77			0.021	0.025	0.089	0.061	0.36	0.14
		liver	93			1.29	1.01	11.6	7.25	4.90	2.92
		kidney	95			18.5	19.6	18.1	15.2	7.96	5.64

Table 3.5. Mean concentrations of major organochlorines in marine species from West Greenland (ng/g wet wt). ΣPCB is the sum of 104 congeners. ΣPCB10 is the sum of congeners 28, 31, 52, 101, 105, 118, 138, 153, 156 and 180. ΣDDT is the sum of pp and op DDE, pp and op DDD and pp and op DDT. ΣCHL is the sum of oxychlordane, trans-chlordane, cis- chlordane, cis-chlordane and trans-nonachlor. ΣHCH is the sum of alfa, beta and gamma HCH. Toxaphene is Total toxaphene (quantified with the technical toxaphene standard).

Species	Tissue	N		ΣPCB	ΣPCB10	ΣDDT	ΣCHL	ΣHCH	ΣCBz	Toxaphene
Deep sea shrimp	meat	11	Mean	1.70	0.69	0.15	0.51	0.06	0.69	
			Sd	2.93	0.87	0.07	0.11	0.04	0.19	
Snow crab	meat	5	Mean	2.15	1.97	3.52	0.36	0.48	0.07	
			Sd	0.82	1.34	0.87	0.16	0.18	0.10	
	”liver”	5	Mean	69.5	41.2	37.9	5.25	2.36	3.04	
			Sd	75.9	44.8	46.2	4.46	1.64	2.83	
Atlantic cod	meat	9	Mean	3.96	1.44	0.60	0.43	0.13	0.27	
			Sd	3.27	1.86	0.30	0.09	0.07	0.10	
	liver	3	Mean	162	53	82.8	65.2	15.1	17.5	
			Sd	24.4	8.61	18.6	19.9	1.0	2.3	
Redfish	meat	5	Mean	9.31	3.17	4.75	3.45	0.66	0.92	
			Sd	6.06	2.05	3.96	2.77	0.57	0.69	
Atlantic salmon	meat	7	Mean	17.9	5.96	12.0	5.1	3.77	1.84	
			Sd	5.26	1.71	3.97	2.04	1.9	0.72	
Capelin	meat	10	Mean	6.12	1.84	5.62	3.38	0.45	0.92	
			Sd	1.45	0.41	1.01	0.68	0.20	0.25	
Greenland halibut	meat	6	Mean	26.7	11.5	14.5	0.88	4.71	0.31	
			Sd	17.1	7.04	8.21	0.54	1.96	0.19	
	liver	5	Mean	1147	492	205	4.58	44.7	3.34	
			Sd	2165	921	286	1.27	49.9	3.97	
Thick-billed murre	meat	19	Mean	19.7	8.42	6.97	4.97	0.729	3.95	27.3
			Sd	11.1	5.03	5.22	5.17	0.238	2.37	9.19
	liver	5	Mean	20.2	8.81	8.11	4.57	0.629	6.47	53.0
			Sd	6.10	2.95	3.41	1.31	0.171	2.14	15.1

Common eider	meat	10	Mean	23.0	12.9	3.84	4.57	0.584	2.51	14.3
			Sd	31.2	20.0	1.40	0.692	0.205	0.819	7.43
	liver	5	Mean	25.5	13.2	5.78	12.8	0.813	3.63	12.4
			Sd	17.7	11.0	4.14	5.55	0.231	0.955	4.92
King eider	meat	10	Mean	14.5	6.46	3.89	4.98	1.03	3.14	8.67
			Sd	5.55	2.33	2.15	1.78	0.377	1.40	11.2
	liver	5	Mean	27.3	8.71	5.70	16.0	1.28	4.13	13.5
			Sd	10.7	2.77	2.66	9.70	0.721	1.79	10.2
Kittiwake	meat	9	Mean	191	98.1	30.9	23.9	4.08	18.8	96.4
			Sd	140	77.0	12.1	6.46	0.732	3.37	32.7
	liver	5	Mean	125	73.8	8.31	4.68	1.09	9.10	47.9
			Sd	125	73.7	5.65	4.65	0.666	4.62	32.7
Ringed seal	blubber	10	Mean	549	287	439	241	74.1	14.9	219
			Sd	231	132	205	114	26.9	5.58	81.0
	meat	20	Mean	26.7	12.0	13.6	7.72	3.04	0.752	8.58
			Sd	28.2	15.3	20.3	11.2	5.13	1.00	14.5
	liver	5	Mean	50.7	8.57	8.26	9.56	2.18	0.658	39.6
			Sd	51.5	1.50	3.01	2.69	0.809	0.312	12.4
	kidney	5	Mean	10.2	2.59	2.15	1.79	0.779	0.384	0.81
			Sd	2.80	0.168	0.484	0.729	0.200	0.166	0.08
Minke whale	blubber	20	Mean	3188	1055	951	74.7	335	108	
			Sd	2741	1073	863	36.6	295	65.3	
Narwhal	blubber	3	Mean	3284	991	1912	1190	128	462	
			Sd	1866	557	1327	736	86	253	
Beluga	blubber	10	Mean	2449	1018	1558	1203	136	260	
			Sd	1131	483	765	624	72.2	158	
	meat	20	Mean	59.5	21.7	29.2	23.6	2.64	8.20	
			Sd	46.0	17.9	25.2	20.1	1.60	5.55	
	liver	5	Mean	55.3	20.4	24.1	17.4	2.60	13.3	
			Sd	25.2	8.93	12.1	8.59	1.22	7.96	
	kidney	5	Mean	76.7	26.1	35.2	21.2	2.48	10.9	
			Sd	72.9	24.3	36.5	19.0	1.99	9.28	
	muktuk	5	Mean	78.5	35.4	57.1	44.7	3.10	6.76	
				42.6	18.8	26.5	24.4	1.45	4.97	

Table 3.6. Mean concentrations of major organochlorines in terrestrial species from West Greenland (ng/g wet wt). For explanation of contaminants see text to table 4.

Species	Tissue	N		ΣPCB	ΣPCB10	ΣDDT	ΣCHL	ΣHCH	ΣCBz	Toxaphene
Ptarmigan	muscle	5	Mean	9.03	1.76	0.043	1.66	0.224	0.217	0.69
			sd	4.16	0.619	0.020	0.064	0.124	0.081	0.49
	liver	5	Mean	18.3	1.55	0.689	0.682	0.160	0.792	0.73
			sd	13.7	1.12	0.461	0.431	0.033	0.702	0.45
Hare	muscle	5	Mean	1.55	0.107	0.015	0.156	0.050	0.357	0.04
			sd	1.08	0.075	0.018	0.091	0.032	0.196	0.04
	liver	5	Mean	0.442	0.099	0.053	3.41	0.054	0.218	0.48
			sd	0.143	0.039	0.056	2.19	0.022	0.049	0.30
	kidney	5	Mean	6.09	0.799	0.175	0.917	0.458	2.46	2.63
			sd	3.78	0.762	0.184	0.665	0.267	1.65	0.08
Lamb	muscle	5	Mean	1.19	0.711	0.332	0.112	0.081	0.593	
			sd	0.808	0.394	0.119	0.049	0.044	0.320	
	liver	5	Mean	5.33	2.04	0.395	0.080	0.148	0.513	
			sd	7.45	1.93	0.256	0.042	0.075	0.130	
	kidney	5	Mean	2.31	0.508	0.115	0.034	0.128	0.212	
			sd	1.82	0.334	0.057	0.019	0.043	0.055	
	fat	5	Mean	7.13	1.85	1.20	0.284	0.219	1.21	
			sd	10.9	0.752	0.653	0.069	0.088	0.288	
Musk-ox	muscle	5	Mean	2.38	1.06	0.15	0.33	0.40	1.97	
			sd	2.92	1.43	0.19	0.33	0.32	2.94	
	liver	5	Mean	2.22	0.835	0.108	0.677	0.587	1.24	
			sd	0.439	0.208	0.021	0.303	0.067	0.198	
	kidney	5	Mean	1.08	0.399	0.057	0.104	0.166	0.434	

			sd	0.957	0.407	0.036	0.016	0.030	0.101	
	fat	5	Mean	3.57	1.88	0.38	0.45	0.65	4.26	
			sd	0.592	0.31	0.25	0.10	0.03	0.04	

Figure 3.1. Cadmium concentrations in meat from Greenland animals and berries. Lines show the Danish food standard limits.

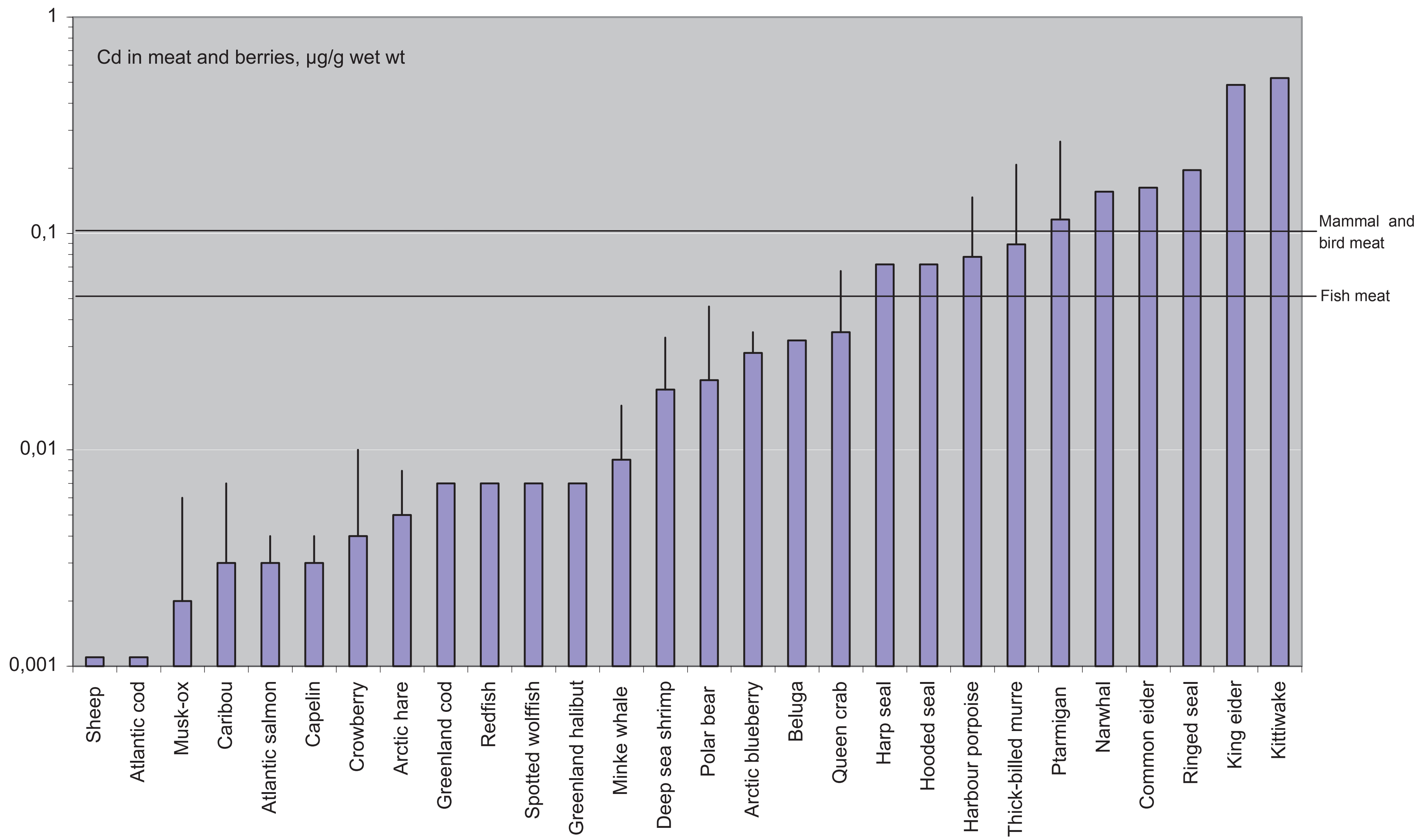


Figure 3.2. Cadmium concentrations in mollusks and liver from Greenland animals. Line shows the Danish food standard limits.

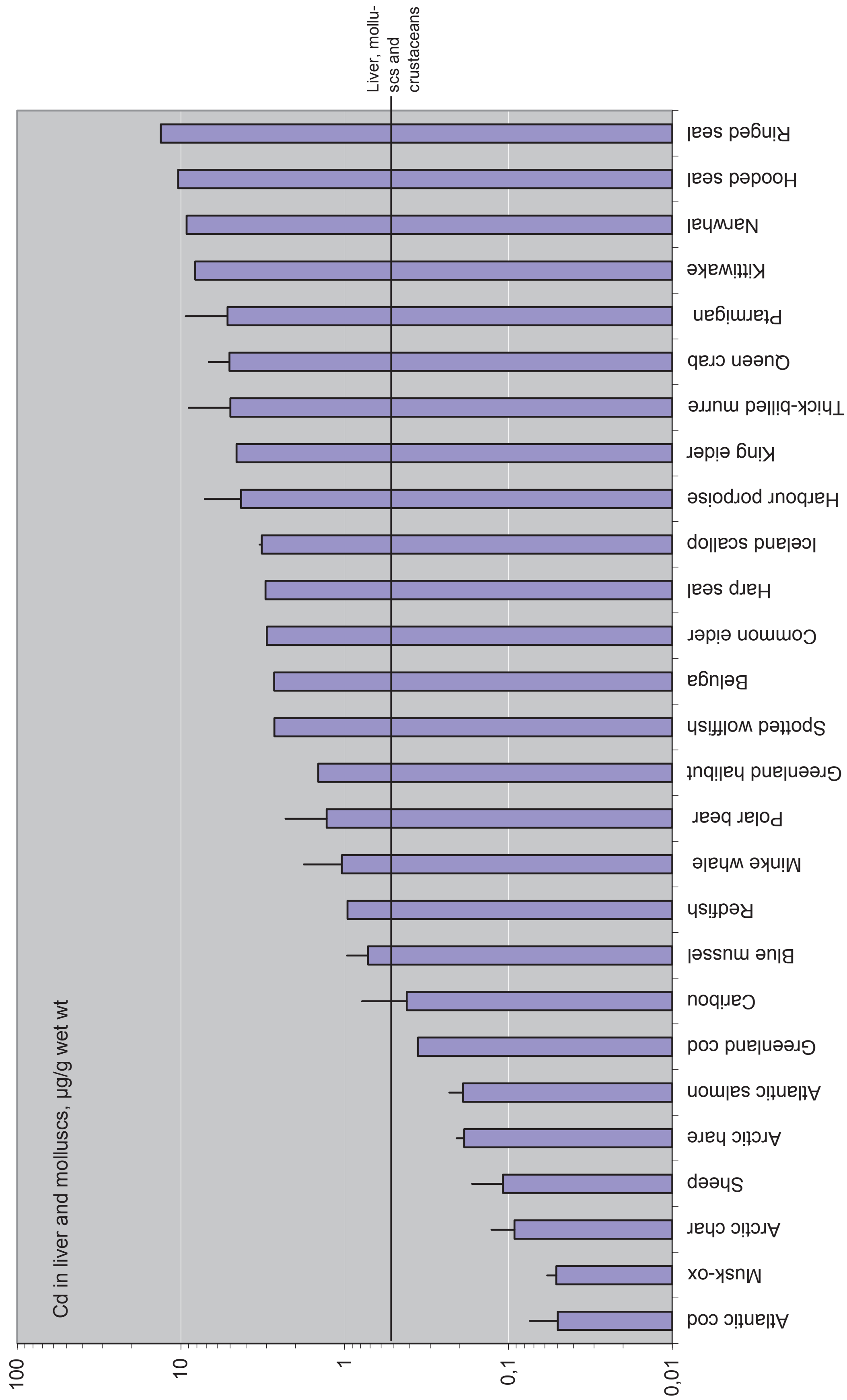


Figure 3.3. Cadmium concentrations in kidney, blubber and muktuk from Greenland animals. Lines show the Danish food standard limits.

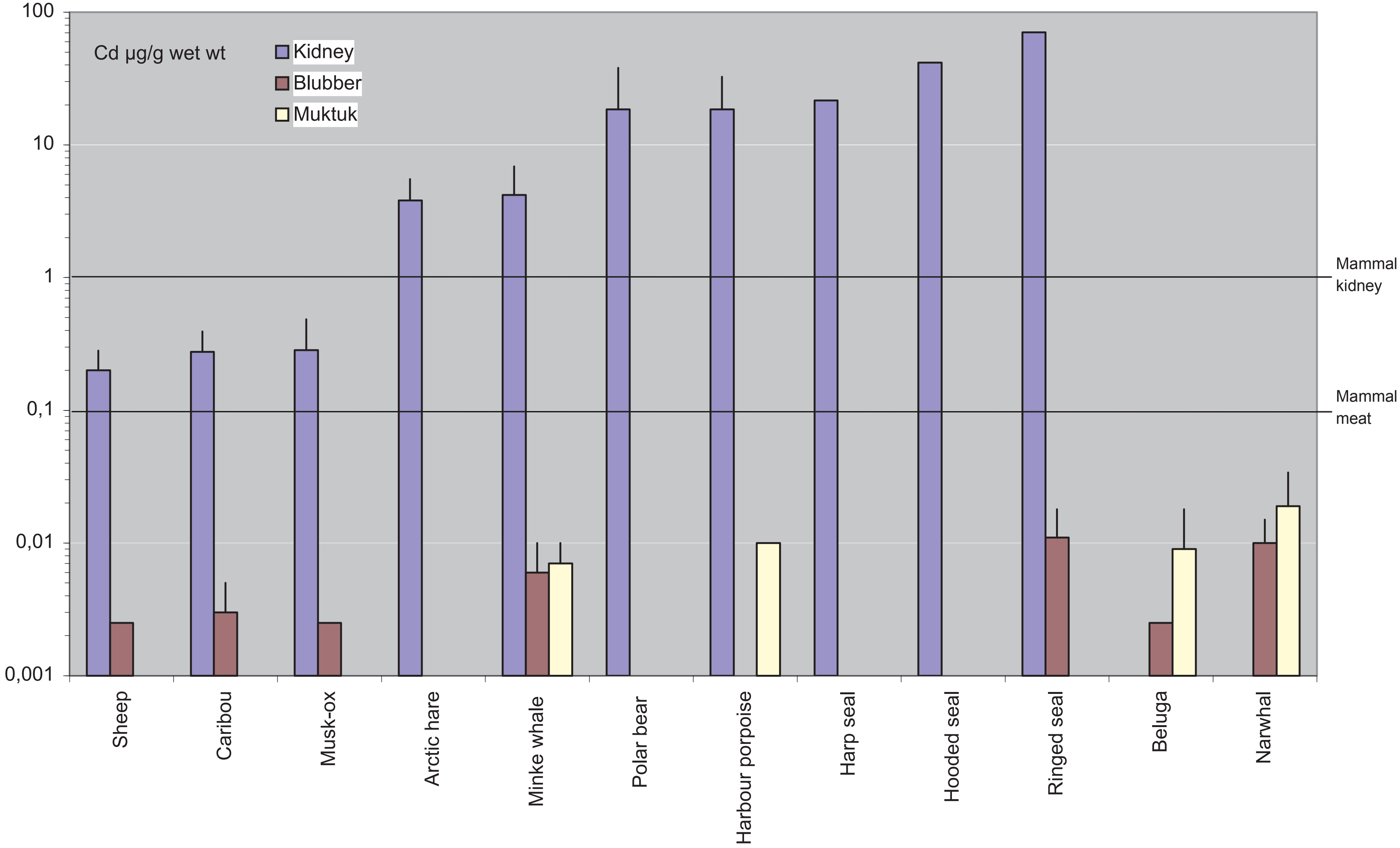


Figure 3.4. Mercury concentrations in meat from Greenland animals and berries. Lines show the Danish food standard limits.

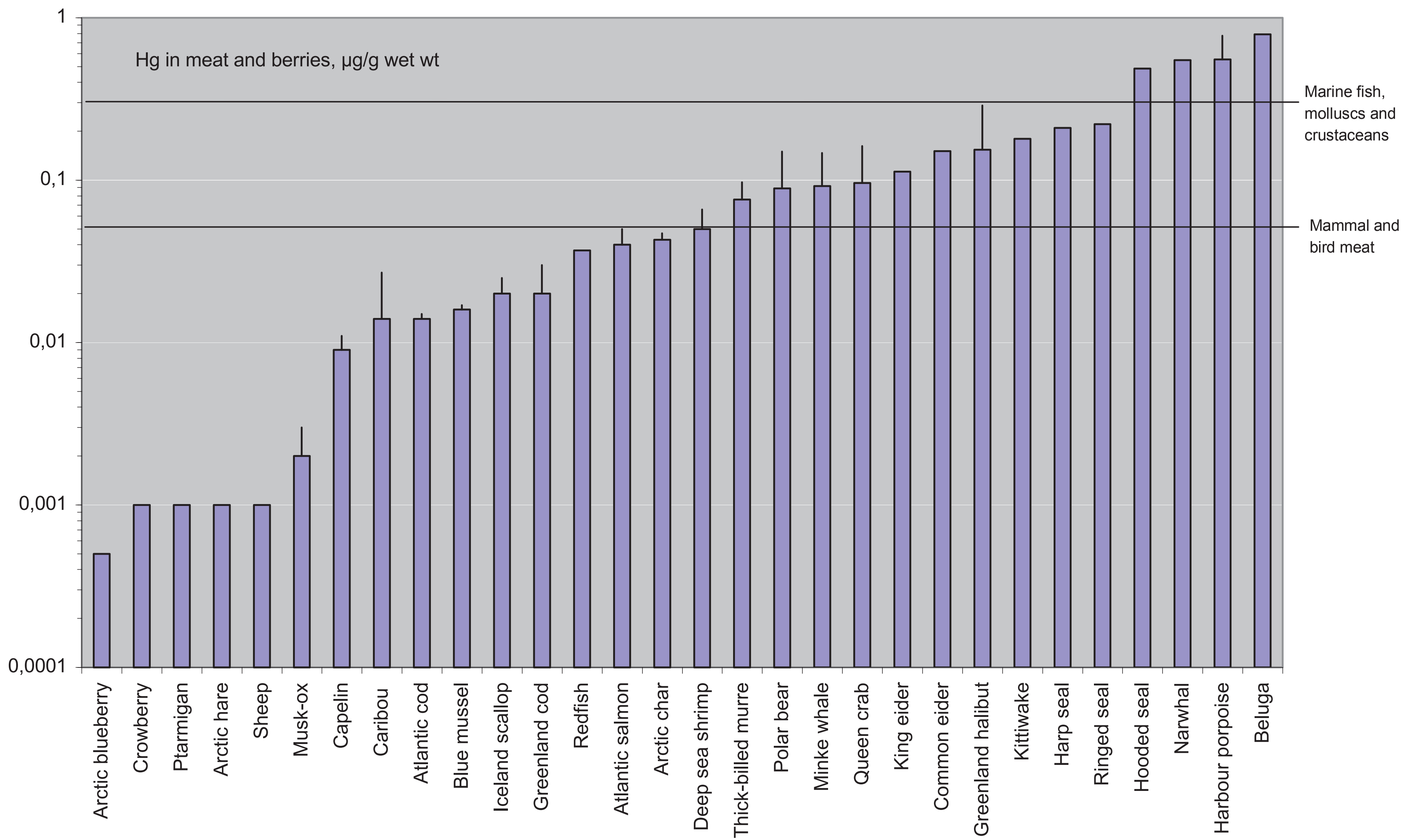


Figure 3.5. Mercury concentrations in mollusks and liver from Greenland animals. Lines show the Danish food standard limits.

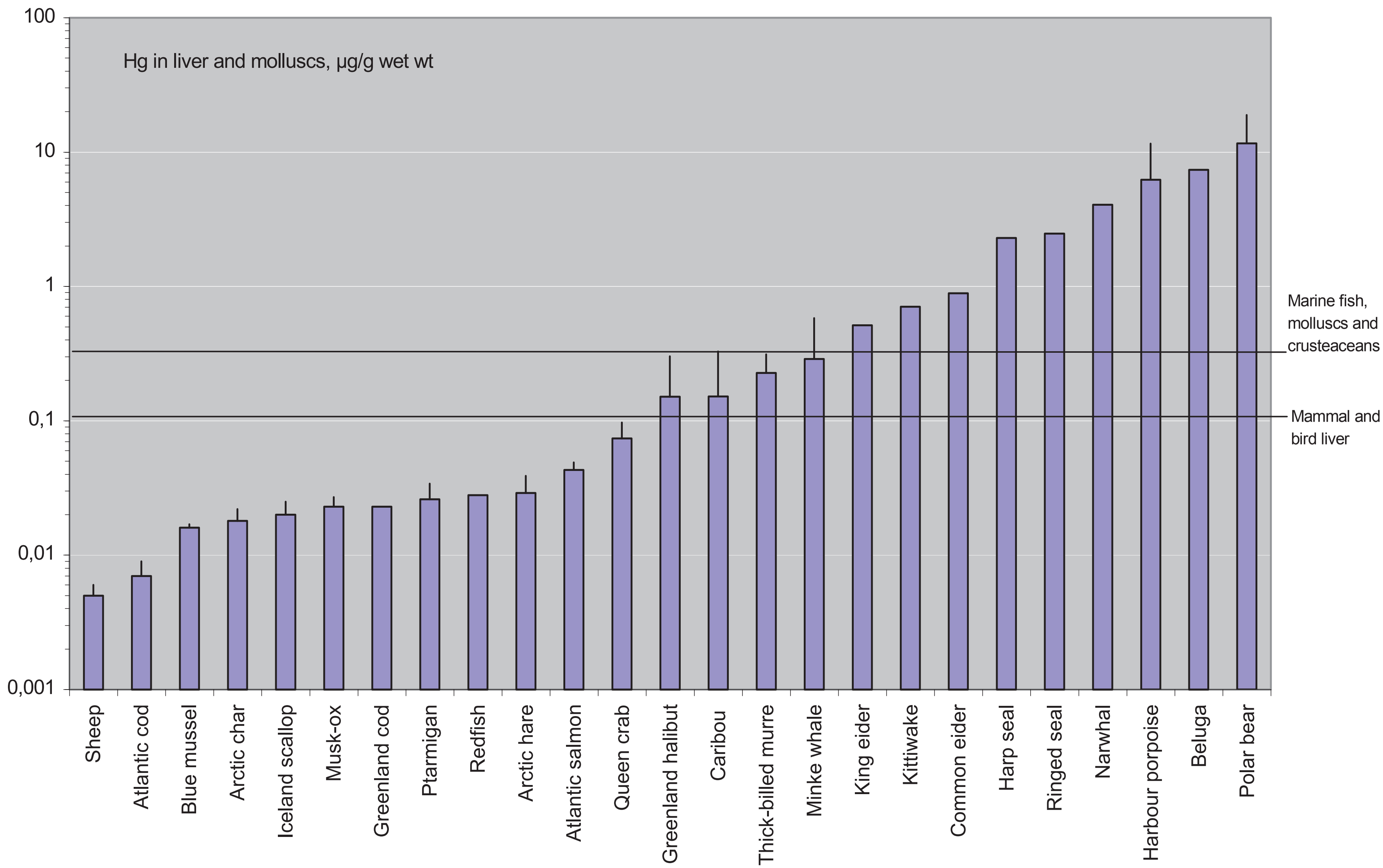


Figure 3.6. Mercury concentrations in kidney, blubber and muktuk from Greenland animals. Lines show the Danish food standard limits.

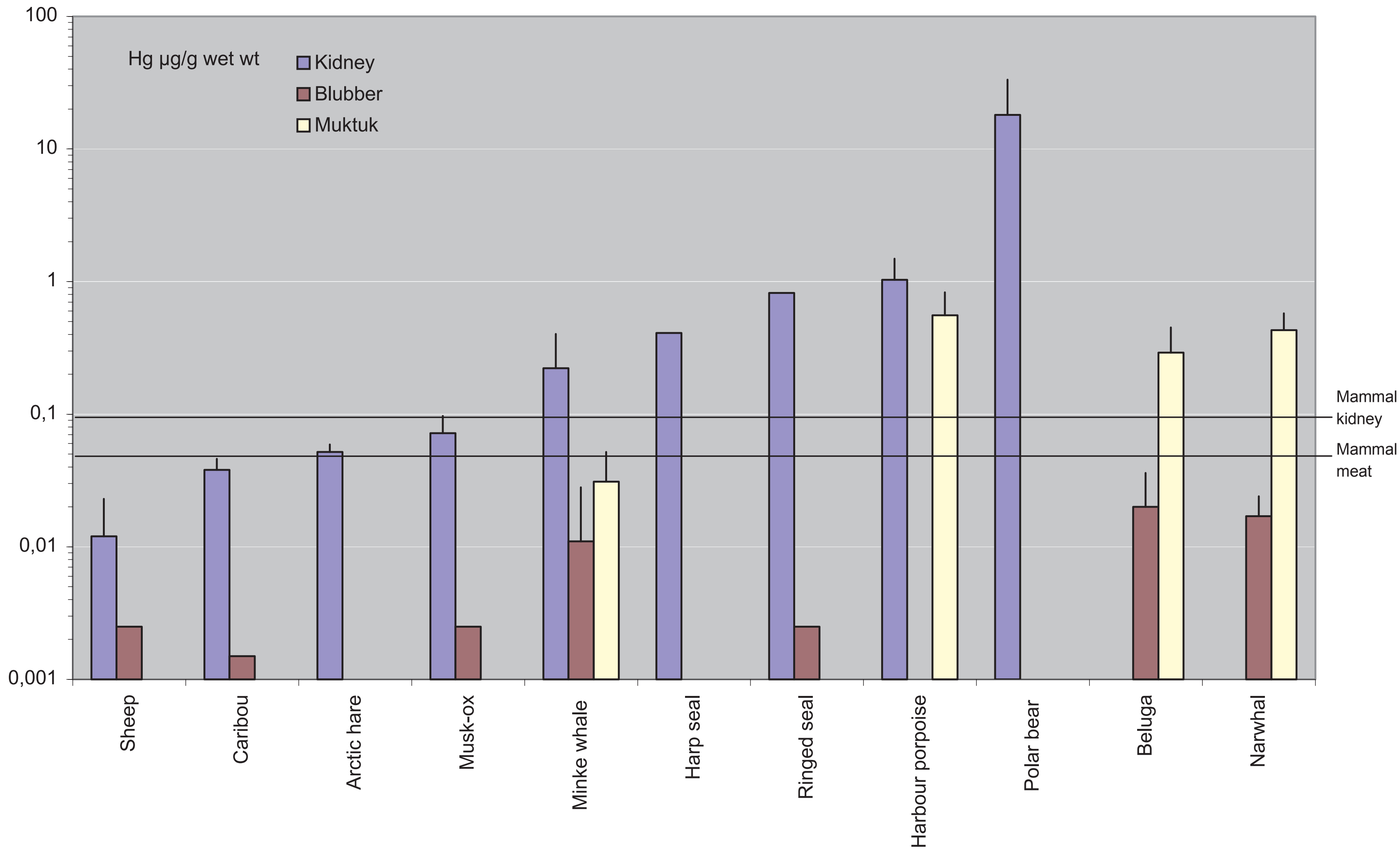


Figure 3.7. Selenium concentrations in meat from Greenland animals and berries.

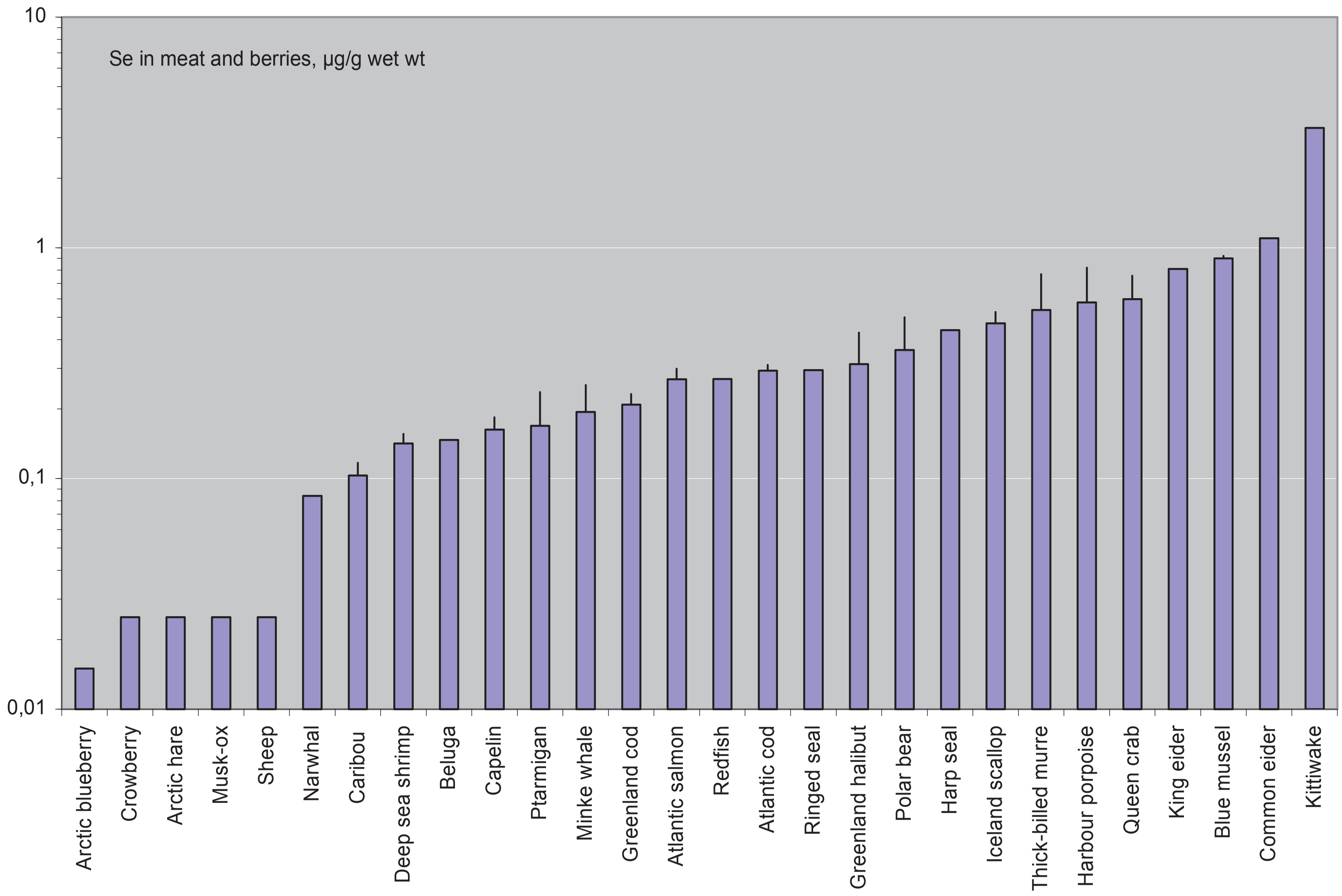


Figure 3.8. Selenium concentrations in mollusks and liver from Greenland animals.

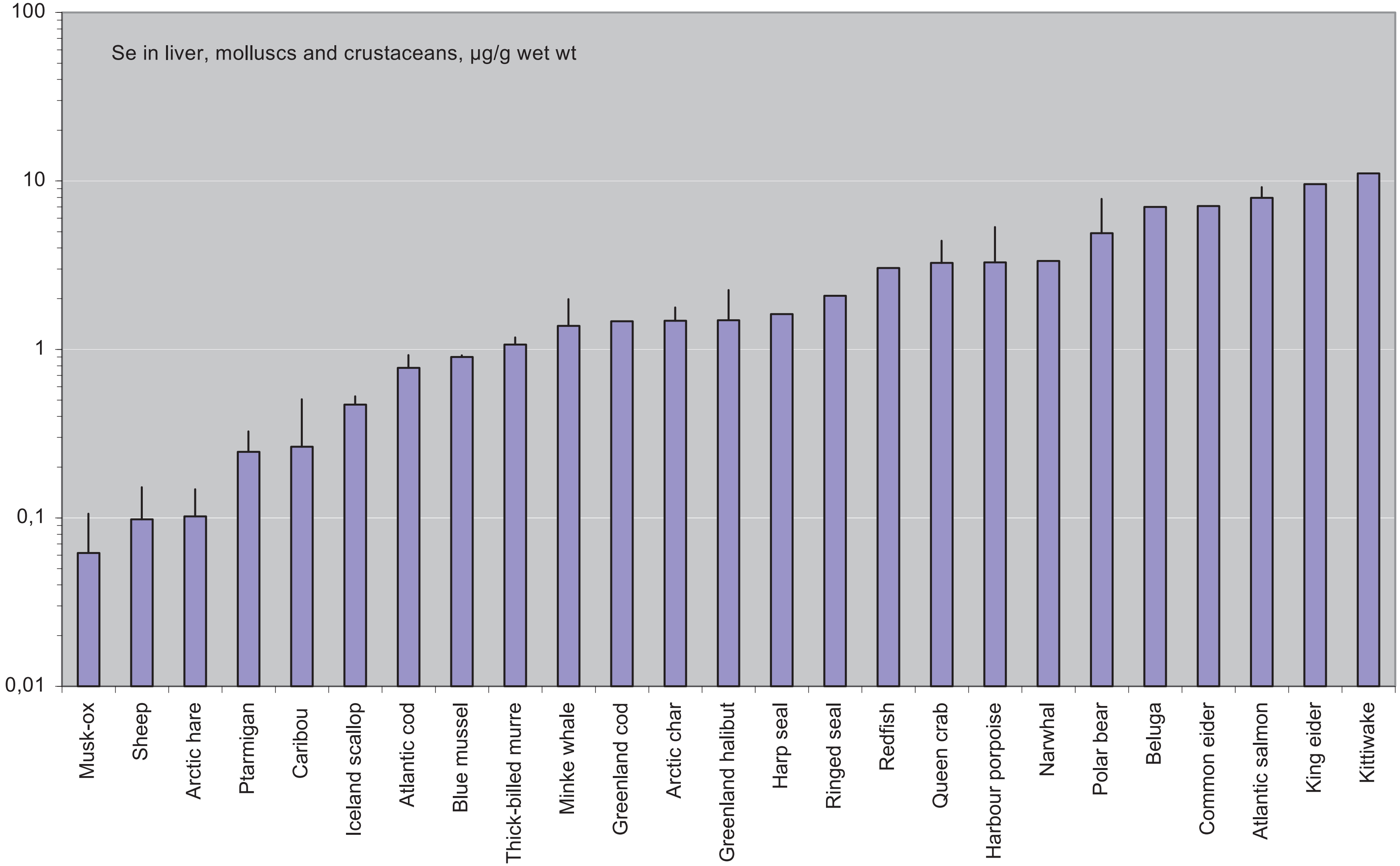


Figure 3.9. Selenium concentrations in kidney, blubber and muktuk from Greenland animals.

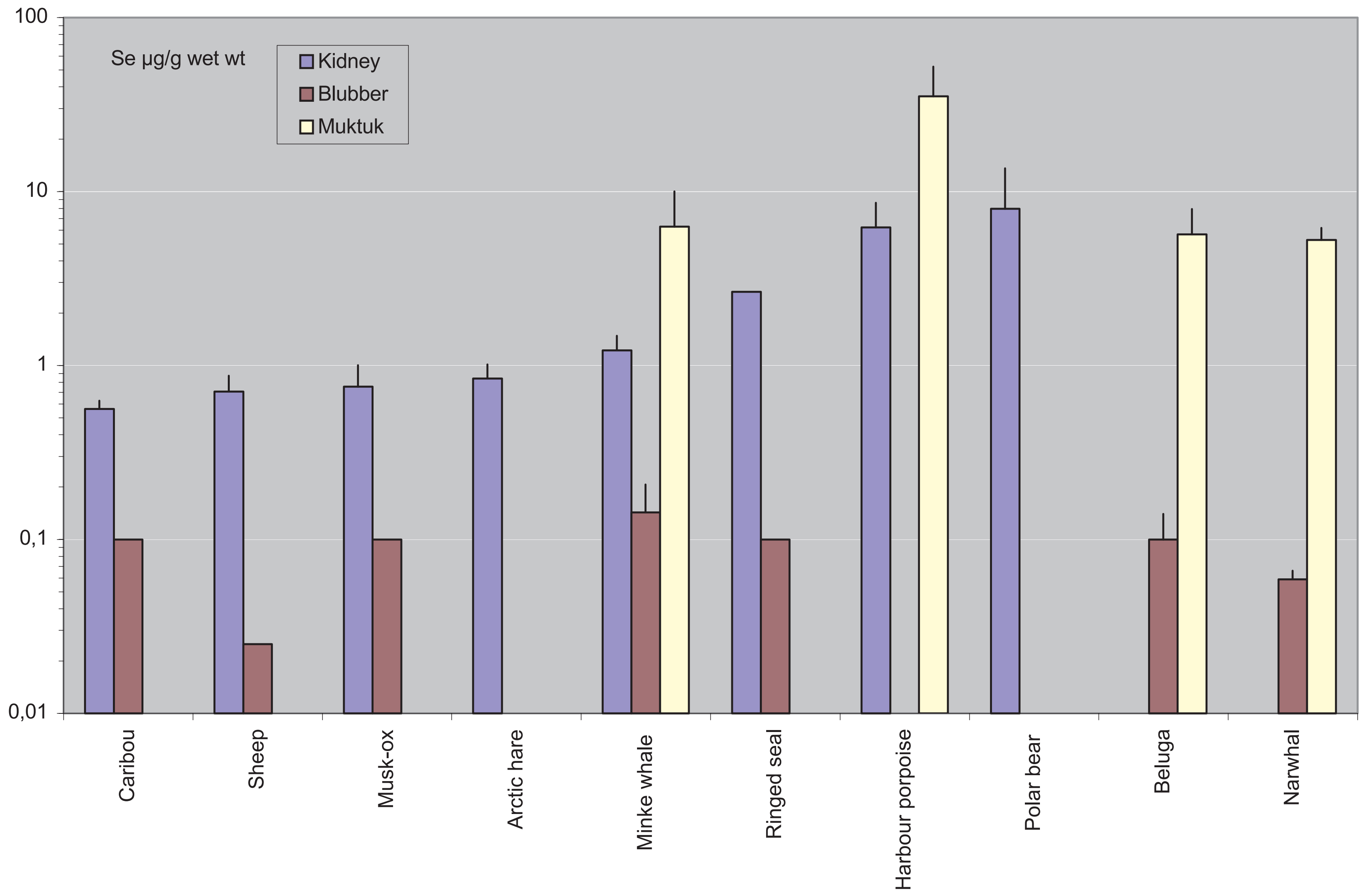


Figure 3.10. Total PCB concentrations in meat from Greenland animals.

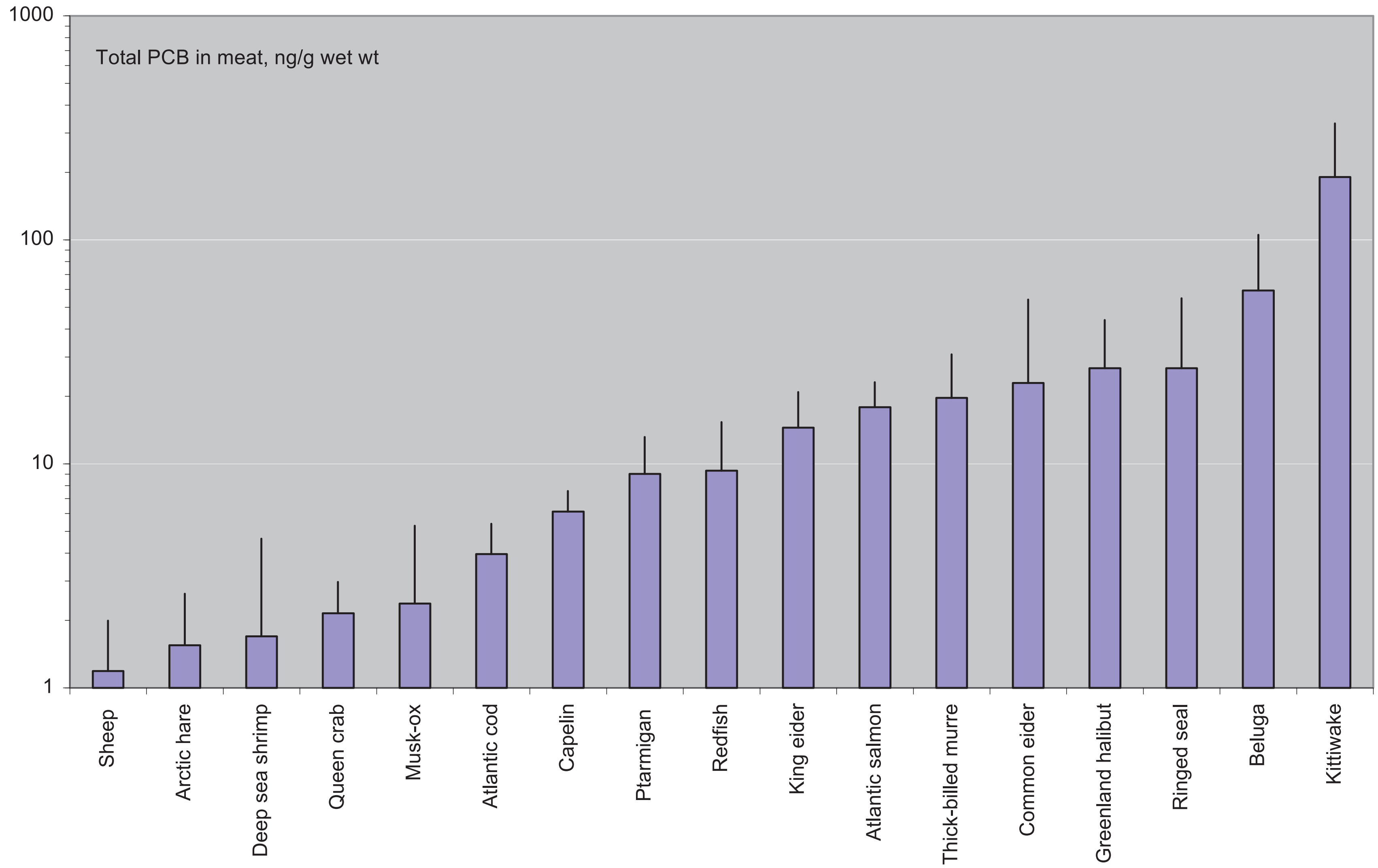


Figure 3.11. Total PCB concentrations in liver from Greenland animals.

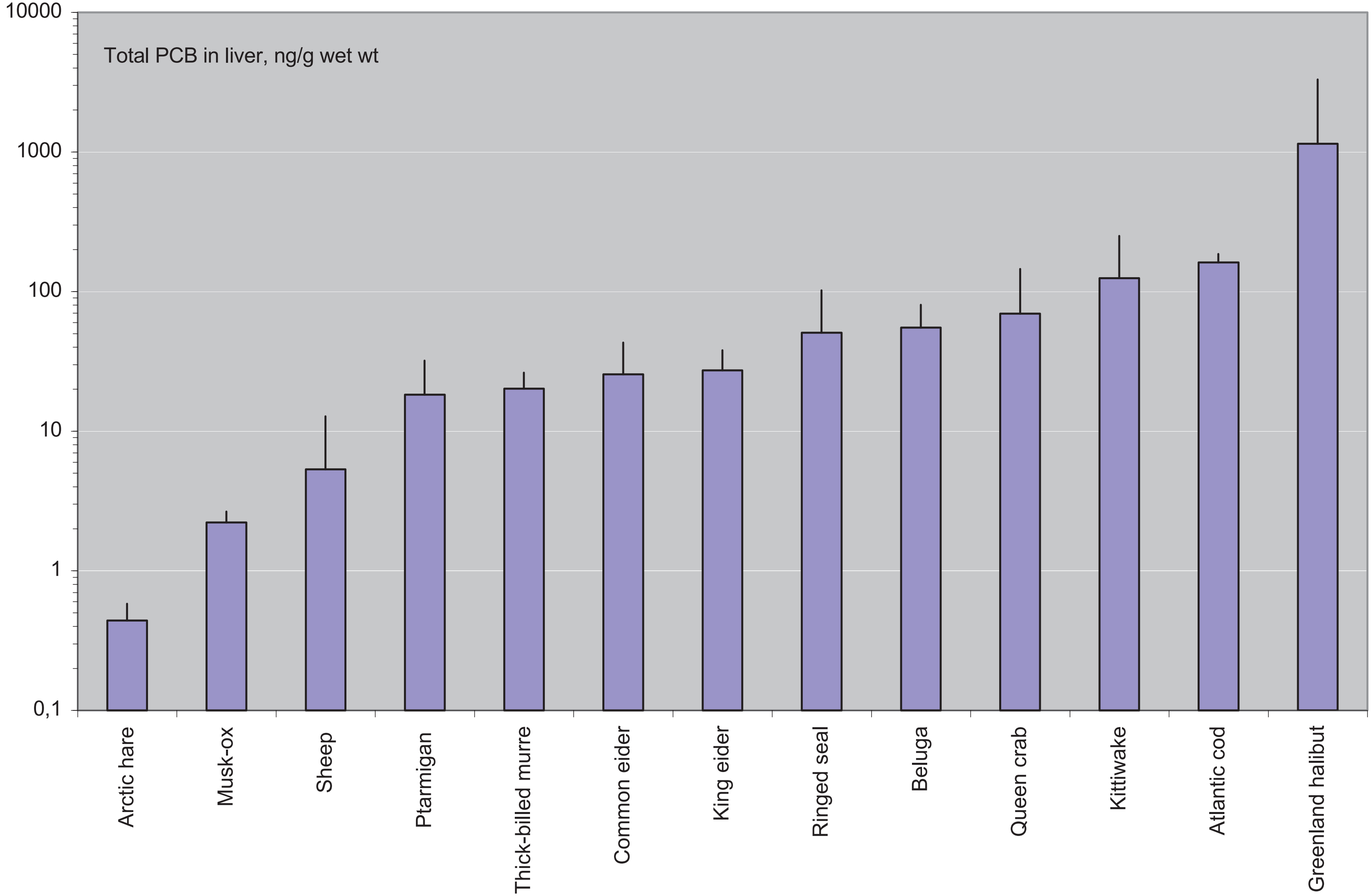


Figure 3.12. Total PCB concentrations in kidney, blubber and muktuk from Greenland animals.

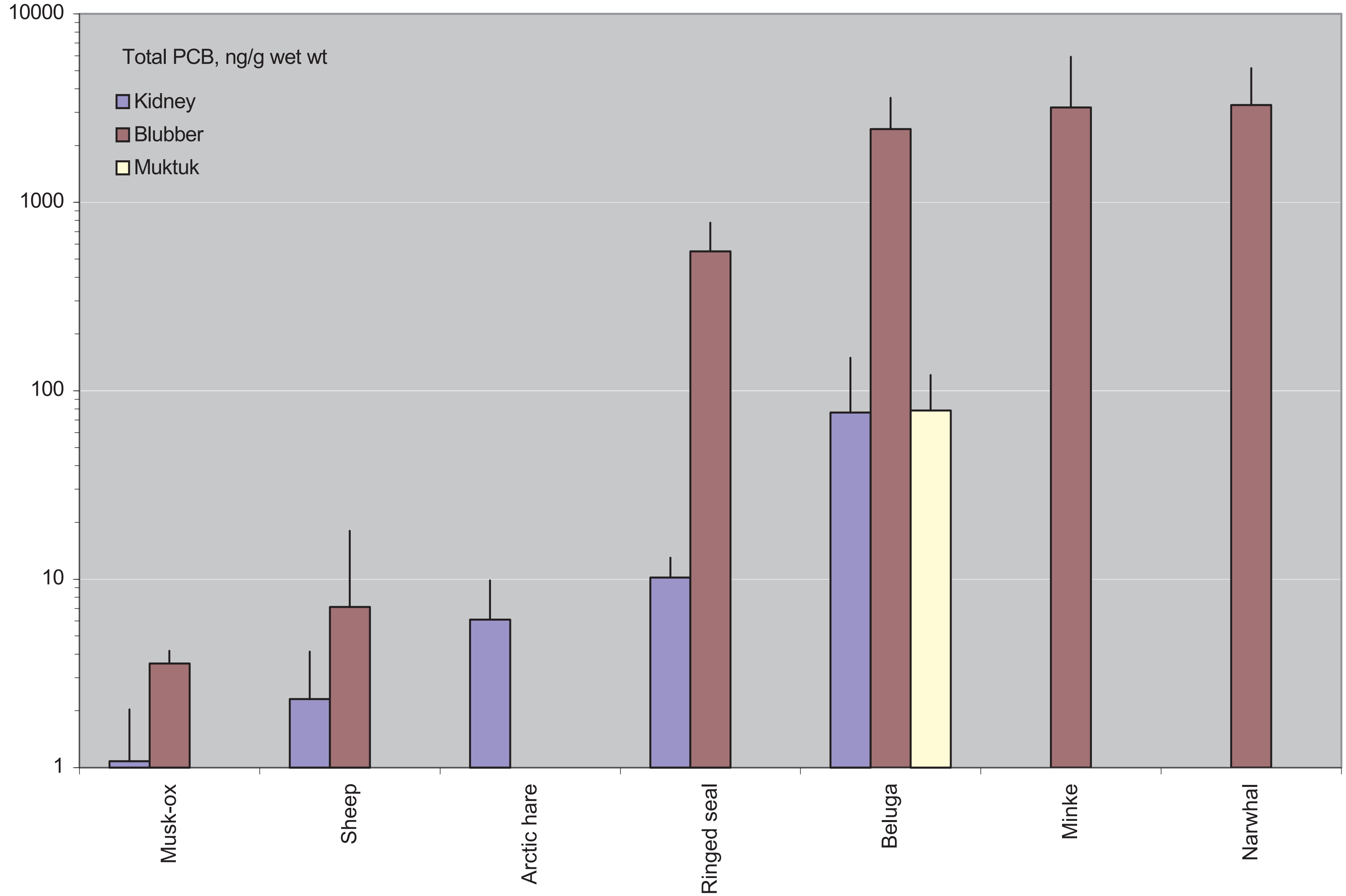


Figure 3.13. Total DDT concentrations in meat from Greenland animals.

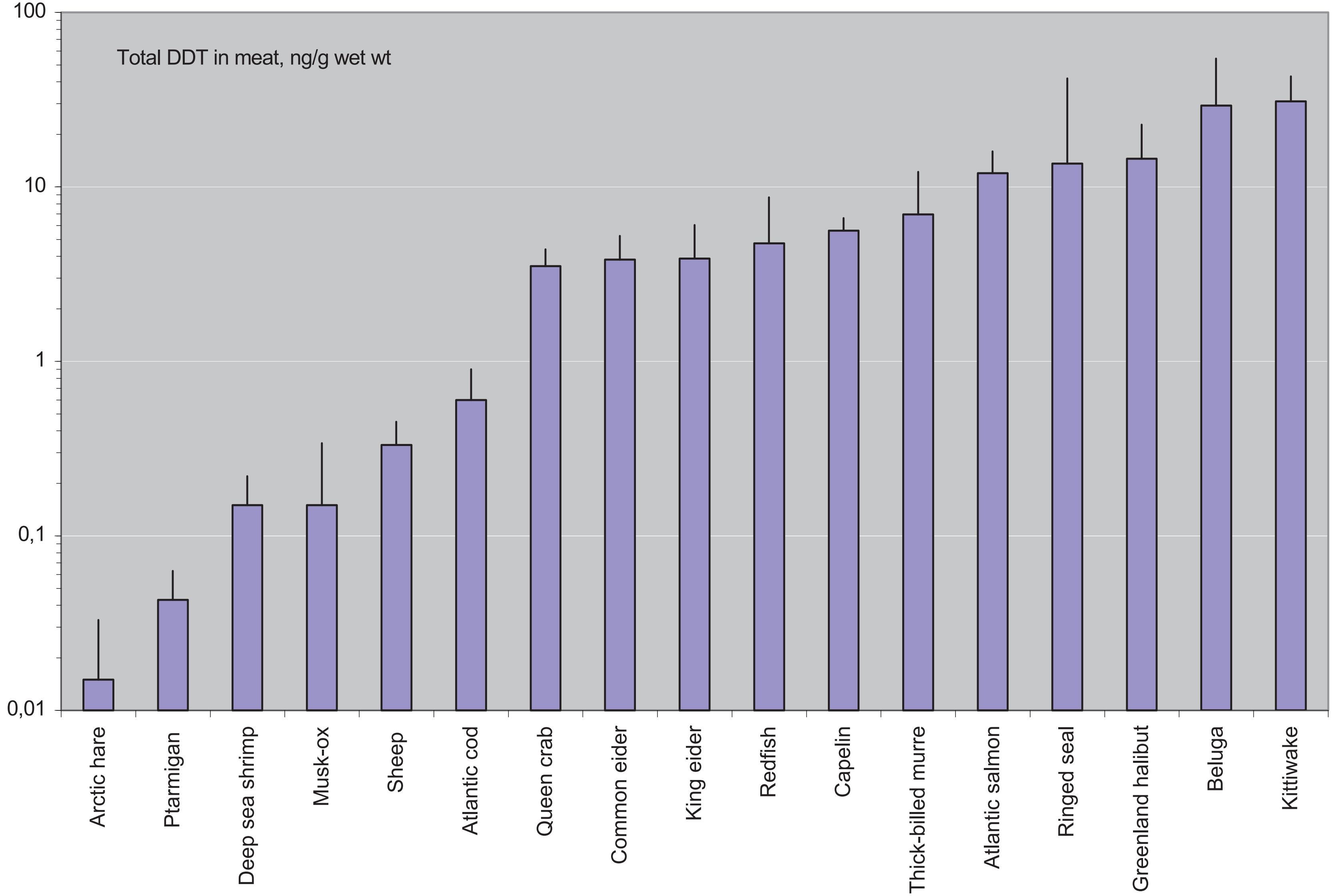


Figure 3.15. Total DDT concentrations in kidney, blubber and muktuk from Greenland animals.

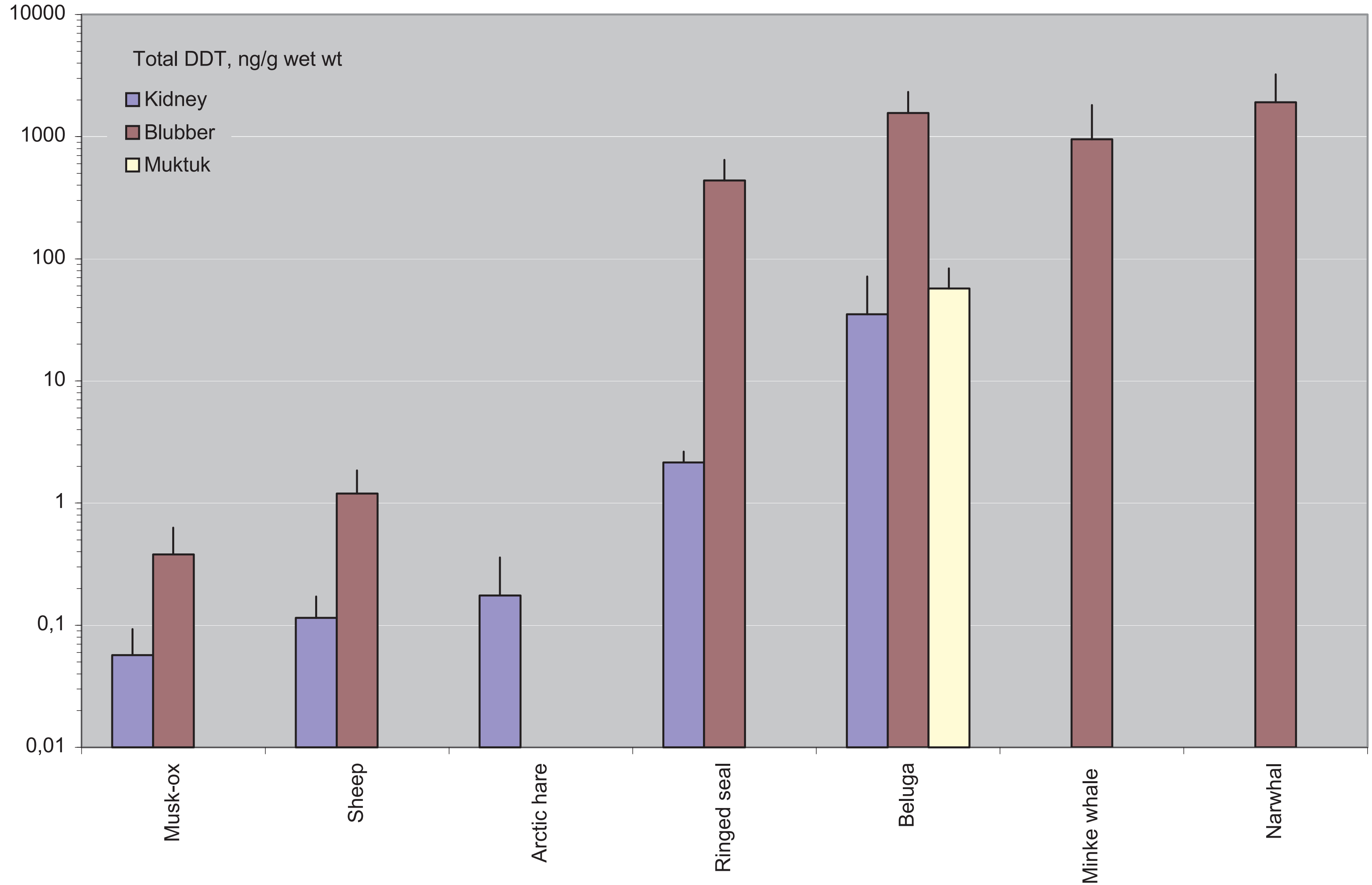
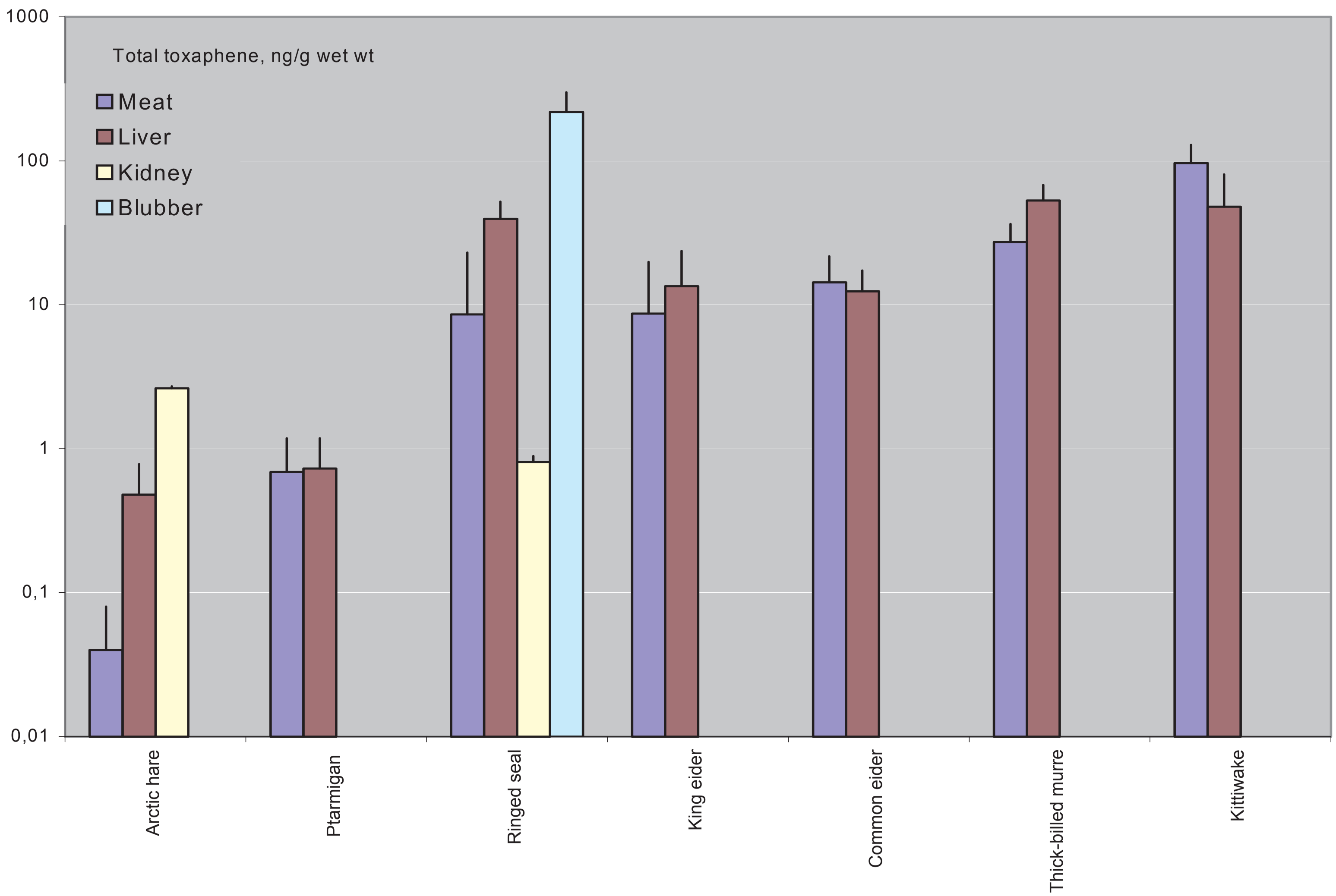


Figure 3.16. Total toxaphene concentrations in meat, liver, kidney, blubber and muktuk from Greenland animals.



Appendix 3.1. List of animal species mentioned in the text in English, Latin, Danish and Greenlandic.

English	Latin	Danish	Greenlandic
Terrestrial			
Crowberry	*Empetrum nigrum*	Revling	Paarnaq
Arctic blueberry	*Vaccinium uliginosum*	Mosebølle	Kigutaarnaq
Ptarmigan	*Lagopus mutus*	Fjeldrype	Aqisseq
Arctic hare	*Lepus arcticus*	Arktisk snehare	Ukaleq
Caribou	*Rangifer tarandus*	Ren	Tuttu
Musk-ox	*Ovibos moscatus*	Moskusokse	Umimmak
Sheep	*Ovis sp.*	Får	Sava
Marine invertebrates			
Deep sea shrimp	*Pandalus borealis*	Dybvandsreje	Kinguppak
Queen crab	*Chionoecetes opilio*	Stor grønlandsk krabbe	Assagiarsuk
Blue mussel	*Mytilus edulis*	Blåmusling	Uiloq
Iceland scallop	*Chlamys islandica*	Kammusling	Uiluik
Marine fish			
Arctic char	*Salvelinus alpinus*	Fjeldørred	Eqaluk
Atlantic salmon	*Salmo salar*	Laks	Kapisilik
Capelin	*Mallotus villosus*	Lodde	Ammassak
Atlantic cod	*Gadus morhua*	Torsk	Saarullik
Greenland cod	*Gadus ogac*	Uvak	Uugaq
Redfish	*Sebastes marinus*	Rødfisk	Suluppaagaq
Spottet wolffish	*Anarhicas minor*	Plettet havkat	Qeeraq
Greenland halibut	*Reinhardtius hippoglossoides*	Hellefisk	Qaleralik
Seabirds			
Thick-billed murre	*Uria lomvia*	Polarlomvie	Appa
Common eider	*Somateria mollissima*	Ederfugl	Miteq siorartooq
King eider	*Somateria spectabilis*	Kongeederfugl	Miteq siorakitsoq
Kittiwake	*Rissa tridactyla*	Ride	Taateraaq
Seals			
Ringed seal	*Phoca hispida*	Ringsæl	Natseq
Harp seal	*Phoca groenlandica*	Grønlandssæl	Aataaq
Hooded seal	*Cystophora cristata*	Klapmyds	Natsersuaq
Whales			
Minke whale	*Balaenoptera acutorostrata*	Vågehval	Tikaagullik
Beluga	*Delphinapterus leucas*	Hvidhval	Qilalugaq qaqortaq
Narwhal	*Monodon monoceros*	Narhval	Qilalugaq qernertaq
Harbour porpoise	*Phocoena phocoena*	Marsvin	Niisa
Polar bear	*Ursus maritimus*	Isbjørn	Nanoq

4 The Human Health Programme in Greenland1997-2001

Bente Deutch

4.1 Introduction

The AMAP, Human Health Programme was established in 1992 as part of an international agreement to monitor and assess contaminant levels, trends, and possible health effects among Arctic residents, primarily indigenous peoples. In the Human Health Programme a number of priority or key contaminants were chosen (persistent organic pollutants, POPs, such as dioxins, PCBs DDT and other pesticides and the heavy metals, mercury, cadmium, and lead). A comprehensive summary of the toxicology of the 11 pesticides , the PCBs, and the heavy metals involved is presented in the Human Health chapters of the international AMAP assessment report AMAP: Arctic Pollution Issues (1998) and in the international AMAP assessment Report (2003).

The first target group was chosen to be pregnant women and their newborn infants, both of which considered to be especially sensitive to adverse effects from toxic contaminants. The fetus is especially vulnerable to the influence of environmental chemicals because of its rapid development of crucial tissues and organs and since most POPs and metals readily cross the placental barrier from the mother to the fetus. The Human Health Expert Group developed a circumpolar blood monitoring study which used a standardized protocol for sampling in all the Arctic countries and a single laboratory for analyses of all samples for organic pollutants which permitted circumpolar comparison of the monitoring data.

The Human Health Programme was implemented in Greenland from 1994. The target area was Disko Bay area where 4 district hospitals participated , Aasiaat, Qasisiannquit, Ilulissat, and Qeqertarsuaq.The protocol of the programme was to contact and include consecutive pregnant women who visited the local district hospital. The women were to be asked to comply to answer a general demographic and lifestyle questionnaire and to permit blood samples from themselves and their newborn infants (cord blood samples). A total of 223 pregnant women were included and blood samples were analyzed from 175 women and 160 infants from the middle of 1994 till autumn1996, phase 1. The collection continued during the interim year 1997 (95 pregnant women and 75 infants). The first partial (n=117) monitoring results of phase 1 were published by Aarkrog et al 1997 (Environmental Project No 356, AMAP Greenland 1994-96) and together with international results in the first AMAP assessment report ("Arctic Pollution Issues"1998). Later more results were included and published by individual authors (Bjerregaard and Hansen 2000, Deutch 1999, Deutch and Hansen 1999, Deutch and Hansen 2000) in various international scientific journals.

From comparison with results from the other Arctic countries it was quite clear that the maternal blood levels of organic pollutants among Inuit women from Disko Bay in Greenland were among the highest in the circumpolar study. Greenland ranged highest for all the PCBs and all the pesticides except DDT for which Russia ranged slightly higher (AMAP 1998). These early results are consistent with the mean values obtained for the whole study group (Bjerregaard and Hansen 2000, Deutch and Hansen 2000).

A pilot study from 6 districts in Greenland 1997-98 also showed large variations in contaminant levels within Greenland, with particularly high PCB levels among men from Ittoqqortoormiit. The lowest concentrations were found on the South West coast in Nuuk in particular. (Deutch and Hansen 2000). In the assessment of results from Disko Bay 1994-97 and the results from the geographical pilot study it was strongly indicated that high blood levels of organic pollutants were significantly correlated both with dietary habits and smoking. This finding was further investigated and supported by a controlled study among men from Uummanaq (Deutch et al 2002).

The high contaminant levels (mercury and PCB) were consistent with high percentages of both men and pregnant women exceeding guidelines. These results have been confirmed by larger study populations from 1999-2000.

The total results from the sampling in Greenland , Disko Bay 1994-96 have not yet been published collectively and some of these results are therefore included in the present report for comparison with later samples.

Thus this report will include, compare and assess results from all the AMAP Human Health Programmes in Greenland 1994-2002, described in the table 4.1.1 below. Some of the results have already lead to a number of publications elsewhere which are also referred to in the table and listed below.

Table 4.1.1. AMAP Human Health Programmes in Greenland 1994-2002.

Location and year	Target group Valid n	Questionnaire	Analysis of blood samples	Status
Disko 1994-96	175 pregnant 160 infants	AMAP, general	metals, POPs, s-lipids	Published (1,2,3,4,5)
Disko 1997	95 pregnant 75 infants	AMAP general	Se, POPs, s-lipids, fatty acids (FA)	Published (5)
Qaanaaq 1997	5 pregnant 4 infants		metals, POPs	
Greenland, 6 districts, 1997	61 men	AMAP general	POPs, , FA, cellular effects	published (5)
Uummanaq 1999	48 men	AMAP general	metals, POPs, s-lipids, FA, cotinine	published (6)
Uummanaq 1999	48 men	food frequency questionnaire		
Ittoqqortoormiit 1999	50 men	food frequency questionnaire		
Ittoqqortoormiit 1999-2000	52 men, 42 wo- men, 8 pregnant	AMAP, + food frequency questionnaire	metals, POPs, s-lipids, FA, cotinine cellular effects	
Tasiilaq 2000-2001	40 men, 42women, 8 pregnant	AMAP,+ food frequency questionnaire	metals, POPs, s-lipids, FA, cotinine cellular effects	
Ilulissat 1999-2000	32 pregnant	AMAP general	as above	
Nuuk 1999-2000	30 pregnant	AMAP general	as above (-FA)	
Greenland 1999-?	Animal samples			

1.AMAP Assessment report 1998. Arctic Pollution Issues
2.Bjerregaard P, and Hansen, JC. Organochlorines and heavy metals in pregnant women from the Disco Bay area in Greenland. Science Tot Environ 2000; 245 (1-3):195-202.
3.Deutch B. Lifestyle and contaminants in Greenland 1994-1996. Master of Public Health Thesis; Publication No 11, Aarhus University 1999
4.Deutch B, and Hansen JC. High Blood levels of persistent organic pollutants are statistically correlated with smoking. Int J Circumpolar Health 1999;58:214-219
5.Deutch B, and Hansen JC. High human plasma levels of organochlorine compounds in Greenland . Regional differences and lifestyle effects. Dan Med 2000;47,2:132-137.
6.Deutch B, Pedersen HS. Bonefeld-Jørgensen EC, Hansen JC. Smoking as a determinants of high human organochlorine accumulation in Greenland. Archives of Environmental Health 2003; 58, 1:1-7..

Already during the first phase it was apparent that the intentions to include consecutive pregnancies were not filled since only <48 % of the expected pregnancies during the proposed experimental period in Disko Bay area were included. The percentage varied by location (local district hospital) and time of year. This resulted in potential risk of selection bias (Deutch 1999).

Comparison with information from the public birth register of Greenland (Greenland Statistics) showed that the birth weight and other anthropometric factors of the infants were significantly higher among the study group than among the non-included pregnant women.
Later during the interim year 1997 and during the phase 2 collection period (1999-2000) the percentage of included pregnancies became even lower. Throughout the whole period there were also various compliance problems in filling out questionnaires, loss of information and of blood samples. The collection of samples from pregnant women was very vulnerable due to the lack of resources and lack of permanent personnel at the Greenland hospital system (Bjerregaard and Hansen 2000, Deutch 1999). Concerning spatial and temporal trend studies representative population groups were needed. It was therefor decided in 1999 to supplement the sampling with a less vulnerable target group of randomly selected men and non-pregnant women of the same age group, see below. It was also decided not to perform contaminant determinations on cord blood since all previous results showed strong and consistent correlations between pollutants in maternal and cord blood.
The sampling procedure was changed to be performed by a District medical officer who visited the locations for 1-2 weeks and collected the questionnaires and blood samples. This improved the compliance to almost 100 %.

Furthermore, from 1999 it was agreed upon by the international Human Health Expert Group to implement the "Human Health Effects Biomarker Programme., which meant that the protocol for blood sampling and analysis was supplemented accordingly. This programme is described in chapter 7, (this volume).

All the programmes have been accepted by the "Ethical Committe for Scientific investigations in Greenland (KVUG). All the above mentioned publications have followed the rules set up by the Danish Environmental Protection Agency(Danish EPA).

4.2 Methodology by project/study group.

4.2.1 Pregnant women and infants 1994-97

4.2.1.1 Purpose.
The purpose of the study was to monitor and assess the contaminant levels in pregnant women and their newborn infant in accordance with the Human Health Programme in Greenland.

4.2.1.2 Material
The material consists of information collected at four district hospitals in the Disko Bay area, Greenland (Aasiaat, Qasisianquit, Ilulissat, Qeqetarsuaq) concerning potentially 223 mother/infant pairs from a similar number of "consecutive" births during the AMAP phase 1 collection period (medio October 1994 to medio October 1996).The collection of data was continued in Disko Bay area during the interim period 1997
(96 mothers,75 infants). In 1999 the sample collection in Disko Bay was only carried out in Ilulissat, (n=30) but in addition collection was carried out in Nuuk aiming at 150 pregnant women but by medio 2001 samples from only 32 women had been received. In year 1999-2000 additional 8 pregnant woman were included from both Ittoqortoormiit and Tassiilaq.
The mothers were of Greenland Inuit, mixed ethnic background, or in a very few cases Danish. There were no formal "a priori" exclusion criteria and the

design of the program was to include consecutive/all pregnant women, but it turned out that only about 30- 40 % of the actual number of pregnancies were included and only live born and singleton babies were actually included in the study. The following data were collected:

4.2.1.3 Methods

1. Questionnaires filled out by the mothers during their pregnancy checkup at the hospital at the 32. gestational week. The questionnaires included questions about demographic and anthropometric factors and a number of lifestyle parameters, smoking and drinking habits in particular, and dietary habits with regard to intake of certain traditional food items, before and during their pregnancy. The questionnaires were formulated in Danish or Inuit language (West Greenlandic dialect) and the women could be assisted by a nurse or midwife in filling out the questions.

2. Blood samples were taken from the pregnant women during the same visit and later from the umbilical cord of the newborn baby.

The samples were frozen and sent to Denmark for further treatment. The Blood samples were analyzed for heavy metal content (Cd, Hg (as total mercury), and Pb in whole blood, Cu, Se, and Zn in plasma, (Cd only from mothers)) and measured in microgram per litre. The heavy metal-analysis took place at . "The National Environmental Research Institute, Dept. Of Arctic Environment, Roskilde, Denmark."

The organochlorines were determined at " Le Centre de toxicologie, Institut National de Santè Publique du Quebec, Canada" according to the consensus in the AMAP, Human Health Expert Group (AMAP 1998)

The following organochlorines were analyzed in plasma: 11 pesticides; aldrin, β-HCH, alphachlordane, gammachlordane, cis-nonachlordane, DDE, DDT, hexachlorbenzene, mirex, oxychlordane, transnonachlordane and 14 PCB-congeners 28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, and 187, as well as aroclor-1260 a sum variable of PCB-compounds. From 1997 toxaphenes were included (parlars 26, 32, 50, 62, 69).The concentrations were measured in µg/l and calculated in microgram per kilogram total plasma lipid. Both the wet weight and the lipid weight contaminant levels will be presented below.

4.2.2 Pregnant women 1999-2001

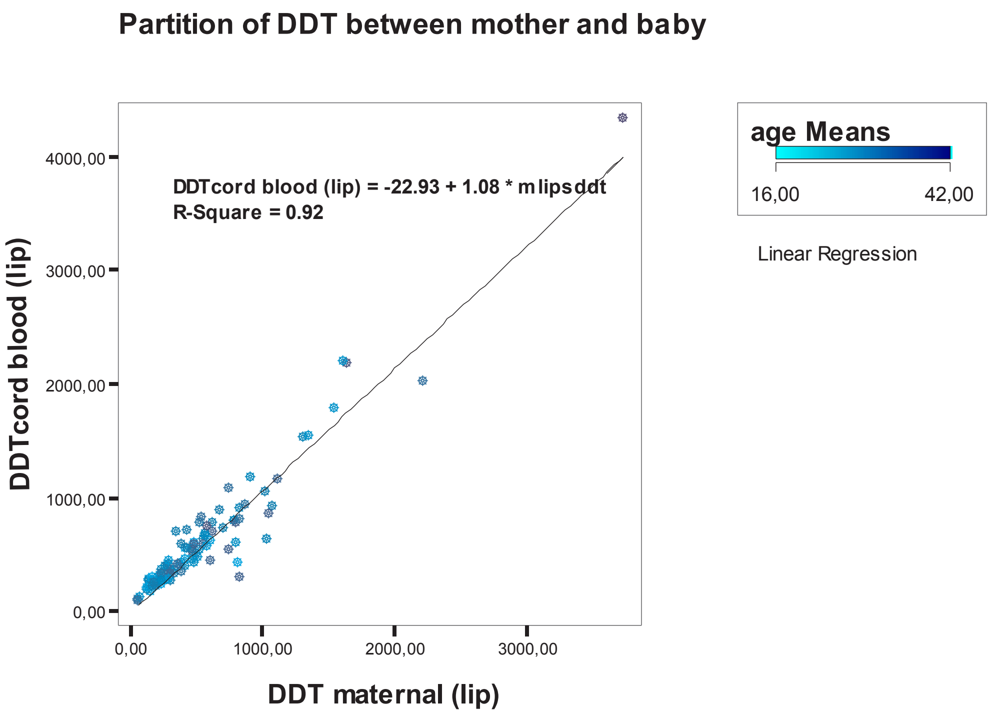
4.2.2.1 Material

From 1999 only blood from pregnant women were analyzed. Umbilical cord blood samples were no longer analyzed for contaminants since the results of the first and interim collections phases showed high and consistent correlations between contaminants in maternal and cord blood, see figure 4.2.1.

4.2.2.2 Methods

From 1999 and onwards the plasma fatty acids were analyzed at "The University of Guelph, Biological laboratory, Guelph, Canada" and the method used plasma phosholipids. (The previous samples from 1994-1997 total plasma fatty acids were determined by Gas liquid Chromatography at "The Department of Environmental and Occupational Medicine, Aarhus University" according to the method described by (Tjønneland et al 1993)). The two methods were compared in samples from 48 men from Uummanaq and were found to be highly consistent. However, fatty acid content of phospholipids are supposedly less subject to day to day variations than total plasma fatty acids.

Figure 4.2.1. Correlation between DDT in maternal and cord blood (lipidadjusted, microgram/kg lipid) from 175 mother/infant pairs Disko Bay 1994-96.



The raw data from questionnaires, results of blood sample analyses, heavy metals, organochlorines, fatty acids and other blood lipids were collected at the Centre of Arctic Environmental Medicine(CAM), Department of Environmental and Occupational Medicine, Aarhus University, where the data were stored and analysed.

All the answers were collected and stored in the SPSS statistics program version 6.1 and later versions presently 10. The data belongs to the Danish Environmental Protection Agency. Permission was given to use the data for research, as a special register which was transferred to CAM by August 1997.

Descriptive statistic analyses were performed of all the included variables. It was evident from the beginning that there was a high ratio of missing values in the data, Both in terms of lost blood samples resulting in no contaminant results or in terms of missing questionnaires or incomplete answering of questionnaires. This lack of compliance was particularly noticeable for lifestyle questions mainly about drinking but also smoking and diet. Consequently special attention was payed to the distribution of these missing values. From the annual, demographic, and geographical distribution of included pregnant women the possibility of selection bias cannot be excluded (Deutch 1999).
Mean values were calculated for all anthropometric and health variables: mothers height, weight, and Body Mass Index (BMI= kg/ square meter); birth weight , height, Body mass Index (BBMI), and head circumference of the baby, and gestational age. Bivariate correlation analyses were performed for all possible constellations.

Average monthly intakes of 10 traditional food items were calculated and bivariate correlation analyses were performed for all mutual constellations. The women were divided into "never smokers", "ever smokers" and "present smokers". And with regard to alcohol consumption into "never drinkers" and "ever drinkers".
Arithmetic and geometric means were calculated for blood concentrations of all heavy metals in mother and child. Bivariate analysis was carried out for all possible mutual contaminant constellations and mother versus child, not shown , published elsewhere (Deutch1999).

Similarly mean values were calculated for all included POP's. However, for alpha chlordane, aldrine and gamma chlordane, the mean values were below the detection limits and these compounds were excluded from the further statistical analysis. For all the remaining organic compounds, bivariate analyses were carried out for substance by substance associations and mother versus child, (Deutch 1999)

Bivariate statistics was performed between heavy metals and POP's, heavy metals and traditional food, POP's and traditional food, and all of these against smoking ,drinking, some demographic variables and the anthropometric and other health variables such as, birth weight and gestational age.

Wherever possible, multiple linear and logistic regression analyses were carried out for plausible associations for which reasonably strong bivariate correlations had been found.

For simplification and comparison with international AMAP-data some group-variables were calculated and used in the presentation of results, namely, the sum of chlordanes, the sum of DDE and DDT, the sum of 14 PCB-congeners, the sum of Toxaphenes (from 1997) and presented together with β-HCH, hexachlorobenzene and mirex.

Chlordane= sum of alpha-chlordane, gamma-chlordane, cisnona-chlordane, transnona-chlordane, and oxychlordanes.
SumDDT= sum of DDE and DDT
SumPCB= sum of all 14 PCB-congeners, namely 28, 52, 99, 101, 105, 118, 128,138, 153, 156, 170, 180, 183, and 187.
Sumtox = toxaphenes Parlar 26 (32) and 50 (62) (69)

The following substances, namely Aldrine, toxaphenes Parlar 32, 62 and 69, were generally below detection limits and were not used in the further analyses. Also gamma chlordane was very low and close to the detection limit.

Table 4.2. 1. Participant profile of pregnant women, demographic and anthropometric data of mother and newborn. Arthmetic means,(minimum – maxi- mum). Empty cells signify that no data is available.

	Disko Bay 1994-96	Disko Bay 1997	Disko Bay 1999-2000	Nuuk 1998-99	Ittoqqor toormiit 99-2000	Tasiilaq 2000
total n	223	96	30	32	8	8
% of total births	48	50				
number of valid question-naires	135	76	22	0	8	8
Age	26.3: (16-42)	25.9: (15.43)	26.1: (16-41)		25.7: (19-34)	26.4: (19-37)
mariage status: single-cohabit	10-123					
no of children	2.1					
weight, kg	60.0: (46-97)	62.3: (43-111)	62.0: (46-85)		67.0: (57-85)	64.9: (54-85)
height, cm	162: (151-176)	163: (150-174)	162: (154-163)		158: (151-163)	157: (151-168)
BMI	22.7: (17,8-35)	23.9: (18-42)	23.6: (18-30)		26.8: (22.8-32)	26.3: (21.3-34.9)
sex of baby boy-girl	49.4-50.5					
weight of baby, gram	3595: (2400-5050)	3647: (2430-4450)	3267: (500-4400)		3601: (3174-4280)	
length of baby, cm	52.2: (47-58)	52.3: (46-57)	50.4: (35-56)		52.3: (50-55)	
BMI of baby BBMI	13.1: (10-16,7)	13.3: (11-17)	12.5: (4.1-14.8)		13.1: (11.7-14.2)	
Gestation, weeks	39.6: (35-43)	39.7: (35-42)				

4.2.2.3 International guideline values

Various international guidelines for pollutants are shown in table 4.3.17. Denmark/Greenland does not have their own specific guidelines.
The guidelines are given as microgram/liter. The US-EPA (USA Environmental Protection Agency) guideline for mercury is based upon the following calculation:(ref National Research Council. Toxicological Effects of Methyl mercury)

C = (d x bw x A x f)/ (b x V) in which
C = blood concentration in microgram /liter
d = daily intake in microgram /kg/day
bw = body weight default value 60 kg for an adult female
A = Absorption factor (0.95)
f = fraction of daily intake taken up by blood (0.05)
b = elimination constant of (0.014 /day)
V = volume of blood in the body (5 L)

The three Canadian guidelines for PCB , aroclor 1260 are proposed as >5 microgram/l level of concern for pregnant women, >20 level of concern for men and post menopausal women, >100 level of action. WHO has a guideline for sum of DDT of 200 microgram /liter. Guidelines for other POPs have not yet established.

4.2.2.4 TEQ values

The TEQ values in picogram/gram are calculated from a weighted sum of 5 PCB congeners. Namely their concentration in microgram per kg lipid, times their TEF-value times 1000, (since pg/g=1000 x microgram/kg):

TEQ=(PCB 105 x 1000 x 0.0001)+(PCB 118 x 1000 x 0.0001)+(PCB 156 x 1000 x 0.0005)+(PCB 170 x 1000 x 0.0001)+(PCB 180 x 1000 x 0.00001).

4.2.3 Pilot study, Geographical distribution of contaminant burden, men from 5 districts in Greenland 1997

4.2.3.1 Purpose

The purpose of the project was to study the spatial trend of contaminant levels in Greenland by an age restricted cross sectional study among younger men

4.2.3.2 Materiel, Participants,

Data were collected during September 1997 to April 1998 from 6 districts in Greenland, covering the following towns, 1. Ittoqqortoormiit (East) 2. Tasiilaq (East).3.Upernavik, (Central west). 4. Ilulissat (Central west). 5. Nuuk (South west) and 6. Nanortalik , (South West). It was planned to collect information from each location concerning 15 younger men, ideally 20-30 years old. The data consisted of blood samples and questionnaire answers about demographic and lifestyle parameters but not anthropometric factors such as height and weight. The blood samples were analysed for Persistent Organic Pollutants, POP's, and fatty acid profiles in plasma and erythrocytes.

The participants were recruited by the local district hospitals, they appear to be consecutive General Practice patients who have contacted the hospital for minor injuries/ complaints within a period of a month or so. Their actual age range was 19-60 years . By mistake the district hospital in Tasiilaq included women instead of men, these were aged 23-42 years. Thus in principle the data from Tasiilaq cannot be directly compared with the other districts, thus they are omitted from the presentation. However, later sampling from 1999-2000 include men and non-pregnant women from the East coast of Greenland and the results from men and women do not differ significantly regarding dietary habits or contaminant blood levels. And the contaminant data from the 10 women from Tasiilaq 1997 were consistent with data from 40 women 2001.

4.2.3.3 Methods

As in the above mentioned mother/ infant studies the blood samples were collected at the local district hospitals, separated into plasma and red blood cells, frozen at -20 C and transported to Nuuk. Here they were stored at -80 C until further transport to The Department of Environmental and Occupational Medicine, Aarhus University, Denmark. The plasma samples were analysed at Le Centre de Toxichologie, Institute National de Santè Publique, Québec, Canada as above for 11 pesticides, 14 PCB-congeners and four toxaphenes of which only parlar 26 and 50 were above detection limits. The red blood cells were analysed at the Department of Environmental and Occupational Medicine, Aarhus, where fatty acid profiles were determined by standard gas chromatography with particular focus on N-3 and N-6 fatty acids according to the method described by Tjønneland et al (1993).

The food frequency questionnaire comprised 10 different traditional food items and 6 frequency categories ranging from once a day to never/ less than once a month. No other items were asked thus e.g. polar bear and all imported goods were omitted.

All the data were analysed by SPSS statistical program, version 9 and 10. Descriptive, statistical analyses were performed for all included parameters. Bivariate correlation analyses were carried out for almost all possible constellations between questionnaire and blood sample answers. Whenever reasonably strong bivariate correlations were found, further statistical analyses were performed e.g. comparison of means by student's t-test or anova. Multiple linear or logistic regression analyses were carried out including the most important determinant parameters.

Dietary biomarkers. The ratios between the fatty acids in total plasma, plasma phospholipids or erythrocytes can in principle be used as indicators of the relative consumption of traditional versus imported food and can thereby act as crosschecks on the dietary information given in the questionnaires (Willet 1998, Tjønneland et al 1993).Whole blood selenium is also a indicator of intake of marine mammals, particularly Whale skin, muktuk (Hansen 1990, Hansen 2000). The different n-3 fatty acids have slightly different distribution in fish and marine mammals. Docosa-pentaenoic acid, (DPA), C: 22.5.3, is relatively low in fish but more prevalent in seal and particularly in polar bear (Kuhnlein 1991) is therefor a good indicator of seal and polar bear intake.

4.2.4 Cross sectional study Uummanaq 1999

From 1999 the collection procedure was changed to improve the representability and compliance. Names and addresses of the participants

were randomly drawn from the public registries and they were personally contacted by a district medical officer, who took the blood samples and surveyed the answering of questionnaires.
All the sampling took place within a short time period of 1-2 weeks during which the medical officer visited the target location, the compliance to participate was over 90%, blood samples were obtained from 100% of the actual participants and the compliance in answering questionnaire was also very high, close to 100%.

4.2.4.1 Purpose, Uummanaq

The purpose of this AMAP associated project was to study the possible association between smoking and high contaminant levels (POPs), which had been observed in the mother /infant study (Deutch and Hansen 1999). However at the same time the procedure for questionnaires and blood samples followed the standard AMAP protocol (with minor changes). Thus the results could also be included in the monitoring and assessment program.

The investigation was originally designed as a Case-control study in a homogenous population with a high exposure level to organochlorine compounds from the food chain. However the small population and the local conditions made it not possible to sufficiently match cases (smokers) and controls (never smokers) thus it can be regarded merely as a restricted cross sectional study.

4.2.4.2 Material

The data were collected in August 1999 in Uummanaq district in Northern Greenland by a District Medical Officer in Greenland. The names and addresses of local middle aged male Inuits (28-54 years) were obtained from the local authorities. The controls were 14 "never-smokers" (who are very rare), they were compared with 6 previous and 28 present smokers restricted by age, Inuit decent, full- or part time occupation as a hunter, general health status and habitual consumption of local Greenlandic food of more than twice a week, It was also attempted to control for anthropometric factors as well but unfortunately this was not possible. The smokers were clearly significantly slimmer than non-smokers, and not overlapping in BMI- values. The results of this study have been prepared as a separate publication (Deutch et al 2003).

The whole group of participants also served as monitoring and assessment material along with men and non- pregnant women from the East Coast, see below. It should be noticed that the Uummanaq participants are not randomly selected like the participants from the East coast. Participant profiles are shown in table 4.2.2. and life style factors in table 4.3.10.

4.2.4.3 Methods

The participants answered the standard questionnaire (developed by the Danish National Institute of Public Health for the AMAP project) about demographic and lifestyle parameters, which included questions about current and previous smoking levels, drinking habits and a 14 item food frequency question. In addition they answered a 30 item 24-hour dietary recall scheme see below under "Dietary Survey pilot study".

Blood samples were taken for determination of plasma organochlorines (microgram per litre and microgram per kg lipid), cholesterol, triglycerides,

phopholipids (g/l and mmol/l), and total fatty acid profiles (distribution in % of total lipids).
Selenium and heavy metals (microgram /l) were determined as additional indicators of marine food product consumption and cotinine (ng/ml) was determined as an indicator of nicotine breakdown products and current smoking status or exposure.

The blood samples were frozen at -20 C and transported to Queen Ingrids Hospital, Nuuk. Here they were stored at -80 C until further transport. As previously (8) the plasma samples were analyzed for 11 pesticides, 14 PCB-congeners (28, 52, 99, 101, 105, 118, 128, 138, 153, 156, 170, 180, 183, 187) and four toxaphenes of which only parlar 26 and 50 were above detection limits. Selenium and heavy metals were analyzed at the National Environmental Research Institute, Dept. of Arctic Environment, Roskilde, Denmark.

Plasma fatty acids were determined at the Department of Environmental and Occupational Medicine, Aarhus University as described by Tjønneland et al (1993). The fatty acid profiles of body lipids (n-3 and n-6 polyunsaturated fatty acids and their ratios) are strong indicators of the relative intake of marine food items. In addition in order to minimize the effects of possible daily variations in plasma fatty acids, the fatty acid profiles were also determined in plasma phospholipids (at the Biology Dept. University of Guelph, Canada). The two types of fatty acid determinations gave similar results and the phospholipids were used in the multi variate analyses.

Plasma cotinine, a biomarker of metabolic nicotine breakdown, was determined using a semi quantitative Cotinine Serum Micro plate assay (STC technologies) according to the instructions by the company. However the samples from the current smokers had to be diluted 5-8 times to obtain a linear response.

All the data were analyzed using SPSS-statistics program version 9 and 10. Descriptive univariate analysis was performed on all included parameters. Bivariate correlation analyses were carried out for almost all possible, and plausible constellations between questionnaire and blood sample answers. Both arithmetic and geometric means of contaminants were calculated and compared by students t-test and anova. but the distributions were relatively even. However in the final linear regression analyses logaritmized concentrations of POP were used to approach normal distributions. Multiple linear regression analyses were performed for a number of plausible models, and model control was performed for the best models. Significance levels were $p<0.05^{*}$, $p<0.01^{**}$, $p<0.001^{***}$.

Table 4.2.2. Participant profile of men and non-pregnant women, demographic and anthropometric data. .Arthmetic means, minimum and maximum

	Uumman-naq 1999	Ittoqqortoormiit 99-2000	Ittoqqortoormiit 99-2000	Tasiilaq 2000	Tasiilaq 2000
Total n	48 men	52 men	42 women	40 men	40 women
Number of valid Questionnaires	48	52	42	40	40
Age	38.1: (28-54)	31.2: (18-45)	32.3: (18-45)	32.6: 19-45)	29.9: (19-45)
etnic index, no of inuit grandparents 1-2-3-4	0-0-1-47	0-6-2-44	0-3-3-36	1-4-0-35	1-4-0-35
Weight, kg	72.9: (60-91)	75.7: 55-1159	68.3: (42-109)	75.2: (57-97)	62.7: (39-95)
Height, cm	169: (158-181)	170: (159-190)	159: (149-171)	170: (160-181)	158: (146-173)
BMI	25.6: (20-33)	26.0: (20-36)	26.9: (19-43.7)	26.0: (20.5-33)	25.1: (17-40)

4.2.5 Men and non- pregnant women East Greenland, 1999-2000.

4.2.5.1 Purpose

The purpose of this study was to follow up on the results from the pilot study from 1997 in which extremely high contaminants levels had been observed among men on the East coast of Greenland (Ittoqqortoormiit) and at the same time continue monitoring and assessing pregnant women and women of birth giving age. Since the populations of Eastern Greenland are so small it would take a long time to collect sufficient number of samples from pregnant women alone and therefor non-pregnant women were included as well.

4.2.5.2 Participants

In Ittoqqortoormiit (Scoresbysund) and Tasiilaq (Ammassalik), Eastern Greenland the names and addresses of 50 men and 50 women (age 20-50) were randomly drawn out from the public register. The persons were contacted by a District Medical Officer and asked to participate in the AMAP 2000, Human Health Programme by answering questionnaires and giving blood - and urine samples after informed consent. The compliance was about 90% (Ittoqqortoormiit: 51 men, 42 women Tasiilaq: 41 men, 40 women and 8 pregnant women). The included participants represented 40 % (Ittoqqortoormiit) and 7% (Tasiilaq) of their age group in the local populations.

4.2.5.3 Methods

Questionnaire. All the 182 participants answered the standard AMAP questionnaire, developed by The Danish National Institute of Public Health regarding demographic anthropometric, and lifestyle factors (smoking habits, drinking habits, and meal patterns) including a limited dietary questionnaire divided into 6 frequency categories ranging from “once a day” to “never”/ or “less than once a month” about habitual/recent use of 6 traditional, Inuit food types as part of a meal (seal, whale, birds, local fish, game and lamb) and 8 Danish food types (fast food, potatoes, other vegetables, butter, cheese, eggs, fresh fruit, milk and yoghourt). Portion sizes were not asked.

Regarding methods the further analysis of contaminants in blood samples the procedure was as above mentioned for Uummanaq.
However, in addition to the organochlorine determinations in the blood samples the human effects biomarker programme was implemented by analyzing hormones or dioxin like activities.
The methods and results will be described in the Human Health Effects Biomarker Program, Chapter 7.

4.2.6 Dietary Survey, pilot study, 1999

4.2.6.1 Purpose.
The purposes of dietary investigations in the Human Health Programme were to estimate food item intake, and eventually to estimate nutrient composition and the dietary content of specific xenobiotic substances with toxic or other adverse effects., in order to make exposure estimates, and finally to relate the exposure estimates to human body levels of contaminant and miscelaneous biomarkers. The wider perspectives aim to rank individuals and to compare population groups within countries or between countries. Thus the dietary investigations serve as part of the basis for public health recommendations for the general population or special risk groups.

4.2.6.2 Participants.
The purpose of this pilot study was to test the compliance in using a self administered, extensive food scheme and to test the typicality of the range of products presented.
As part as other ongoing, AMAP associated projects, 50 men in Ittoqqortoormiit and 48 men in Uummanaq were drawn from the public register in 1999 and asked to participate reporting habitual dietary habits, by 24 hour recall, 24HRC. Their age range was 30-50 and they were all of Inuit decent. The 50 men from Ittoqqortoormiit only participated in the actual dietary questionnaire, the 48 men from Uummanaq also participated in giving blood samples and other questionnaire information as part of another study (Deutch et al 2003).

4.2.6.3 Methods: Dietary questionnaire by 24 hour recall.
The participants were asked to fill out a 2 page food scheme concerning the previous 24 hours, divided into early morning, mid morning, midday, afternoon and evening. The scheme comprised 32 traditional and Danish (imported) food categories. The relative and absolute intakes in gram per day were estimated by using standardized portion sizes, Danish. Food Item groups were calculated as sums of single items from the list.

4.2.6.4 Dietary Questionnaire, East Greenland 1999-2001.
In addition to the AMAP questionnaire, see above, the 182 participants from Ittoqqortoormiit and Tasiilaq answered a more extensive, 60 item, semi quantitative food frequency questionnaire (FFQ) of which the format was adapted from Willet (1998). The questionnaire included 25 local Inuit food items, mainly sea mammals and fish, 22 imported food items (Danish meat, vegetables, fruit, bread, and milk products), and various liquids: water, coffee, tea, juices, beer wine, and liquor. The participants were asked to indicate their average use during the last year by choosing between 8 frequency categories ranging from "almost never" to ">5 times a day". The whole frequency range was used and the compliance in checking off food items was almost 100%. Standard portion sizes were used to calculate monthly and daily intakes in grams for single food items and for food item groups.

4.3 Results by project/ study group

4.3.1 Pregnant women and infants.1994-2001

4.3.1.1 Participant profile and lifestyle.

The participant profiles are shown in table 4.2.1. It should be noticed that the number of included pregnant women are less than 50% of the total expected pregnancies, and the number of valid questionnaire only about 60% of the included participants. Thus furthermore there is low compliance in answering questions about smoking and drinking. Thus selection bias cannot be excluded (Deutch 1999)

The age mean and range is however the same for all locations. Height is lower and weight and BMI slightly higher on the East coast which may be both a lifestyle and genetic difference. The weight of the newborn baby is very much the same, except for Disko Bay 1999 where one preterm baby of 500 gram is included in the study.

Regarding the lifestyle questions (table 4.3.1) the compliance was about 60% but lower regarding drinking questions which are not included in this table for that reason. Based upon their self reporting the participants were categorized into three smoking status groups: 0= never smoker, 1= previous smoker and 2= present smoker. From 1999 serum cotinine determinations were introduced. The smoking categorization was confirmed in almost all cases. However the detected serum cotinine per reported daily cigarette was rather high 15-20ng/ml. This may be a genetic phenomenon or underreporting. Regarding the traditional food questions, the reported intakes were very similar, except that seal intake was slightly higher on the West coast.

Table 4.3.1. Lifestyle factors among pregnant women according to self reported AMAP questionnaires, the formulation of the diet question were slightly changed after 1997. Cotinine, a nicotine breakdown product is included as validation on smoking reporting.

	Disko Bay 1994-96	Disko Bay 1997	Disko Bay 1999-2000	Ittoqqortoormiit 99-2000	Tasiilaq 2000
Total n	223	96	34	8	8
Number of valid Questionnaires	134	50	21	8	8
Smoker: never-Previous-present	29-27-78	3-16-31	1-8-12	0-2-2	0-5-3
Smokeyears	0-9.6-12.1	0-8.5-10.7	-	-	- -13-6
Cigarettes per day	0.2-4.0-6.8	0-6.0-7.8	0-7.8-7.4	- -3.5-3.5	- -8.4-7.5
Cotinine, ng/ml, never-previous-present			4-24-114	- -14-138	- -7.8-105
Birds (meals per month)	1.9	2.4	3.1	0.5	0.9
Fish	3.9	3.1	3.5	3.0	3.6
Game	1.0	1.7	0.8	0.8	0.4
Lamb	2.6	2.2	2.2	0.3	0.6
Polar bear	not asked-	Not asked	Not asked	1.0	1.0
Seal meat	5.9	4.9	3.9	2.8	3.9
Whale meat	2.4	1.7	0.5	1.5	1.9
Marine fish and mammals meals	20	17			
Inuit meals			8.0	5.0	15.6
Danish meals			16.0	24.0	12.1

4.3.1.2 Dietary Biomarkers

The dietary biomarkers for pregnant women are shown in table 4.3.2. The fatty acid distribution throughout Greenland shows the following characteristic. The total plasma lipids, cholesterol and triglycerides are slightly elevated in pregnant women , compared with non-pregnant women, table 4.3.12. This is probably a result of their condition rather than a dietary deviation. The plasma levels of n-3 fatty acids measured as single fatty acids , their sum, and the ratio between n-3 and n-6 fatty acids are all lower on the South West coast,(Disko Bay and Nuuk) compared to the East Coast (Ittoqqortoormiit and Tasiilaq) indicating a lower intake of marine fish and mammals and a more westernized diet.

Table 4.3.2. Biomarkers of pregnant women, total plasma lipids, fatty acids in % of total plasma lipids, triglycerides, cholesterol and Selenium. Arithmetic means, (minimum - maximum).

	Disko Bay 1994-96	Disko Bay 1997	Disko Bay 1999-2000	Nuuk 1998-99	Ittoqqortoormiit 99-2000	Tasiilaq 2000
Total n	225	96	30	32	8	8
Number of blood samples	175	96	30	32	8	8
Total lipids, g/L	9.34: (6.1-14.8)	9.2:	6.0: (3.7-8.4)	8.20: (4.4-11.4)	7.2: (4.2-10.89)	8.0: (6.7-9.6)
Linolic acid, 18.2.6		21.5:	19.3:		18.4:	19.6:
Arachidonic acid 20.4.6		2.2:	5.4:		6.3:	4.2:
Eicosapentaenoic acid, 20.5.3		1.0:	1.4:		2.6:	1.9:
Docosapentaenoic acid 22.5.3		0.42:	0.94:		1.1:	1.1:
Docosahexaenoic acid, 22.6.3		2.4:	5.2:		5.8:	6.1:
Sum n-3		3.8:	8.2:		10.2:	9.9:
Sum n-6		23.8:	28.7:		28.5:	27.0:
n-3/n-6 ratio		0.20:	0.30:		0.38:	0.38:
Triglycerides Mmol/L	2.85: (0.88-8.54)		1.14: (0.5-2.5)	2.07: (0.54-3.7)	1.49: (0.9-3.1)	2.12:
Cholesterol Mmol/L	6:72: (4.6-9.7)			6.18: (3.8-9.0)		6.07:
Selenium, microgram/L blood		140: (64-422)	186: (83-817)	144: (59-584	142: (67-277)	183: (120-360)
Selenium, microgram/L plasma	62.5: (3.8-135)	68: (40-127)				81.3:

The selenium blood levels of pregnant women are almost the same in Disko Bay, Nuuk, Ittoqqortoormiit, and Tasiilaq table 4.3.2. However in Uummanaq, table 4.3.12, Selenium is almost double that of the other stations indicating a large consumption of whale particularly Muktuk, whale skin which is an important source of selenium. This is consistent with previous measurements from the Northwest coast, Thule, where blood selenium also is very high(Hansen 2000).

4.3.1.3 Contaminants, heavy metals and POPs wet weight and lipid weight.

4.3.1.3.1 Heavy Metals

The blood levels of total mercury among pregnant women and infants are lowest in Nuuk, table 4.3.3 and 4.3.4, with middle levels in Disco Bay and the East coast. The Hg level is constant in Disko Bay between 1994 and 1999-2000.

Cd is higher in Disko Bay than on the East coast and Pb is higher on the West coast than on the East coast.The blood levels of heavy metals in cord blood

Table 4.3.3. Contaminants in maternal blood in wet weight, microgram/L plasma. Geometric means, minimum and maximum. Nd = not detected.

	Disko Bay 1994-96	Disko Bay 1997	Disko Bay 1999-2000	Nuuk 1998-99	Ittoqqor-toormiit 99-2000	Tasiilaq 2000
Total n	225	96	30	32	8	8
Number of blood samples	175	96	30	32	8	8
Hg	12.7: (1.7-76)		12.4: (1.7-78.2)	4.46: (1.3-21)	10.5: (3.9-27.3)	19.7: (6.5-60)
Pb	34.7: (8.9-180)		50: (24-140)	37.4: (25-77)	30.8: (23-47)	23.8: (16-33)
Cd	1.34: (0.01-7.0)		1.15: (0.6-2.1)	0.69: (0.19-2.4)	0.95: (0.6-1.54)	0.66: (0.25-2)
Aldrin	Nd	Nd	Nd	Nd	Nd	Nd
Beta HCH	0.17: (0.03-0.8)	0.15: (0.03-0.5)	0.07: (0.01-0.18)	0.11: (0.05-0.26)	0.24: (0.12-0.61)	0.20: (0.1-0.4)
Sum of chlor-danes	1.82: (0.05-19)	1.89: 0.05-13.7)	1.06: (0.05-3.8)	0.70: (0.08-3.4)	3.5: (1.4-10.6)	4.9: (2.1-9.1)
DDE	3.69: (0.48-30)	3.56: (0.56-17)	1.72: (0.4-6.0)	2.0: (0.6-7.8)	5.2: (2.7-18.1)	11.0: (5.9-20)
DDT	0.13: (0.02-1.5)	0.11: (0.01-13)	0.04: (0.01-0.37)	0.04: (0.01-0.34)	0.26: (0.14-1.30)	0.35: (0.2-0.8)
DDE+ DDT	3.89: (0.5-31.5)	3.79: (0.59-17)	1.82: (0.4-6.0)	2.05: (0.64-8.1)	5.94: (2.9-19.4)	11.4: (6-21)
Hexachlo roben-zene	0.89: (0.13-7.0)	0.80: (0.14-4.0)	0.39: (0.1-1.6)	0.38: (0.14-1.2)	0.78: (0.37-1.97)	1.05: (0.4-1.9)
Mirex	0.08: (0.01-0.66)	0.08: (0.01-1.9)	0.04: (0.01-0.19)	0.03: (0.01-0.15)	0.18: (0.05-0.88)	0.30: (0.1-0.7)
PCB, 14 conge-ners	5.19: (1.1-34)	5.30: (1.0-20.5)	2.48: (0.72-8.1)	3.02: (0.9-10.2)	14.5: (5.1-49)	14.7: (8-25.6)
Aroclor 1260	14.2: (3.0-95)	14.6: (3.0-60)	6.4: (2.0-22.3)	7.85: (2.6-28.3)	36.0: (13.6-125)	37.6: (22-60)
Toxaphen es, 4 conge-ners		0.60: (0.01-4.7)	0.24: (0.05-1.06)	0.27: (0.05-1.4)	0.60: (0.37-1.22)	1.35: (0.4-2.9)
DDE: DDT	28.9: (8.6-300)	33.3: (0.06-300)	47.6: (13.4-432)		20.3: (14-38)	31.4: (16-60)

from1994-96 , table 4.3.4, are strongly correlated with levels in maternal blood,(Deutch1999), and measurements were therefor abolished after 1996.

Table 4.3.4. Contaminants in, cord blood (wet weight, microgram per litre. Geometric means , minimum and maximum), and ratio between cord and maternal blood concentrations (cord/maternal). Nd = not detected.

	Disko Bay 1994-96	Disko Bay 1997	Cord/maternal 1994-97
total n	160	70	
Hg	24.7: (0.9-180)		1.94
Pb	27.7: (9.8-143)		0.80
Cd	Not measured	Not measured	Not measured
Aldrin	Nd	Nd	
beta HCH	0.04: (0.01-0.23)	0.04: (0.01-3.4)	0.24
Sum of chlordanes	0.39: (0.05-3.7)	0.34 (0.05-2.0)	0.20
DDE	0.99: (0.14-7.7)	0.91: (0.18-4.7)	0.26
DDT	0.03: (0.02-0.29)	0.02: (0.01-0.08)	0.21
DDE+DDT	1.02: (0.16-7.9)	0.93: (0.18-4.76)	
Hexachloro Benzene	0.24: (0.04-1.77)	0.20: (0.05-0.95)	0.26
Mirex	0.016: (0.01-0.09)	0.014: (0.01-0.07)	0.19
PCB, 14 congeners	1.17: (0.30-7.63)	1.03: (0.2-3.97)	0.21
Aroclor 1260	3.22: (0.66-21.8)	2.7: (0.5-11)	0.23
Toxaphenes, 4 congeners		0.09: (0.01-0.47	0,15
DDE:DDT	30.5: (10-254)	38.4: (8-220)	1.05

4.3.1.3.2 Organic Pollutants

The contaminant levels in Disko Bay appear to be constant between 1994 and 97 and slightly lower in 1999. In general the 1999 samples from Disko Bay and Nuuk show the lowest contaminant levels, and the samples from the East coast, Ittoqortoormiit and Tasiilaq the highest. Considering that the numbers of included women are very low, these results may not be representative.

Table 4.3.5. Contaminants in manternal blood lipid adjusted. lipid adjusted weight microgram/kg total plasma lipid.Geometric means, minimum and maximum. Nd = not detected.

	Disko Bay 1994-96	Disko Bay 1997	Disko Bay 1999-2000	Nuuk 1998-99	Ittoqqortoormiit 99-2000	Tasiilaq 2000
Total n	225	96	30	32	8	8
Number of blood samples	175		30	32	8	8
Aldrin	Nd	Nd	1.75: (1.2-2.4)	1.21: (0.88-2.25)	1.42: (0.93-2.4)	nd
Beta HCH	17.47: (4.9-89)	16.06: (4.2-52.1)	11.6: (2.1-30.4)	13.3: (4.7-33.7)	34.2: (16-81.49	24.8: (7-55.3)
Sum of chlordanes	203: (6-2037)	206: (5.4-1465)	153: (9.6-610)	84.5: (7.2-445)	490: (169-1113)	611: (271-1164)
DDE	383: (60-3600)	389: (61-2023)	292: (74-968)	243: (59-1022)	739: (397-1677)	1374: (757-2349)
DDT	13: (1-1600)	12: (1.2-1494)	6.1: (1.4-58)	5.7: (1-37.7)	36.5: (17-120)	44: (23-94)
DDE+DDT	396: (63-3724)	401: (55-3294)	287: (76-908)	250: (60-1061)	777: (312-2651)	1418: (780-2445)
Hexachlorobenzene	90: (13-625)	88: (16-416)	66: (19-234)	46.6: (13-152)	111: (66-215)	132: (48-132)
Mirex	9.17: (1-72)	8.42: (1-218)	6.1: (1.6-28.7)	4.4: (1-15.4)	24.9: (6.6-81.4)	37.7: (14-72)
PCB, 14 congeners	561: (135-3810)	580: (115-2242)	410: (130-1261)	368: (88-1342)	2071: (634-5358)	1835: (943-2855)
Aroclor 1260	1539: (317-10160)	1619: (329-6250)	1084: (373-3610)	957: (246-3714)	5113. (1672-14325)	4692: (2496-7128)
Toxaphenes, 4 congeners		90: (1-514)	43.1: (9.6-141)	32.9: (4.7-188)	86.8: (37.6-175)	169: (51-346)
TEQ	15.3: (3.7-103)	15.6: (3.3-53.5)	11.2: (4.2-30)	10.0: (3-38)	54.1: (17-142)	50.6: (24-92)

However the pregnant women from the East Coast are part of a population sample randomly drawn from the public register, and in addition the contaminant levels found for pregnant women are consistent with contaminant levels found for non-pregnant women, table 4.3.13 and 4.3.14. Beta HCH is slightly higher on the East Coast, Chlordanes almost double on the East Coast, DDT and DDE are lowest in Nuuk and Disko Bay 1999 and 2-3 times higher on the East Coast.

Hexachlorobenzene is lowest in Nuuk and Disko Bay 1999 otherwise similar in East and West. Mirex, PCB-congeners and Aroclor 1260 are much higher on the east coast and this is also consistent with the larger population samples from men and non-pregnant women 1999-2001, (tables 4.3.13 and 4.3.14). Organic contaminants in cord blood are highly significantly p<0.001*** (table 4.3.6.) correlated with maternal blood, after lipid adjustment at a close to 1:1 basis except for mirex and toxaphenes, see also figure 4.2.1.

Table 4.3.6. Contaminants in infants, cord blood(lipid adjusted weight microgram/kg total plasma lipid).Geometric means, minimum and maximum and ratio between cord blood and maternal blood concentrations (cord/maternal). Nd = not detected. p<0.01**, p<0.001***

	Disko Bay 1994-96	Disko Bay 1997	Cord/mater-Nal blood 1994-97
Total n	160	55	
Aldrin	Nd	Nd	-
Beta HCH	17.6: (4-127)	13.7: (3.2-52)	0.94***
sum of chlordanes	164: (14-127)	146: (1.5-873)	0.76***
DDE	412: (40-4202)	395: (85-1880)	1.05***
DDT	13.8: (4.1-111)	10.3: (2.8-39)	0.96***
DDE+DDT	426: (44-4300)	405: (86-1904)	
Hexachloro Benzene	106: (10.6-964)	84.8: (20-423)	1.07***
Mirex	5.39: (2.7-49.6)	5.96: (2.4-30.4)	0.65***
PCB, 14 congeners	491: (96-4144)	448: (95-1842)	0.83***
Aroclor 1260	1340: (179-11820)	1196: (253-4918)	0.81***
Toxaphenes, 4 congeners		39.5: (64-200)	0.48**

No associations were found between maternal blood POP concentrations and gestation time, birth weight, babyBMI or other anthropometric factors.

4.3.2 Geographical study 1997

4.3.2.1 Participants, lifestyles and biomarkers

Regarding age the participant differ by district. The men from Nuuk are slightly but not significantly younger than the other men and the men from Ilulissat are slightly older than the others. The participants also differ by district with regard to several lifestyle factors, namely both drinking and smoking levels and consumption of traditional food items per month, table 4.3.7. The men from Ittoqqortoormiit differ significantly from the other men having a higher alcohol consumption both as volume and frequency. They also range somewhat but not significantly higher regarding cigarettes per day and percentage of smokers. The men from Nanortalik report the highest number of traditional meals.

Table 4.3.7. Participant profile and biomarkers of men (1997), total plasma lipids, fatty acids in % of total plasma lipids,Arithmetic means, minimum and maximum.

	Ittoqqortoor-miit	Nanortalik	Nuuk	Ilulissat	Upernavik
Total n	15	6	15	15	11
Age	38.1:	36.0	29.0	42.4	31.6
Smokers %	86	80	80	80	73
Cigarettes per day	10	2.4	8.8	8.1	9.2
Units of alcohol/ month	73	29	23	31	15
Marine food/ month	21.3	31.0	15.3	24.7	24.6
Total lipids, g/L	6.12: (4.6-9.4)	6.28: (5.3-7.0)	6.66: (4.4-9.9)	7.22: (3.2-10.09	6.13: (5.2-7.8)
Linolic acid, 18.2.6	13.3:	9.9:	16.9:	14.7:	13.8:
Arachidonic acid 20.4.6	8.34:	7.76:	8.68:	8.07:	9.08:
Eicosapentaenoic acid, 20.5.3	6.21:	7.89:	3.09:	4.05:	3.62:
Docosapentaenoic 22.5.3					
Docosahexaenoic acid, 22.6.3	7.08:	8.82:	5.87:	6.82:	6.72:
Sum n-3	16.83:	20.0:	11.70:	13.86:	13.13:
Sum n-6	24.0:	19.1:	28.2:	25.0:	25.6:
n-3/n-6 ratio	0.45:	0.66:	0.21:	0.37:	0.34:

4.3.2.1.1 Biomarkers.

The fatty acid profiles in particular the n-3/n-6 ratios are consistent with the reported number of traditional seafood meals, being highest in Nanortalik (0.66) and lowest in Nuuk, (0.21).In fact the n-3/ n-6 ratio in Nuuk is almost as low as ratios among European populations, table 4.3.16

4.3.2.2 Contaminants

The mean values of organochlorine plasma levels vary by district as shown in table 9 and 10., both in terms of relative distribution and total burden. The levels of beta HCH, chlordanes, DDT, Mirex and PCB are particularly high in Ittoqqortoormiit and significantly higher than all other districts except Nanortalik, student T-test $p<0.05$. Hexachlorobenzene and Toxaphene levels appear to be higher on the West Coast but mainly in Ilulissat. The high levels found in Nanortalik are consistent with a high reported consumption of tradional seafood meals and a high n-3/n-6 ratio but based only upon 6 men may not be representative for the background population.

Table 4.3.8. Contaminants in men (1997) in wet weight, microgram/L plasma. Geometric means, minimum and maximum.

	Ittoqqortoormiit	Nanortalik	Nuuk	Ilulissat	Upernavik
Total n	15	6	15	15	11
Age	38.1: (19-60)	36.0: (20-39)	20.0: (19-37)	42.4: (22-46)	31.6: (25-38)
Aldrin	0.01:	0.01:	0.01:	0.01:	0.01:
Beta HCH	0.56: (0.17-1.8)	0.2: (0.08-0.3)	0.17: (0.06-0.66)	0.33: (0.07-0.85)	0.27: (0.06-1.8)
Sum of chlordanes	7.65: (0.9-61)	7.54: (3-14.5)	2.48: (0.4-12)	7.44: (0.8-24)	3.16: (1.2-15)
DDE	10.9: (1.6-32)	14.9: (7-27)	4.9: (1.3-16)	8.65: (1.9-25)	4.67: (2.2-17)
DDT	0.17: (0.04-98)	0.79: (0.3-2.2)	0.1: (0.03-0.37)	0.15: (0.04-0.76)	0.10: (0.04-0.24)
DDE+DDT	11.1: (1.6-33)	15.7: (7.4-29)	5.0: (1.3-16)	8.8: (2.0-25)	4.8: (2.2-17.2)
Hexachloro Benzene	1.45: (0.4-3.9)	1.2: (0.4-2.6)	1.0: (0.2-5)	2.7: (0.4-8.4)	0.9: (0.2-2.7)
Mirex	0.52: (0.02-2.2)	0.61: (0.3-1.4)	0.15: (0.06-0.5)	0.27: (0.07-0.6)	0.16: (0.05-1)
PCB, 14 congeners	40.8: (6.6-126)	21.2: (9.6-40)	7.6: (2.4-26.8)	13.6: (2.8-29)	6.6: (3.9-29)
Aroclor 1260	107: (18-331)	63: (29-113)	21: (7-71)	39: (8-87)	18: (10-81)
Toxaphenes, 4 congeners	0.71: (0.18-2.1)	1.56: (0.5-3.7)	0.78: (007-5.2)	1.86: (0.2-7.0)	0.79: (0.3-3.1)

Table 4.3.9. Contaminants in men (1997), lipid adjusted weight microgram/kg total plasma lipid.Geometric means, minimum and maximum.

	Ittoqqortoormiit	Nanortalik	Nuuk	Ilulissat	Upernavik
Total n	15	6	15	15	11
Age	38.1: (19-60)	36.0: (20-39)	20.0: (19-37)	42.4: (22-46)	31.6: (25-38)
Aldrin	1.65: (1-2.2)	1.60: (1.4-1.9)	1.5: (1-2.2)	1.4: (1-3.1)	1.6: (1.3-1.9)
Beta HCH	93: (24-290)	32: (15-46)	26: (11-69)	49: (13-127)	30: (15-72)
Sum of chlordanes	1265: (149-9485)	1206: (567-2122)	382: (86-12399	1074: (145-2784)	518: (158-2586)
DDE	1798: (271-5344)	2383: (1179-4576)	755: (264-1964)	1249: (345-3968)	767: (323-2931)
DDT	29: (5-158)	127: (54-372)	15: (5-40)	22: (5-120)	17: (6-44)
DDE+DDT	1830: (278-5394)	2516: (1260-4949)	770: (264-1994)	1277: (360-3979)	786: 329-2972)
Hexachlorobenzene	240: (68-629)	192: (75-371)	155: (50-531)	378: (69-1333)	147: (39-397)
Mirex	86: (3-328)	98: (55-200)	24: 10-53)	39: (13-102)	25: (8-172)
PCB, 14 congeners	6746: (1116-20400)	3395: (1803-5800)	1166: (449-2792)	1963: (510-37539	1075: (526-4637)
Aroclor 1260	17627: (3050-53387)	10007. 5471-16949)	3270: (1320-7395)	5618: (1418-10634)	2957: (1410-13965)
Toxaphenes, 4 congeners	117. (22-338)	249: 92-569)	119: (16-569)	269: (34-1015)	128: (42-455)

4.3.3 Men and non-pregnant women 1999-2000

4.3.3.1 Participant profile.

The men and women who had been randomly drawn among 18-50 year age group from the public register had approximately the same mean age of 29.9-38.1 years, with the men from Uumannaq being the oldest. The ethnic index was measured as number of Grenlandic grandparents was almost the same for all groups and none had zero Greenlandic grandparent, more than 85 % had 4 Greenlandic grandparents,

Their mean body weight was almost the same but the ranges were larger on the East coast
The average height was 169-170 for men and 10 cm less for women consistent with Greenland statistics for the whole country. The BMI mean values were also quite comparable.

Table 4.3.10. Participant profile of men and non-pregnant women, demographic and anthropometric data. Arthmetic means, minimum and maximum

	Uummanaq 1999	Ittoqqortoormiit 1999-2000	Ittoqqortoormiit 1999-2000	Tasiilaq 2000	Tasiilaq 2000
Total n	48 men	52 men	42 women	40 men	40 women
Number of valid Questionnaires	48	52	42	40	40
Age	38.1: (28-54)	31.2: (18-45)	32.3: (18-45)	32.6: 19-45)	29.9: (19-45)
Etnic index, no of inuit grandparents 1-2-3-4	0-0-1-47	0-6-2-44	0-3-3-36	1-4-0-35	1-4-0-35
Weight, kg	72.9: (60-91)	75.7: (55-115)	68.3: (42-109)	75.2: (57-97)	62.7: (39-95)
Height, cm	169: (158-181)	170: (159-190)	159: (149-171)	170: (160-181)	158: (146-173)
BMI	25.6: (21-33)	26.0: (20-36)	26.9: (19-43.7)	26.0: (20.5-33)	25.1: (17-40)

4.3.3.2 Lifestyle factors.
The lifestyle factors are shown in table 4.3.11. The men and women from the East coast were selected randomly and therefor their rate of smoking can be considered representative, the number of never smokers was extremely low (2-10%) both among men and women, the number of previous smokers ranged from 10-20%. The debut age for smoking was typically around 15 and the number of smoking years ranged from 9-17 among previous smokers and 14-18 among present smokers. Their self reported smoking status was compared with their serum cotinine levels, the never smokers had a close to zero cotinine level, consistent with their reporting, and so did the previous smokers in Tassiilaq. In Ittoqqortoormiit, however, the cotinine levels among previous smokers were 74 and 33 ng/ml among men and women respectively which indicate the use of 5-3 daily cigarettes. Among the current smoking women in Ittoqqortoormiit the average cotinine level was 174 ng/l and the self reported number of daily cigarettes only 6.4. This would correspond to 27ng cotinine/cigarette which is significantly higher than for the other groups and indicates under-reporting.

The 48 men from Uummanaq were selected for a case-control study and the high ratio of never smokers should not be considered representative of the

basic population, the self reported cigarette use was consistent with the cotinine levels.
Concerning diet the reported intake frequency of fish, seal, whale, and Inuit meals were highest in Uummanaq and lowest in Ittoqqortoormiit , whereas game and polar bear intake was highest in Ittoqqortoormiit.

Table 4.3.11. Lifestyle factors among men and non-pregnant women according to self reported AMAP questionnaire. Cotinine , a nicotine breakdown product is included as validation of the smoking reporting.

	Uummanaq 1999	Ittoqqortoormiit 1999-2000	Ittoqqortoormiit 1999-2000	Tasiilaq 2000	Tasiilaq 2000
Total n	48 men	52 men	42 women	40 men	40 women
Number of valid questionnaires	48	52	42	40	40
Smoker: never-Previous-present	14-6-28	2-10-40	1-6-35	4-8-28	3-4-32
Smokeyears	0-10-20-	0-17-16	0-9.4-18	0-13-18	0-11.6-14.3
Cigarettes per day	0-18-12.6	0-12.4-11.0	0-3-6.4	0-10.8-11.2	0-8.7-8.8
Cotinine, ng/L, never-previous-present	0-20-251	0-74-248	0-33-174	1.3-4.3-195	0-4.3-188
Birds, (meals per month)	1.9	1.4	2.0	1.2	1.2
Fish	7.1	1.8	2.1	3.3	4.9
Game	1.0	2.2	3.2	0.5	0.4
Lam	2.0	0.8	0.8	0.9	1.1
Polar bear	-not asked	3.0	3.1	1.3	1.6
Seal	12.0	3.2	2.9	5.5	5.6
Whale	2.8	1.2	1.1	1.4	1.5
Inuit meals	17.0	6.0	8.0	10.9	12.5
Danish meals	9.4	15.6	16.2	14.6	14.5

4.3.3.3 Dietary markers.
The fatty acid profiles (table 4.3.12) followed the overall reported dietary composition, the n-3/n-6 ratio and EPA were highest in Uummanaq consistent with diet based more highly upon marine mammals and fish. Blood levels of 20.5.3 and 22.5.3 varied by district both in terms of absolute values and their mutual ratios.
On the East Coast the n-3/n-6 ratio was lower particularly among men from Ittoqqortoormiit. This resulted both from a lower concentration of n-3 particularly of 20.5.3 (EPA) and a higher concentration of linoleic acid

Table 4.3.12. Dietary markers of men and non- pregnant women,total plasma lipids, fatty acids in % of total plasma lipids, triglycerides, cholesterol.
Arithmetic means, minimum and maximum, Selenium geometric means

	Uummanaq 1999	Ittoqqortoormiit 1999-2000	Ittoqqortoormiit 1999-2000	Tasiilaq 2000	Tasiilaq 2000
Total n	48 men	52 men	42 women	40 men	40 women
Total lipids, g/L	6.2:	6.83:	7.12:	7.33:	6.67:
Linoleic acid, 18.2.6	13.6:	19.8:	17.6:	19.1:	18.5:
Arachidonic acid 20.4.6	4.6:	5.6:	5.8:	4.7:	4.9:
Eicosapentaenoic acid, 20.5.3	4.3:	1.6:	2.5:	2.9:	2.8:
22.5.3 Docosapentaenoic	1.4:	1.13:	1.34:	1.16:	1.21:
Docosahexaenoic acid, 22.6.3	5.7:	4.2:	5.7:	5.5:	5.8:
Sum n-3	12.6:	7.8:	10.5:	10.6:	10.8:
Sum n-6	21.0:	28.8:	26.6:	26.3:	26.0:
n-3/n-6 ratio	0.60:	0.27:	0.40:	0.40:	0.42:
Triglycerides Mmol/L	0.98:	1.42:	1.40:	1.55:	1.29:
Cholesterol Mmol/L	5.01:	5.36:	5.63:	5.90:	5.41:
Selenium, microgram/L blood	354: (122-1890)	169: (81-635)	241: (103-678)	172: (89-322)	187: (90-415)
Selenium, microgram/L plasma	112: (77-153)	88.6: (57-200)	89.5: (62-122)	80: (55-122)	74: (45-161)

4.3.3.4 Contaminants

4.3.3.4.1 Heavy Metals

The only population group that has an extreme, high level of Hg is Uummanaq, with 52 microgram per liter, which is 2-5 times higher than the other stations, table 4.3.13. This is consistent with the high blood Selenium level se above table 4.3.12 and indicates a high whale consumption.

The lead levels are not in general particularly high, although higher on the East Coast and higher among men, table 4.3.13, see also table 4.3.3.

The cadmium levels which indicate both seafood intake and smoking are higher on the East Coast particularly among men in Ittoqqortoormiit . However the group of 48 men from Uummanaq which are selected for a case control study includes a higher than normal ratio of non-smokers (14/48) where as the number of non -smokers or previous smokers are much lower on the East coast se table 4.3.11. Therefor the overall Cd level in Uummanaq cannot be considered representative of the location. The Cd-level among the smokers in Uummanaq is 1.71 microgram/L which is comparable to the value found among men in Ittoqqortoormiit and almost double as high as among non-smokers. The Cd levels are not significantly correlated with traditional food intake but highly significantly correlated with smoking $r=0.37$, $p<0.001$***. None of the metals appear to have decreased in levels over the time period covered by the study.

Table 4.3.13. Blood contaminants in men and non-pregnant women in wet weight, microgram/L. Geometric means, minimum and maximum.

	Uummanaq 1999	Ittoqqortoormiit 99-2000	Ittoqqortoormiit 99-2000	Tasiilaq 2000	Tasiilaq 2000
total n	48 men	52 men	42 women	40 men	40 women
Hg	52.0: (9-140)	14.2: (2-73)	18.2: (4-48)	26.0: (4-82)	24.7: (7-155)
Pb	59.9: (11-379)	70.7: (38-148)	57.8: (28-156)	51: (22-123)	37.9: (18-140)
Cd	0.76: (0.03-4.62)	1.65: (0.1-7)	1.38: (0.1-5)	1.22: (0.3-3	1.23: (0.3-3)
Aldrin	Nd	0.01	0.01	0.01	0.01
beta HCH	0.40: (0.16-0.98)	0.49: (0.07-2.6)	0.56: (0.07-2.0)	0.16: (0.01-0.7)	0.16: (0.03-0.7)
Sum of chlordanes	10.86: (3-26.9)	5.91: (0.9-27)	6.6: (0.6-24)	3.4: (0.15-19)	3.28: (0.63-23)
DDE	11.9: (3-27)	8.46: (2-38)	11.75: (1.6-43)	6.53: (0.42-36)	7.60: (1.5-29)
DDT	0.29: (0.1-1.1)	0.22: (0.01-1.5)	0.51: (0.05-2.8)	0.16: (0.01.0.7)	0.22: (0.01-1.44)
DDE+DDT	12.2: (3.4-27.3)	8.68: (2-40)	12.3: (1.7-46)	6.7: (0.4-36)	7.82: (1.5-30.5)
Hexachloro Benzene	3.1: (0.9-8.0)	1.18: (0.17-4.3)	1.6: (0.3-4.9)	0.83: (0.13-2.45)	0.80: (0.22-2.8)
Mirex	0.54: (0.14-2.3)	0.39: (0.04-2.2)	0.35: 0.02-1.33)	0.24: (0.01-1.33)	0.23: (0.02-1.2)
PCB, 14 congeners	17.7: (5.9-40)	29.1: (3.4-180)	30.8: (2.5-106)	10.54: (0.7-49)	10.52: (2.2-39)
Aroclor 1260	47.5: (14-94)	78.9: (9.6-404)	85.1: (7.3-263)	26.1: (1.7-119)	26.6: (5.1-90)
Toxaphenes, 4 congeners	2.12: (0.75-6.0)	1.24: (0.03-4.1)	1.26: (0.14-7.3)	0.89: (0.05-6)	0.88: (0.18-3.8)
DDE:DDT	41: (13-100)	38: (9-286)	23: (6-74)	40: (13-130)	35: (12-193)

Previous to AMAP surveys heavy metals have been analysed in blood from various target groups and locations in Greenland during the period 1979-87

(Hansen 1981, 1990 and Hansen pers.comm) Only very few of these previous studies cover target groups which are comparable with the present results regarding sex- and agegroup, namely men from Uummanaq 1979 and men and women from Tasiilaq 1981. Among men from Uummanaq the aritmetic mean blood level of Pb changed from 160 microgram/litre (1979) to 60 microgram /litre (1999), among men from Tasiilaq 164 microgram/litre (1981) to 51 (2000) and women 140(1981) to 38 microgram/litre (2000). All these changes were highly significant drops in Pb blood levels. Among men from Uumanaq Hg increased significantly from 40 (1979) to 60 microgram/litre(1999). Cd blood levels did not decrease significantly during the same time period.

4.3.3.4.2 Organochlorines.

The following applies both to contaminant levels in wet weight (table 4.3.13) and lipid weight levels (table 4.3.14) of organochlorines in plasma. Comparisons by independent samples t-test between the three geographical groups are shown in table 4.3.15

The sum of chlordanes, DDTs, hexachlorobenzene, mirex and toxaphenes are highest in Uummanaq and lowest in Tassiilaq, whereas beta-HCH, and particularly PCB-congeners (and Aroclor1260) are by far the highest in Ittoqqortoormiit, almost three times the level in Tasiilaq.

Table 4.3.14. Contaminants in men and non-pregnant women, lipid adjusted weight microgram/kg total plasma lipid.Geometric means, minimum and maximum.

	Uummanaq 1999	Ittoqqortoor-miit 99-2000	Ittoqqortoor-miit 99-2000	Tasiilaq 2000	Tasiilaq 2000
Total n	48 men	52 men	42 women	40 men	36 women
Aldrin	Nd	0.01	0.01	0.01	0.01
Beta-HCH	65.3: (24-181)	70.1: (13.7-384)	78.1: (9.8-291)	21.4: (1.6-68)	23.3: (5.5-91)
Sum of chlordanes	1759: (455-4981)	866: (126-3945)	926: (109-3378)	464: (32-1724)	492: (111-1789)
DDE	1920: (507(4153)	1238: (323-5064)	1649: (289-5846)	889: (67-4367)	1140: (286-3867)
DDT	46.7: (15-147)	33.0: (1.2-201)	70.9: (8.3-359)	22: (1.6-111)	32.7: (1.7-194)
DDE+DDT	1972: (523-4204)	1271: (325-700)	1720: (297-6200)	911: (68.4478)	1173: (288-4060)
Hexachloroben-Zene	496: (138-1244)	173: (33-639)	225: (42-685)	112: (20-350)	119: (41-377)
Mirex	88: (21-343)	57.6: (7.3-338)	49.7: (4.7-234)	32.9: (2.1-158)	35.0: (3-199)
PCB, 14 congeners	2871. (908-6181)	4255: (643-26568)	4325: (570-13241)	1436: (112-4526)	1576: (320-6700)
Aroclor 1260	7795: (2460-16750)	11553: (1827-59598)	11953: (1627-36380)	3556: (279-11249)	3986: (815-16287)
Toxaphenes, 4 congeners	344: (115-814)	121: (4-635)	178: (20-941)	121: (8.3-720)	131: (31-508)
TEQ	78: (32-2059)	110: (17-851)	109: (13-386)	43: (3-140)	45: (10-210)

Table 4.3.15. Arithmetic means of organochlorine blood levels from 3 districts 1999-2000 and significance levels in independant samples t-test.- $p<0.03$*, $p<0.01$**, $p<0.001$***

Lipidadjusted POP, Microgram/kg lipid	Uummanaq a)	Ittoqqortoormiit b)	Tasiilaq c)
beta HCH	71.1, b,c***	101.3 c***	28
sum of chlordanes	1979, b,c***	1225, c***	632
DDT	2160, b 0.1 ns c*	1815, c**	1331
Hexaclorobenzene	561, b,c***	248, c***	139
Mirex	106, b,c***	79.5, c***	50.3
sum of PCB	3138, b,c***	5819,c***	1929
sum of Toxaphenes	380, b,c***	201, c ns	172

Table 4.3.16. Blood levels of fatty acids (% of total lipids) and contaminants in plasma of 67 Danish women of childbearing age (25,5 years (16-36)) shown for comparison with the corresponding results from Greenland.

Fatty acids, (n=47)		Contami-nants (n=67)	wet weight microgram/ liter	lipid weight microgram/ kg lipid
Total lipids, g/L	5.6: (3.8-8.4)	Beta HCH	0.10: (0.03-0.28)	18.6: (5.3-55.7)
Linoleic acid, 18.2.6,%	29.9:	Sum of chlordanes		
Arachidonic acid 20.4.6,%	6.3:	DDE	0.82: (0.27-4.36)	150: (51-695)
Eicosapentaenoic acid, 20.5.3,%	0.82:	DDT	0.03: (0.0-0.4)	5.1: (0-77)
Docosapentaenoic acid 22.5.3,%	0.53:	DDE+DDT		155:
Docosahexaenoic acid, 22.6.3,%	2.53:	Hexachloro Benzene	0.16: (0.08-0.26)	29.1: (13-51)
sum n-3,%	4.5:	Mirex	0.0013: (0.0-0.07)	0.19: (0-7.9)
sum n-6,%	34.6:	PCB,14 congeners	1.17: (0.52-2.2)	210: (100-393)
n-3/n-6 ratio	0.13	Aroclor 1260	3.28: (1.48-6.44)	585: (257-1150)
Triglycerides mmol/L	1.08: (0.25-2.49)	Toxaphenes 5 congeners	Nd	nd
Cholesterol mmol/L	4.84 (3.0-7.60)	DDE:DDT		29:
		TEQ picogram/kg		6.9: (3.2-13.7)

4.3.4 Percentages of samples exceeding guidelines for blood levels of pollutants

The percentage of blood samples which exceed various international guideline values are shown in table 4.3.17. For all pregnant women except for women from Nuuk a very high percentage exceed the guidelines for mercury and in addition the non-pregnant women (of fertile age) have correspondingly high exceeding %. In contrast only a few persons(0-14%) exceed the guideline for lead.

Tabel 4.3.17. Percentages of bloodsamples exceeding various guidelines for mercury, lead and PCB-aroclor 1260 (microgram /liter) among pregnant woman, non-pregnant women of reproductive age and men.
(W Greenland:Nanortalik, Nuuk, Illulissat, Upernavik.)

Location and year	Partici-pants	Mercury >4.4 US-EPA	Mercury >20. WHO	Lead >100	Aroclor >5, (Ca) level of corcern, Pregnant	aroclor >20 level of concern (Ca)	aroclor >100. level of action (Ca)
Disko bay 1994-96	Pregnant n=175	93%	25%	2%	93%	37%	0%
Disko bay 1997	Pregnant n=95				95	17	0
Ilulissat 1999	Pregnant n=30	80	31	7	52	7	0
Nuuk 1999	Pregnant n=34	44	44	0	81	0	0
Ittoqqort. 1999	Pregnant n=8	63	12.5	0	100	62.5	12.5
Tasiilaq 2001	Pregnant n=8	100	50	0	100	74	0
Iittoqqort. 1999	Women n=42	93	45	10	100	90	50
Tasiilaq 2001	Women n=40	100	73	4	98	60	0
Denmark 1998	Women n=67				10	0	0
Iittoqqort. 1997	Men n=15				100	93	60
Greenland, W, 1997	Men n=46				100	60	2
Uummanaq 1999	Men n=48	100	96	14	100	94	0
Ittoqqort. 2000	Men n=52	94	27	10	100	94	43
Tasiilaq 2001	Men n=40	98	70	2	97	81	2

Concerning PCB guidelines 52-100% of the pregnant women exceed the level of concern and in Ittoqqortoormiit 12.5 % (one pregnant woman) exceeds the level of action. Among the non-pregnant woman of fertile age the exceedances are even slightly higher, in Ittoqqortoormiit 50 % exceed the action level. Also among the men in Ittoqqortoormiit 43 % exceed the action level. The exceedances in Ittoqqortoormiit 1999 confirm results from 1997(Deutch and Hansen 2000). The exceeding % among Danish women is only 10 (thus only 10% of non-pregnant women in Greenland).

Figure 4.3.1. Human plasma PCB-aroclor1260 (microgram/litre) as a function of agegroup and district among women from East Greenland 2000-2001, (n=94) compared to Canadian guideline values (5, 20, and 100 microgram/litre) see table 4.3.17

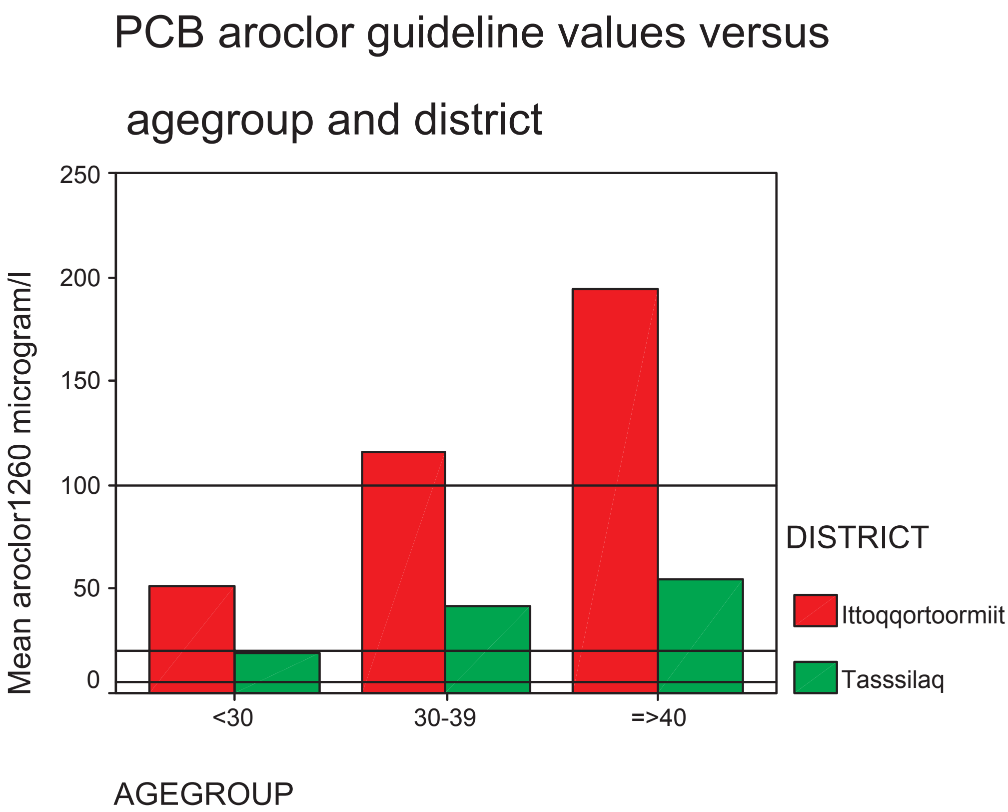
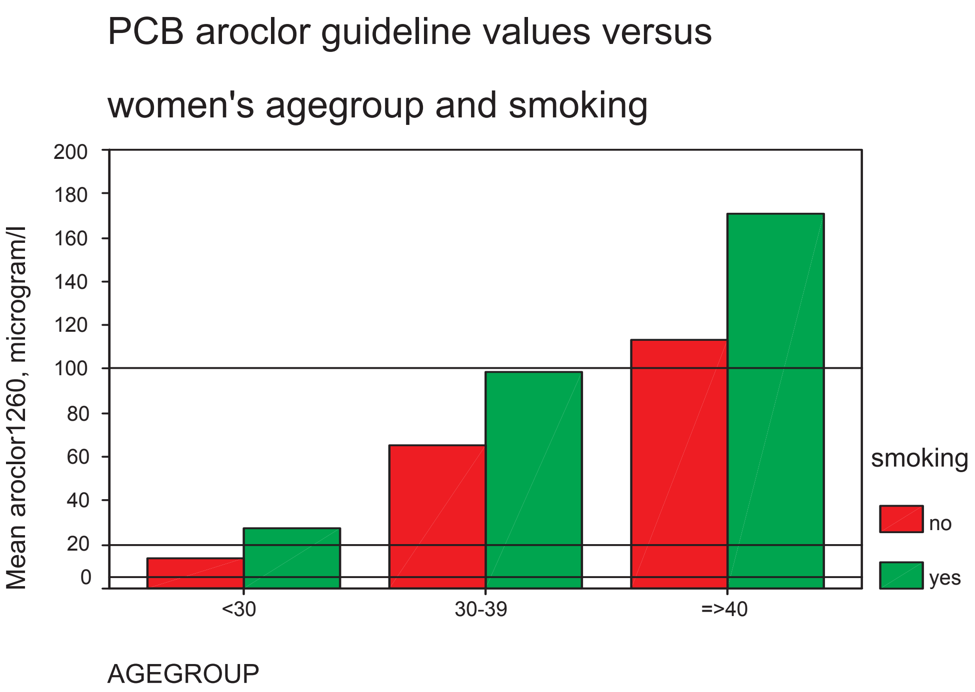


Figure 4.3.2. Human plasma PCB-aroclor1260 (microgram/litre) as a function of agegroup and present smoking status among women from East Greenland 2000-2001, (n=94) compared to Canadian guideline values (5, 20, and 100 microgram/litre) see table 4.3.17



4.3.5 Dietary Surveys 1999-2000

4.3.5.1 Dietary survey pilot study 1999 by 24 hour recall

The Dietary survey, pilot study from 1999, compared 50 male Inuits from Ittoqqortoormiit with 48 male Inuits from Uummanaq and showed mean Intake in gram during the last 24 hours estimated by a 24 hour recall (24HRC) frequency scheme and standard portions sizes in grams (table 4.3.18). Food type groups were compiled from single food items from a 32 food item list, polar bear intake was not asked in Uummanaq. The total intake is the sum of all products eaten (not just the typical product presented in the table). The intake of seal, whale, imported meats , potatoes and total amount of solids were very similar in the two groups but bread, pasta, and rice intake was higher in Ittoqqortoormiit and fish intake was lower The total intake in grams were higher in Ittoqqortoormiit but this was mainly due to a higher liquid consumption.

Table 4.3.18. Results from 24 hour recall dietary questionnaire among 20-50 year old Inuits in Ittoqqortoormiit, Eastern Greenland compared with Uummanaq, Western greenland 1999. arithmetic means (gram/day). Independent samples t-test for equality of means, $p<0.05^{*}$, $p<0.01^{**}$, $p<0.001^{***}$.

Food types:	Ittoqqortoormiit 50 men	Uummanaq 48 men
Birds, gram per day	16	
Bread	262	96
Dairy	91	57
Eggs	30	
Fish	14	65
Fruit	96	79
Game	0	25
Pasta and rice	96	18
Potatoes	120	140
Polar bear	36	
Imported meat	193	133
Seal	105	132
Whale	56	61
Liquids	2367	1279
Total, solids	1115	847
Total liquids and solids	3482	2126

Results from the small dietary questionnaire (AMAP) among 20-50 year old Inuits in Ittoqqortoormiit were compared with Tasiilaq, Eastern Greenland 2000-2001, through estimated monthly food consumption frequencies, (arithmetic means are tested by Independent samples t-test for equality of means, $p<0.05^{*}$, $p<0.01^{**}$, $p<0.001^{***}$.) Table 4.3.19. The differences between men and women were not found to be significant and are thus not shown separately.

Table 4.3.19. Results from dietary questionnaire among 20-50 year old Inuits in Ittoqqortoormiit compared with Tassiilaq, Eastern Greenland 2000-2001. Estimated monthly food consumption frequencies, arithmetic means. Independent samples t-test for equality of means, p<0.05*, p<0.01**, p<0.001***.

Monthly meal frequency Årithmetic means	Ittoqqortoormiit, 51 men and 42 women	Tassiilaq, 41 men, 40 women, 8 pregnant women.
Birds	1.65 p=0.07	1.17
Local fish	1.96*	4.14
Fruit	5.53	6.86
Game	2.67***	0.46
Lamb	0.84	1.03
Potatoes	13.6***	18.7
Seal	3.01***	5.5
Whale	1.11	1.44
Vegetables	6.89***	11.75

4.3.5.2 AMAP Questionnaire

The food frequencies measured by the AMAP questionnaire, which covers the habitual recent intakes were in general quite similar in Ittoqqortoormiit and Tasiilaq. However local fish, seal, potatoes and vegetable consumption was significantly higher in Tassiilaq and game (reindeer, muskox , hare) was higher in Ittoqqortoormiit

According to the AMAP Questionnaire the sums of single local products were higher than the reported frequency of Inuit meals and the intakes were lower in Ittoqqortoormiit than in Tasiilaq

Table4.3.20. Results from dietary survey by semi quantitative food frequency questionnaire, FFQ, among 20-50 year old Inuits in Ittoqqortoormiit compared with Tasiilaq, Eastern Greenland 2000-2001,The differences between men and women are not significant and therefore not listed separately. Daily intakes in grams, arithmetic means and (medians). Independent sample's t-test for equality of means, $p<0.05$*, $p<0.01$**, $p<0.001$***.

Food types:	Ittoqqortoormiit, 51 men and 42 women	Tassiilaq, 41 men, 40 women , 8 pregnant women.
Seal products	37.7 (15.3)	45.2 (16.3)
Baleen whale products	9.1 (7.7)	10.9 (7.7)
Toothed whale products	26.1 (19.3)	27.6 (18.3)
Seal and whale blubber	8.7 (6.0)	10.6 (6.0)
Fish products	61.2 p=0.06 (40.8)	96.3 (36.7)
Birds	4.8 (3.3)	2.9 (3.3)
Polar bear	30.5** (20.0)	14.8 (10.0)
Walrus	17.6* (10.0)	10.4 (10.0)
Game	65.7*** (43.3)	33.7 (26.6)
Danish meat products	108.2 (75.0)	118.4 (80.0)
Vegetables	142.6 (113.3)	172.0 (161.7)
Fruit	52.6** (30.0)	100.0 (36.7)
Milk Products	122.9* (41.3)	217.0 (98.0)
Bread	126.5 (85.0)	123.3 (100.0)
Liquids	1532 (1608)	1540 (1506)
Greenland food products, Solids	252.5 (198.5)	241.5 (174.7)
Danish food products, Solids	552.9 (443.7)	730.7 (610.5)
Total liquids + solids	2332.5 (2385)	2509 (2396)

4.3.5.3 Semiquantitative Food Frequency Questionnaire

Results from dietary survey by semi quantitative food frequency questionnaire, FFQ, among 20-50 year old Inuits in Ittoqqortoormiit were compared with Tasiilaq, Eastern Greenland 2000-2001 as shown in table 4.3.20.Daily intakes in grams calculated from monthly frequency and standard portions sizes are shown as arithmetic means and (medians)

Arithmetic means are compared by Independent samples t-test for equality of means, $p<0.05^{*}$, $p<0.01^{**}$, $p<0.001^{***}$.)
The results of this dietary survey by FFQ which aimed at covering the last year, were in general somewhat similar between Ittoqqortoormiit and Tassiilaq and the means and median intakes of the food item groups were almost identical with a few exceptions (table 4.3.20) see below.

The total intakes as grams of Greenland products were the same but the total intakes of Danish food were slightly, but not significantly higher in Tassiilaq. Among the Greenland products, intakes of polar bear, walrus and game were significantly higher in Ittoqqortoormiit and intake of seal and - fish products were higher but not significantly higher in Tassiilaq. Among the Danish products, meat and bread intakes were the same, but milk products, fruit and vegetables were higher in Tassiilaq. Butter and margarine intakes (not listed) were similar since they followed the bread intakes. Liquid intake was the same, and sugar which was associated with coffee and tea drinking was the same in the two towns.

Figure 4.3.3. Relative intakes (gram/day) of local and Danish food by 52 men and 50 women from Ittoqqortoormiit 2000 estimated by a Semiqauntitative Food Frequency Questionnaire

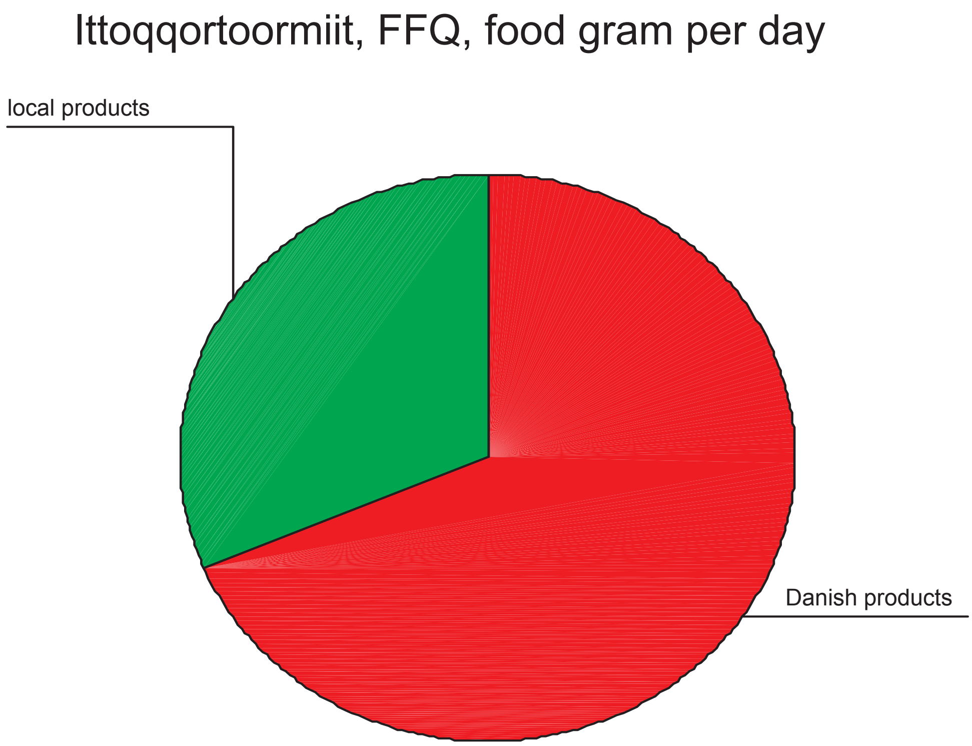


Figure 4.3.4. Relative intakes (gram/day) of local and Danish food by 40 men and 48 women from Tassilaq 2001 estimated by a Semiqauntitative Food Frequency Questionnaire

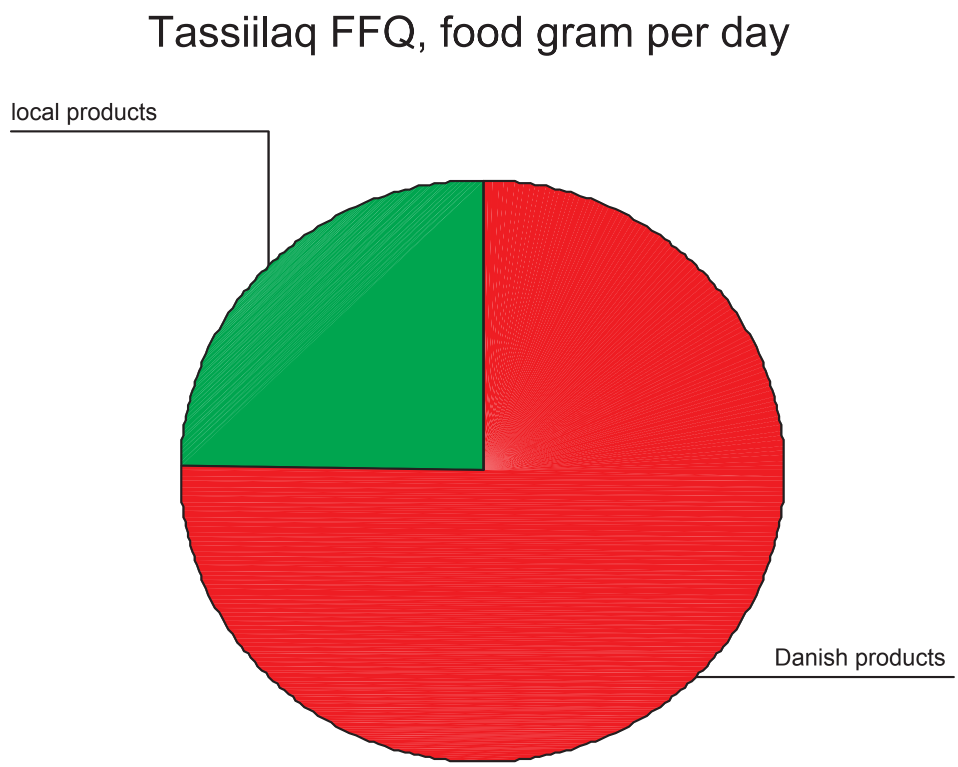


Figure 4.3.5. Relative intakes (gram/day) of local and Danish food by 52 men and 50 women from Ittoqqortoormiit 2000 estimated by a Semiqauntitative Food Frequency Questionnaire

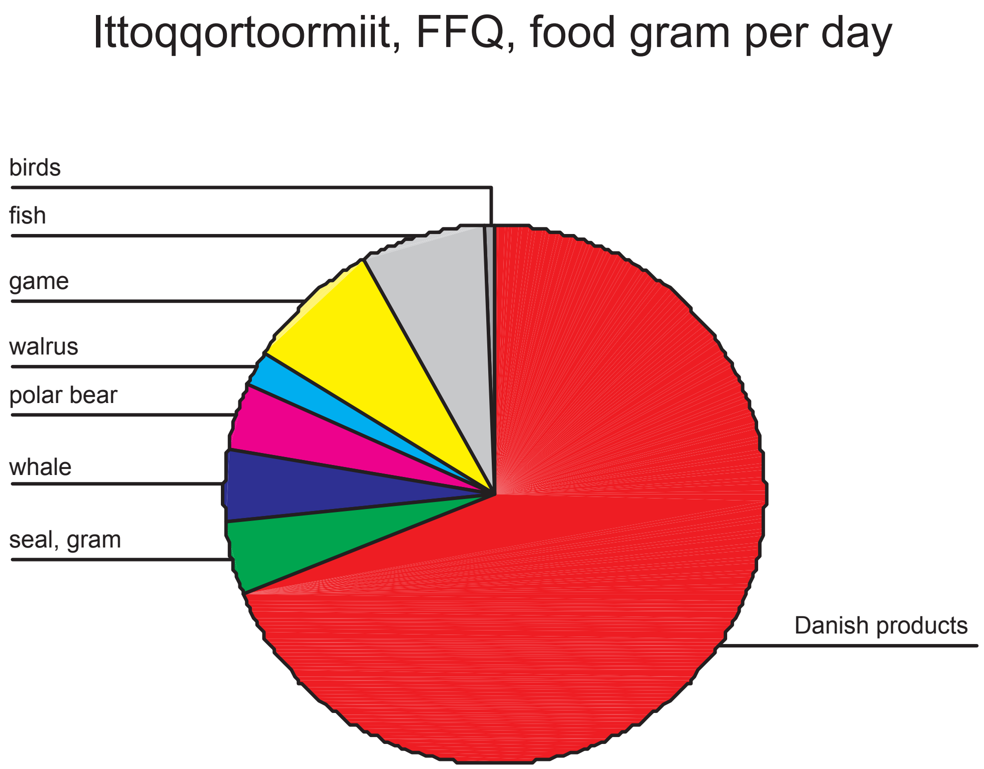


Figure 4.3.6. Relative intakes (gram/day) of local and Danish food by 40 men and 48 women from Tasiilaq 2001 estimated by a Semiqauntitative Food Frequency Questionnaire

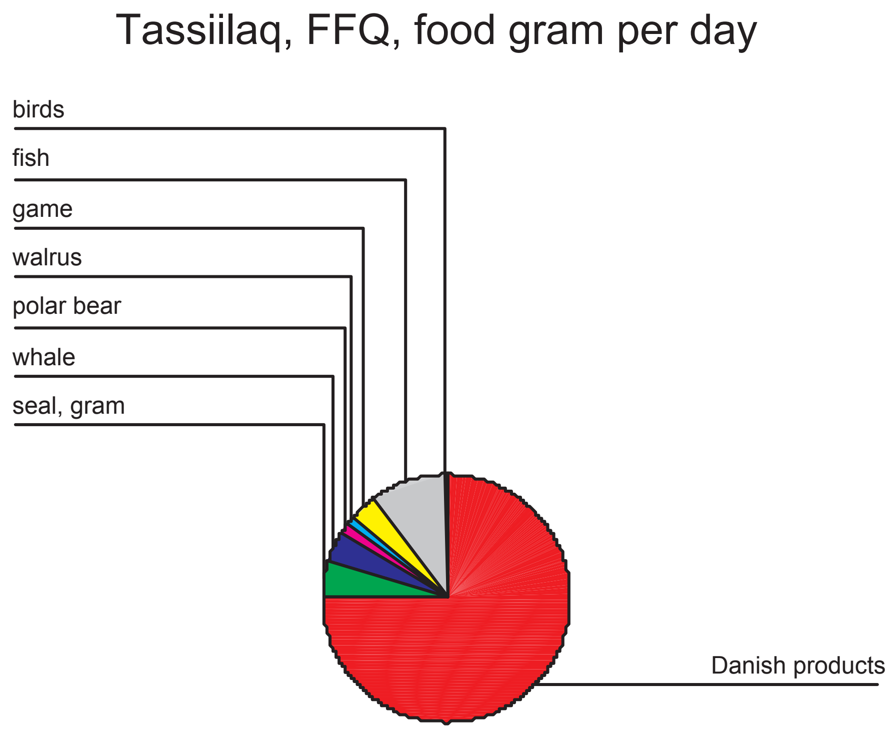


Figure 4.3.7. Relative intakes (gram/day) of local food by 52 men and 50 women from Ittoqqortoormiit 2000 estimated by a Semiqauntitative Food Frequency Questionnaire

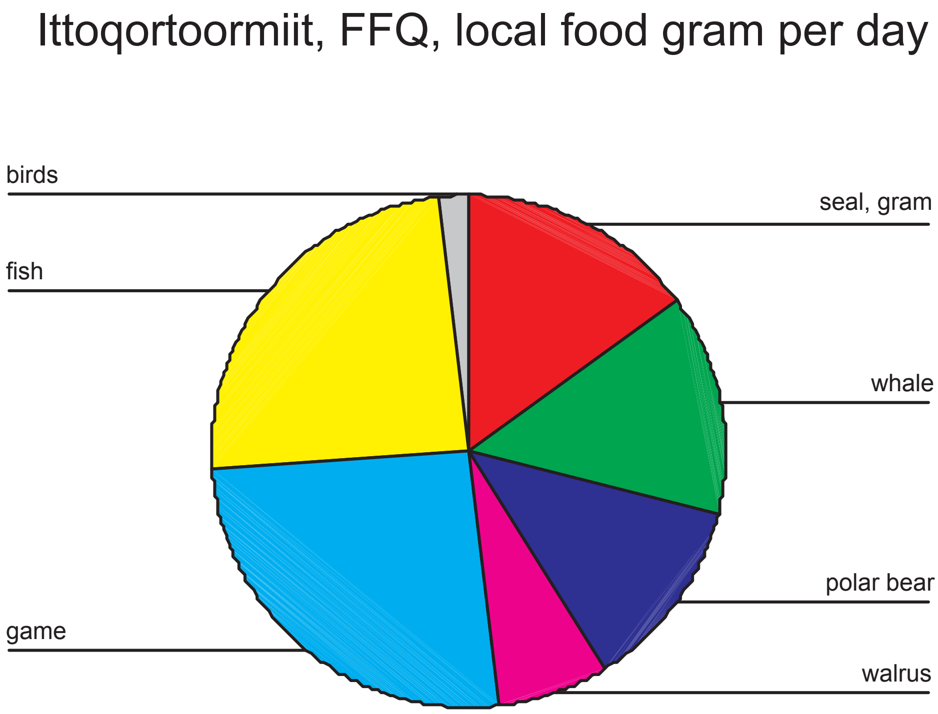
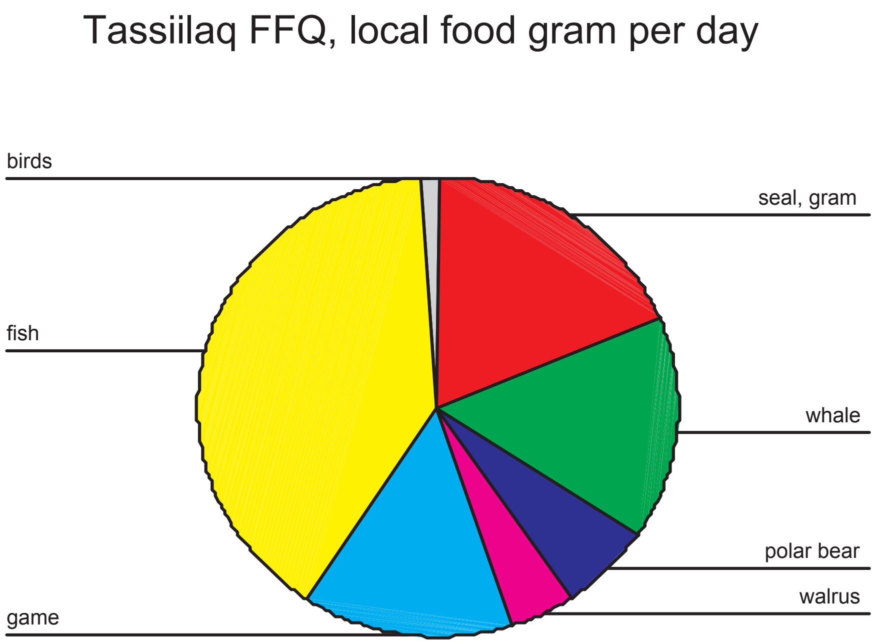


Figure 4.3.8. Relative intakes (gram/day) of local food by 40 men and 48 women from Tasiilaq 2001 estimated by a Semiqauntitative Food Frequency Questionnaire



In terms of solid food weight Greenlandic food yielded 31.3 % in Ittoqqortoormiit and and 24.8% in Tasiilaq , which supported the picture that the food intake in Tassiilaq was slightly more " westernized" and at the same time more balanced / versatile.
The food intakes were also compared between men and women (for both towns) and were found to be very similar, only deviating for fruit ($p=0.02$) and vegetables ($p=0.07$) which were higher among women. The overall differences between men and women were so small that the results are not shown separately.
Smokers were also compared with non-smokers but there were no significant differences. The effect of age was also considered , but the intake of the included traditional food items appeared to be independent of age within the range tested (20-50 years).
Based on data from 1994-95 from Disko Bay area Pars (2000) published the results of a dietary study by several methods, SQFFQ, 24HRC and 48HRC. She found that the local food was about 22% of the total intake and that traditional food was more common among men and among the older age groups.

The present dietary survey results based upon 182, 20-50 year old Inuits living in Eastern Greenland 2000-2001, from Ittoqqortoormiit (51 men and 42 women) and Tassiilaq (41 men, 40 women and 8 pregnant women) were furthermore compared between the two methods applyed, the brief AMAP questionnaire (using 14 food categories and 6 frequency categories) and the semi quantitative food frequency questionnaire, table 4.3.21. The FFQ answers, using 8 frequency categories and 60 single food item types, were compiled into food-group categories, which were comparable with the other questionnaire in terms of monthly frequency. The two methods were compared by difference of arithmetic means, and their mutual correlation were measured by Pearson correlation coefficients(significance levels $p<0.05$*, $p<0.01$**, $p<0.001$***).

Table 4.3.21. Dietary survey results based upon 182, 20-50 year old Inuits living in Eastern Greenland 2000-2001, Ittoqqortoormiit (51 men and 42 women) Tassiilaq (41 men, 40 women and 8 pregnant women). Comparison between to methods, the brief AMAP questionnaire using 14 food categories and 6 frequency categories and the semi quantitative food frequency questionnaire, FFQ, using 8 frequency categories and 60 single food item types, which were compiled into food group categories, made comparative with the other questionnaire. Monthly frequency, arithmetic means, and Pearson correlation coefficients, $p<0.05^*$, $p<0.01^{**}$, $p<0.001^{***}$.

Food types	AMAP questionnaire	Semi quantitative FFQ	Bivariate correlation coefficients (Pearson)
Birds	1.4	2.3	0.36***
Fish (local)	3	18.6	0.42***
Fruit	6.2	22.6	0.12 ns
Game	1.6	5.6	0.46***
Lamb	0.9	1.8	0.28***
Potatoes	16.1	13.6	0.24***
Seal	4.3	10.8	0.69***
Whale	1.3	14.1	0.09 ns
Vegetables	9.2	23.1	0.24**
Total	44	112.5	

In general the mean food type consumption frequencies estimated from the FFQ were higher than those from the AMAP questionnaire, particularly when the food group was compiled from several single items, (fish, fruit, whale, vegetable) and not so much when the food group only consisted of few or single items (birds, lamb, seal). The FFQ also covered a longer period (one year) than the AMAP questionnaire. However the bivariate correlation coefficients were very high between the two methods except for fruit and whale intake. The best agreement was found for seal intake, table 4.3.21.

Both methods supported the general picture that the diet was more versatile in Tassiilaq relying more on different products both traditional and Danish especially fish, fruit and vegetables.

4.3.5.4 Dietary survey results and dietary biomarkers

Regarding men and non-pregnant women , table 4.3.11 and 4.3.12, the picture is much the same as for pregnant women with higher plasma levels of n-3 on the east coast than in the larger towns and settlements on the South west coast. The only exception is Uummanaq, but the participants have a high ratio of hunters who presumably consume more marine products.The Docosa-pentaenoic acid, 22.5.3, levels are high in both Uummanaq, Ittoqqortoormiit and Tassiilaq indicating high intakes of seal and or polar bear, according to the dietary questionnaires above, polar bear intake is common on the East Coast particularly in the North.

Table 4.3.22. Associations between diet and plasma fatty acids, and between lipid adjusted POPs and plasma fatty acids among 182 Inuits on the East Coast of greenland 2000. Pearson bivariate correlation coeffecients and significance levels, p<0.05*, p<0.01**, p<0.001***.only the strongest associations are shown.

Diet/fatty acids	EPA 20.5.3	DPA 22.5.3	DHA 22.6.3	n-3/n-6
Frequency of seal per month	0.24**	0.17*	0.24**	0.24**
Frequency of polar bear per month	-0.009	0.23**	0.11	0.09
Frequency of All local products	0.014	0.08	0.07	0.04
POPs/fatty acids				
Beta HCH	0.13	0.47**	0.16*	0.21**
Chlordanes	0.20**	0.48**	0.21**	0.26**
DDE	0.23**	0.29**	0.14	0.19*
Hexachloro-benzene	0.26**	0.52**	0.25**	0.31*
Mirex	0.26	0.45**	0.16*	0.26**
PCBs	0.19*	0.55**	0.21**	0.29**
Toxaphene	0.21*	0.31**	0.26**	0.24**

All the POPs are positively correlated with n-3 fatty acids and most of them highly significantly. This strongly documents that n-3 fatty acids and the POPs come from the same sources into the human body, and that these sources are the marine animals. Furthermore in particular plasma 22.5.3 was strongly and highly significantly correlated with all POPs. These associations were stronger and more significant than those found for 20.5.3 and 22.6.3 and for the n-3/ n-6 ratio.(table 4.3.22)

The bivariate correlations between the reported dietary frequencies and the POPs supported the same picture, although the associations were not quite as consistent and strong, table 4.3.23, shown for 182 Inuits on the East coast 1999-2000.

4.3.6 Associations between contaminants and other factors

4.3.6.1 Versus diet and dietary markers

Bivariate correlation coefficients between dietary frequencies and plasma fatty acids are shown in table 4.3.22 along with correlations between plasma POPs and plasma fatty acids. The correlations between dietary factors and plasma POPs are shown in table 4.3.23, only the strongest associations are shown. The frequency of reported seal intake per month was consistently correlated with all long-chain n-3 fatty acids and the n-3/n-6 ratio. Polar bear intake was strongly associated with 22.5.3. Apart from that neither fish, birds, nor whale intakes were correlated with fatty acids.

Table 4.3.23. Associations between dietary factors and lipid adjusted POPs. Pearson bivariate correlation coeffecients and significans levels, p<0.05*, p<0.01**, p<0.001***. Only significant associations are shown.
A. Amap questionnaire. F. Food frequency questionnaire

	Aroclor 1260	Beta HCH	Chlor-Danes	DDE	hexachlor benz.	Mirex	PCB 14 con-geners	Tox 5 con-geners
Danish meals, A				-0.18*	-0.18*		-0.15 p=0.05	-0.17*
Inuit meals, A	0.29**	0.26**	0.31**	0.28**	0.28**	0.27**	0.30**	0.28**
fish,A								
game (muskox, reindeer hare), A							0.24**	
seal, A						0.17*		
seal meat, F			0.15*					
seal blubber,F								
whale, A								
whale blubber, F								
polar bear,F	0.18*	0.18*			0.16*		0.18*	
birds, F							0.16*	0.22**
fish, F								
Muskox, F	0.21*	0.28**	0.20**				0.20**	

Inverse correlations with Danish food intake were found for several POPs: DDE, hexachlorophene, PCBs and toxaphenes and positive correlations with Inuit food were found for all the studied POPs . However reported seal and polar bear intakes were not consistently correlated with all the POPs. Fish intake was not correlated but intake of muskox was correlated with four different POPs. Bird intake and toxaphenes were highly correlated.

Although seal and whale blubber are known to contain high concentrations of almost all the lipophile POPs (Johansen et al, 2002, chapter 3), surprisingly neither the reported seal blubber or whale blubber intakes appeared to be related to the plasma POP levels. However, as stated above the fatty acid 22.5.3 which is highly prevalent in seal and polar bear blubber was strongly associated with all POPs.
This suggests that the dietary questionnaire answers were not sufficiently valid to indicate specific sources of organic contaminants.

4.3.6.2 POPS and metals versus other lifestyles, smoking
Not only diet but also other demographic and life style factors were predictors or determinants of high contaminant levels in blood. Since the substances are metabolized / excreeted at a very slow rate they are accumulated with age (bioaccumulated). Age is therefore always a determinant/ predictor of higher blood levels. But also a number of other lifestyle factors than diet seem to matter e.g. smoking and possibly alcohol intake.

Multiple linear regression analysis (table 4.3.24) of pooled data (n=175) from the mother/infant surveys in Disko Bay, 1994-96 and 1997-98 shows parameters associated with high plasma POP levels (logarithmic concentrations) in maternal blood. Smoking is consistently and highly significantly correlated with high POP levels. Reduced models show that alcohol intake is not a predictor for for high POP levels except mirex.(Deutch and Hansen 2000).
The same pattern is found in the geographical pilot study among men from 5 districts of Greenland, (table 4.3.25) here the objective measure, plasma n-3/n-6, is substituted for the more subjective "Marine food " intake.

Table 4.3.24. Multiple linear regression analysis of pooled data (n=175) from the mother/infant surveys in Disko Bay, 1994-96 and 1997-98 for parameters associated with high plasma POP levels (logarithmic concentrations) in maternal blood. Standardized correlation coefficients and p-values .

	Age a)	Alcohol intake b)	Marine food c)	Smoking d)
Beta HCH R square =0.25	0.43 p=0.001	0.13 ns	0.12 ns	0.17 0.025
Chlordanes R square =0.24	0.36 p=0.001	-0.01 ns	0.22 0.026	0.28 <0.001
DDT (sum) R square =0.26	0.44 p<0.0001	0.16 ns	0.16 0.036	0.21 0.006
Hexachlorbenz. R square =0.28	0.40 p<0.0001	-0.2 0.04	0.25 0.001	0.21 0.001
Mirex R square =0.30	0.48 p<0.0001	0.25 0.007	0.18 0.016	0.27 <0.001
PCB (sum) R square =0.33	0.50 p<0.0001	0.13 ns	0.17 0.021	0.25 0.001

a) adjusted for alcohol, marine food, smoking, plasma lipids.
b) adjusted for age, marine food, smoking, plasma lipids.
c) adjusted for age, alcohol, plasma lipids, smoking.
d) adjusted for age, alcohol, marine food, plasma lipids.

Table 4.3.25. Multiple linear regression analyses of data from the geographical survey of men in5 districts in Greenland 1997-98, (n=61) for parameters associated with high plasma POP levels , as above(Deutch and Hansen 2000)

	Age a)	Region b) East=1, West=2	Plasma n-3/n-6 c)	Smoking d)
Beta HCH R square =0.76	0.39 p<0.0001	-0.42 0.000	0.31 <0.0001	0.13 0.06 ns
Chlordanes R square =0.69	0.41 p<0.0001	-0.14 ns	0.43 <0.0001	0.26 0.002
DDT (sum) R square =0.63	0.34 p<0.001	-0.11 ns	0.49 <0.0001	0.27 0.002
Hexachlorbenz. R square =0.60	0.46 p<0.0001	-0.05 ns	0.31 0.002	0.15 0.09 ns
Mirex R square =0.57	0.43 p<0.0001	-0.17 0.08 ns	0.37 <0.0001	0.15 ns
PCB (sum) R square =0.80	0.34 p<0.0001	-0.50 0.000	0.37 <0.0001	0.21 0.002
Toxaph. (sum) R square =0.62	0.33 p=0.004	-0.25 0.017	0.40 <0.0001	0.22 0.02

a) adjusted for alcohol, smoking, plasma lipids, plasma n-3/n-6 and region.
b) adjusted for age, alcohol,smoking, plasma lipids, plasma n-3/n-6
c) adjusted for age, alcohol, plasma lipids, region, and smoking
d) adjusted for age, alcohol, plasma lipids, plasma n-3/n-6, and region

In the restricted crossectional study from Uummanaq, plasma cotinine was used as a biomarker of nicotin breakdown.
Multiple linear regression analyses were performed using various models that were based upon the assumptions that POP accumulation depends upon the dietary source, the time of accumulation (age), and potential modifiers of the metabolism such as smoking (table 4.3.26)

Most of the POPs were positively correlated with the age of the participants despite the narrow age span. The plasma POP concentrations (microgram /l) were positively associated with several plasma lipid fractions: total lipids, phospholipids and in particular with plasma triglycerides. BMI was also positively associated with plasma triglycerides.

All the measured POPs: beta-HCH, sum of Chlordanes, DDE, Hexachlorobenzene, Mirex, the sum of 14 PCB-congeners (and individual congeners), toxaphene, and DDE: DDT ratio were significantly correlated with reported smoking status and plasma cotinine levels after adjustment for age, BMI and plasma n-3/n-6 ratio.

The self reported "cigarettes per day" and "cigarette years" were also positively associated with plasma POPs but only borderline significant 0.05<p<0.10, not shown. Plasma cotinine (ng/l) indicator of smoking level gives the same associations as smoking level reported as never, previous, or present smoking status,

Thus in general the more objective biological markers for diet and smoking respectively were better correlated with effects than the self reported questionnaire answers.
In this group Body mass index, BMI, was found to be inversely correlated with POP accumulation in the whole group, but only significant for 5 out of 8 compounds. BMI was negatively associated with smoking status (non-smokerversus smoker) and smoking level among smokers.

The results of multiple linear regression analysis showed that smoking (cotinine), age, Body Mass Index (BMI), and n-3/n-6 fatty acid ratios in plasma were important predictors for high blood levels of all the measured POPs with very high total R square values.This study has been reported and discussed in greater detail elsewhere (Deutch et al 2003)
The same assumptions and multiple linear regression analuses were applied to the larger population sample from the East Coast. Among the 182 men and women from the East Coast a similar effect on POP accumulation of smoking and cotinine was found, however the significance levels were not as strong, this was mainly caused by a very small ratio of non-smokers making this groups too small for good statistical power.
Regarding the above reported negative association between plasma POP concentrations and BMI, this effect was only found among men and not among women and therfor it is not a pure volume effect.
The associations between various diet markers, lifestyle factors, and contaminant levels on the East Coast are illustrated by the figures 4.3.9, 4.3.11, 4.3.12 below.

Figure 4.3.9. Plasma PCB (microgram/kg lipid) shown in a 3-dimensional plot as a function of plasma fatty acids (C22:5.3 medians and C20:5.3 tertiles) to illustrate the strong association with C22:5.3 from large marine mammals.
East Greenland, n=188.

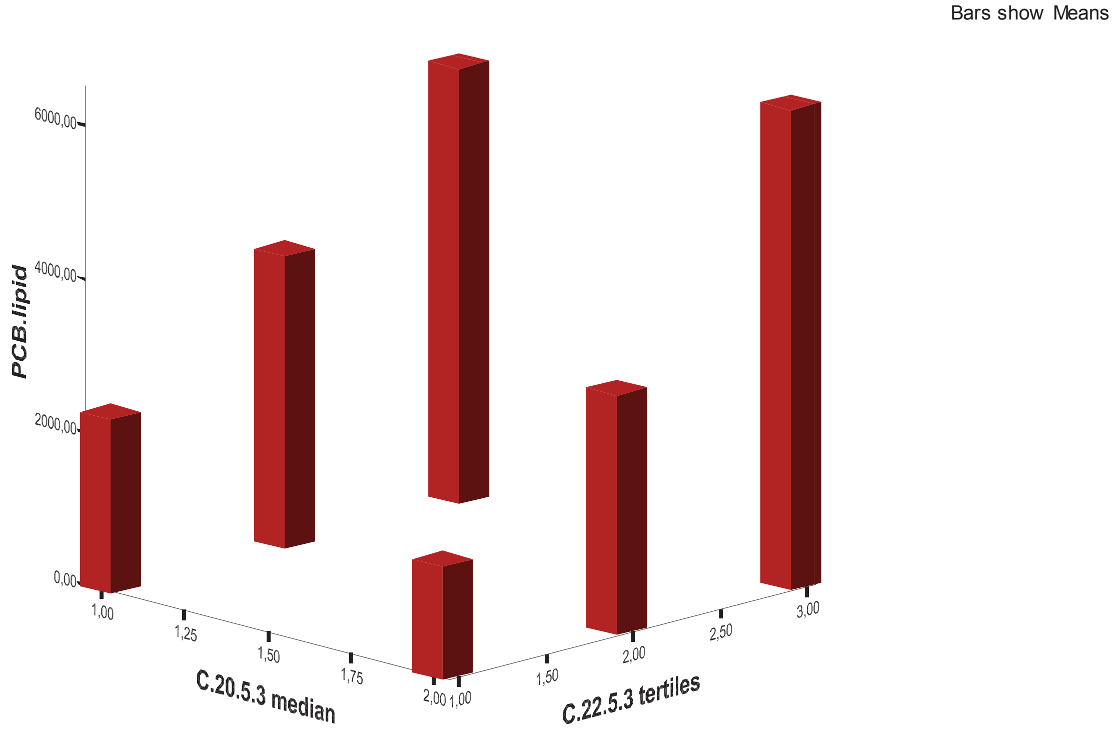


Figure 4.3.10. Fatty acid ratios in blubber/fat of marine animals, placed according to their appproximate placement in the food chain, trophic level.

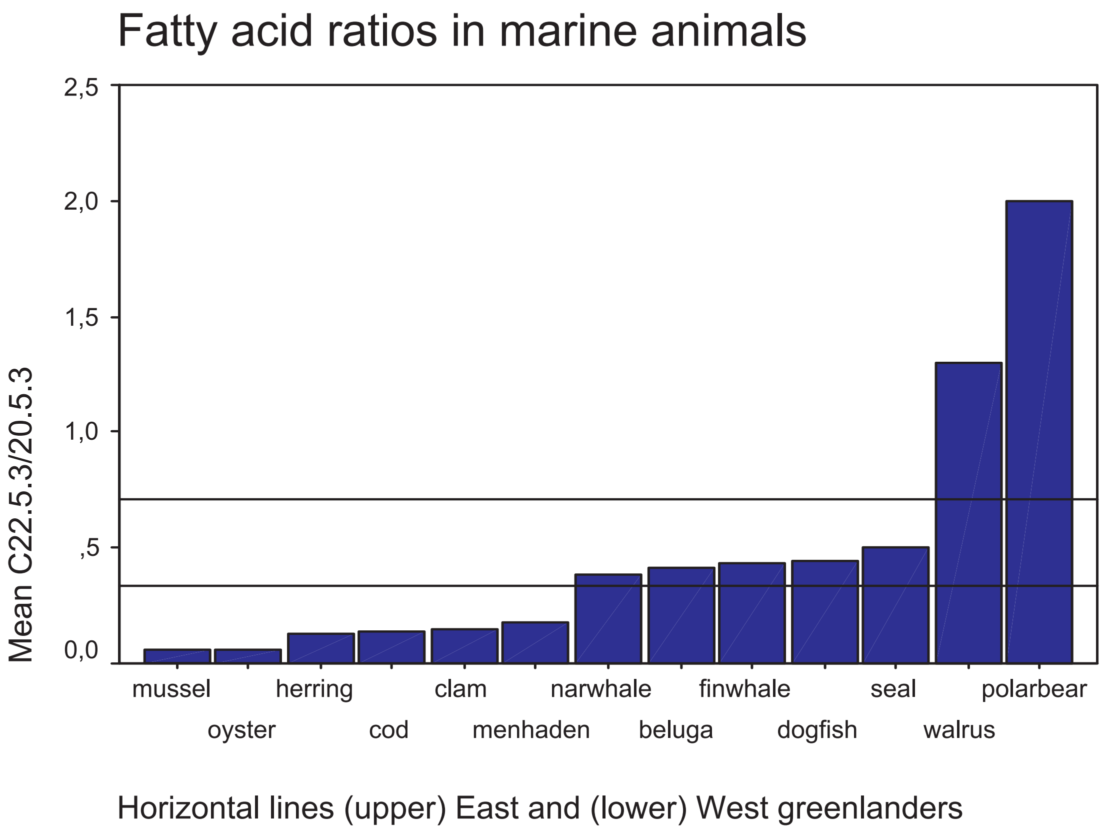


Figure 4.3.11. Plasma PCB-aroclor1260 , East Greenland, 2000-2001, (n=188) versus low, medium and high reported mean seal intake (15, 30, and 90 g/day) and present smoking status.

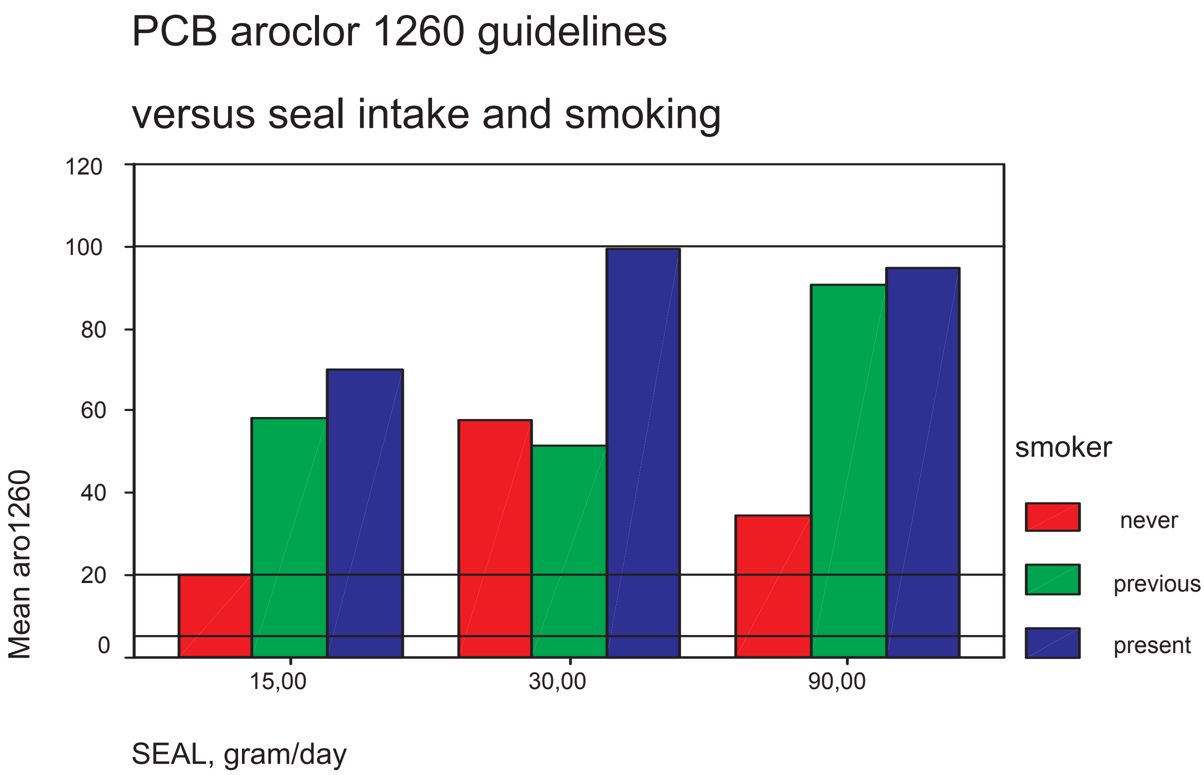


Figure 4.3.12. Plasma PCB-aroclor1260 , East Greenland, 2000-2001, (n=188) versus low, medium and high reported mean polar bear intake (10, 20, and 100 g/day) and present smoking status.

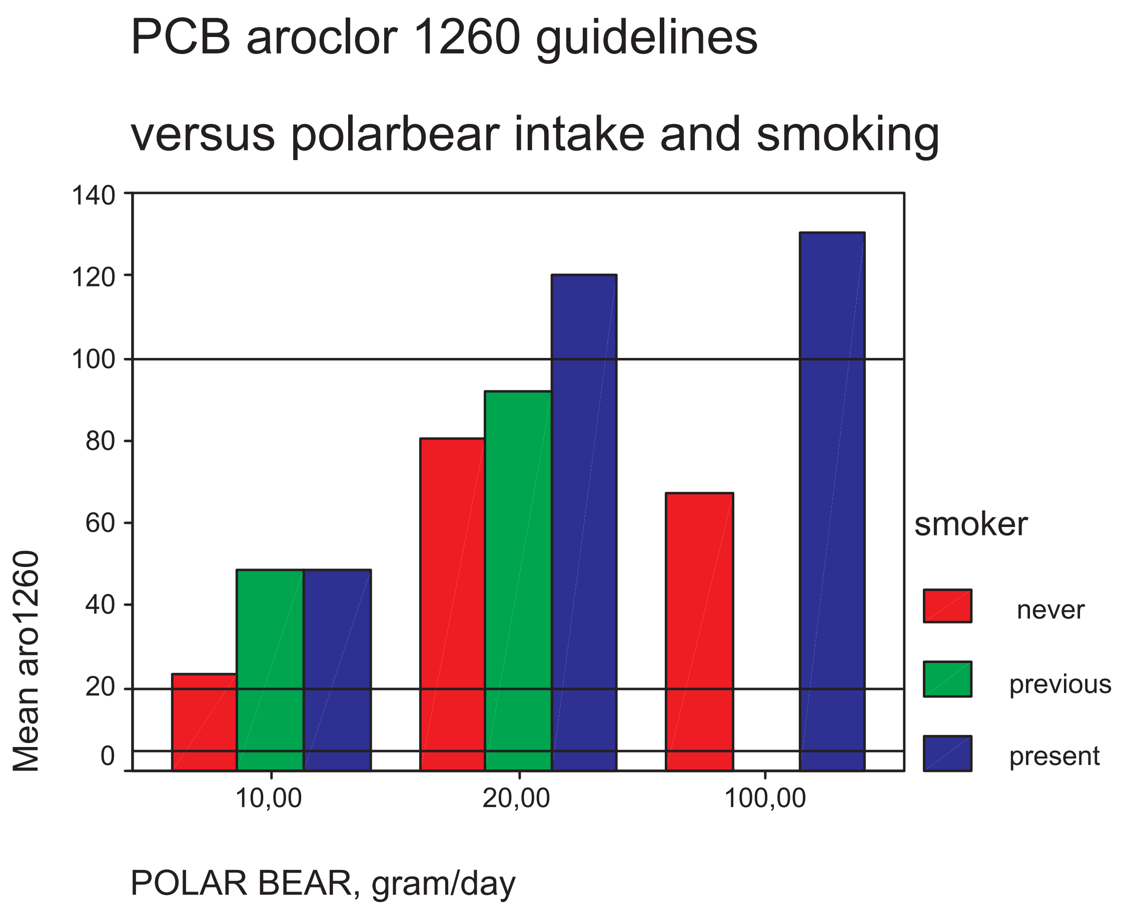


Table 4.3.26. Multiple linear regression analysis of parameters associated with high plasma POP levels in 48 Inuit hunters from Uummanaq, Greenland. Dependent variable: Triglyceride adjusted plasma POPs (natural logarithm) versus the independent variables cotinine, (ng/l), age, BMI and phospholipid-n-3/n-6, (full model, FM) and for reduced models (RM) with BMI or cotinine removed. Standardized correlation coefficients and p-values are shown (Deutch et al 2002).

	R-square	Cotinine	Age	BMI	n-3/n-6
beta HCH	0,53 FM	0,25 p=0,047	0,31 0,01	-0,28 0,02	0,49 0,000
	0,46 RM	0,38 0,002	0,33 0,01		0,47 0,000
	0,45 RM		0,24 0,04	-0,40 0,001	0,48 0,000
chlordanes	0,59 FM	0,25 0,038	0,32 0,005	-0,31 0,007	0,52 0,000
	0,51 RM	0,39 0,001	0,35 0,006		0,49 0,000
	0,51 RM		0,26 0,07	-0,43 0,000	0,51 0,000
DDE	0,52 FM	0,39 0,003	0,34 0,006	-0,20 0,099	0,43 0,000
	0,49 RM	0,49 0,000	0,36 0,005		0,41 0,001
	0,38 RM		0,23 0,071	0,38 0,003	0,43 0,001
Hexachlorobenzene	0,60 FM	0,30 0,012	0,34 0,003	-0,27 0,015	0,53 0,000
	0,54 RM	0,42 0,000	0,36 0,000		0,50 0,000
	0,51 RM		0,25 0,026	-0,41 0,000	0,52 0,000
Mirex	0,63 FM	0,26 0,024	0,38 0,001	-0,42 0,000	0,43 0,000
	0,49 RM	0,45 0,000	0,41 0,002		0,40 0,001
	0,56 RM		0,31 0,005	-0,55 0,000	0,43 0,000
sum PCB	0,58 FM	0,35 0,003	0,42 0,000	-0,29 0,008	0,45 0,000
	0,54 RM	0,48 0,000	0,44 0,000		0,42 0,000
	0,51 RM		0,32 0,007	-0,45 0,000	0,45 0,000
Toxaphenes	0,50 FM	0,26 0,047	0,27 0,03	-0,18 0,13	0,54 0,000
	0,48 RM	0,34 0,005	0,28 0,03		0,52 0,000
	0,42 RM		0,20 0,111	-0,31 0,011	0,53 0,000
DDE:DDT	0,33 FM	0,37 0,015	0,45 0,003	-0,22 0,12	0,03 0,82
	0,29 RM	0,47 0,001	0,46 0,002		0,03 0,93
	0,23 RM		0,33 0,024	-0,37 0,008	0,06 0,67

4.3.7 Dietary exposure from local food items.

In chapter 3, “Contaminants in Subsistence animals in Greenland”, Johansen et al (2003) have presented contaminant data concerning both heavy metals and organic pollutants measured in a number of local animal and plant products which have been collected along the South western coast of Greenland.
The list covers several species of seabirds, a few species of landbirds, 5-6 species of marine fishes and two fresh water species. From larger animals it includes the 3 most commonly eaten species of seals and whales in addition to all the mammalian terrestrial species. From almost all the species samples have been analyzed from both meat, liver, kidney and fatty tissue especially blubber. The list (table 3.4) mainly contains data regarding Cd and Hg and only very few data on Pb, the organochlorines are listed in tables 3.5and 3.6. The metal analyses have been performed for a slightly larger number of species than the analyses of organic contaminants. In this report data for Polar bear only contains heavy metals no organochlorines.
So although the list is not yet complete it covers a substantial and representative selection of locally eaten Greenland food items in South Western Greenland.Thus in principle it is possible to use these data for at least a provisional estimation of the human dietary exposure form local food to the contaminants concerned. Pars (2000) have made an extensive dietary survey in South Western Greenland (N=410, 180 men and 230 women) using several parallel dietary methods to probe the issue. From a semi quantitative food frequency questionnaire she has obtained mean intakes in gram per day for a large number of local food items.

These two above mentioned data sets have been used to calculate the relative exposure contributions from the various local food items as well as the total human dietary exposure to heavy metals, (Cd and Hg) and organochlorines: BetaHCH, Chlordanes, DDT, Hexchlorobenzene, and PCB as well as the intake of selenium. In the chapter 3, Johansen et al (2003) present PCB both as sum of PCB s which includes 104 congeners and as sum of 10 congeners, which has been used in the following calculation because this value closely overlaps with the 14 congeners used in the Human Health studies. Both for mercury and selenium special calculations have been performed, not only for the total intake but for the bioavailable intake,which is a more realistic measure of the possible toxicological effect and for comparison with “Provisional Tolerable Weekly Intake”, PTWI. However, it should be emphasized that the local food is only about 25 % of the total diet and also the imported food contains a certain level of contaminants.

The calculations are based upon the following assumptions: Daily mean intakes (gram) are based on men from all age groups, the total bird intake (20 g) is evenly distributed on the four types of seabirds with available contaminant data. The total fish intake (60g meat and 7 g liver) is distributed proportionally on the most commonly eaten species namely Atlantic cod and Greenland halibut. The whale intake (15 g meat, 6 g blubber, 1 g liver, 0.3 g kidney and 21 g muktuk) is evenly distributed on the three included species, Minke whale, Beluga, and Narwhal. Regarding seal intake (73 g meat, 30 g blubber, 11g liver and 9 g kidney) the dietary survey does not discriminate among different species. Thus Ring seal, which has the most complete contaminant data has been used, and together with Harp seals it is the most commonly eaten seal in Greenland (Piniarneq 2001 in Hansen 2001). For some species the dietary survey distinguishes between spring and fall

consumption, if so, the calculation is based upon an average between the seasons.
No dietary survey results are presented for marine invertebrates, Caribou, and Polar bear, thus these are not included in the calculations. Polar bear is very rarely consumed on the West Coast except in the far North.

4.3.7.1 Metals
For the calculation of the relative and total bioavailable intakes of mercury and selenium, it has been assumed that in liver and kidney about 90% of the mercury is selenium bound on a one-to-one molar basis and therefor unavailable, according to Egeland et al (1998). Regarding comparison with Provisional tolerable Weekly Intakes, PTWI it has been assumed that the average person in the dietary study weighs 60 kg., which is probable an underestimation of about 15 %.

Table 4.3.27 Provisional calculated weekly intakes of the heavy metals Cd, Hg and of Se compared to guideline values for Provisional Tolerable Weekly Intakes, PTWI (micrograms per 60 kg person per week.

	Cadmium	Mercury	Selenium
PTWI,	420 (WHO)	300 total(WHO) 200 methyl	2800 (Yang 1989)
US-EPA (0.1 microgram 1kg/day)		42 methyl	
Estimated total intake	5870	557	1900
Estimated available intake	2500 (conservative estimate, see text)	290	1650

The estimated intake of Cadmium seems extremely high and may not be realistic, The relative contribution from various food organs is shown below in a Pie graph, figure 4.3.15, about 75 % (4466 microgram) is ascribed to seal kidney. which has a listed Cd content of 70.4 microgam per gram (ring seal) and estimated intake of once a month or 9 grams a day (Pars 2000). The Cd concentration in Ring seal kidney is somewhat but not unrealistically higher than harp seal (21 microgram) and hooded seal (47 microgram). But the estimated weight intake of seal kidney may be an overestimation. However even if both the concentration of Cd and the intake of kidney were reduced to 50%, the contribution from kidney would be 1100 and the total estimated Cd intake would be approximately 2500 microgram per week, still way above the PTWI. In a previous publication Johansen et al (2000) estimated the weekly Cd intake to be 1004 microgram but Seal kidney was not included. How much of the Cd intake is taken up is another question but it is assumed that it is very low and depends on the dietary source and body iron stores and serum-ferritin. Cd-uptake is negatively correlated with serum ferritin (Vahter et al 1996).The iron status and serum ferritin is high in Greenland and positively correlated with intake of traditional food (Milman et al 2001).

Blood levels of cadmium are usually higher among Inuit populations than among caucasians (AMAP 1998, Human Health Chapter 12) typically north Europeans have mean Cd blood levels < 0.5 microgram/litre whereas Inuit populations have Cd blood levels >1.2, see also this chapter 4.3.3.3.1. However, the mean blood Cd levels are not significantly correlated to intake of traditional food or plasma n-3/n-6 but highly significantly correlated to smoking (r =0.37 p<0.001***) which may account for as much as 60 % of the total burden.. Thus the high Cd levels in the traditional food items appear not to be a very important contributor to human Cd levels in Greenland (Hansen et al 1990 , Deutch et al 2003)

The the distribution of total and bioavailable mercury and selenium intakes are illustrated below in pie graphs (figures 4.3.13-4.3.16)
The relative and total estimated intakes of mercury and Selenium (table 4.3.27) seem more realistic and the total intakes are below or close to the PTWI, (Yang et al 1989). However these numbers are about 50% lower than and not in particularly good agreement with a previous publication by Johansen et al (2000) which were calculated in the same way but included fewer food items (meat and liver) in the study. It only demonstrates the great difficulties in making exposure estimates from calculated intakes.

The Pies show that the main contributors to bioavailable mercury intake are seal and whale meat, whereas the contribution from internal organs liver and kidney are of much less importance. The absolutely dominating contributor to bioavailable Se intake is not surprisingly muktuk, but other good sources are organs and meat of all marine animals.

4.3.7.2 Organochlorines
Below similar calculations are performed for organochlrines using the values presented by Johansen et al in tables 3.5 and 3.6

Table 4.3.28 Provisional calculated intakes of various POPs compared to guideline values. The calculations are based upon (n=180) from a dietary study by Pars(2000) and animal contaminant data by (Johansen et al 2003)

	Chlordanes	DDT sum	betaHCH	Hexachloro-Benzene	PCB, sum of 10 congeners
Microgram per day	15.174	27.848	4.575	2.694	20.787
Microgram/ kg/day	0.25	0.46	0.08	0.045	0.35
Canadian TDI microg/kg/day	0.05	20	0.3	0.27	1(aroclor) 0.3 sum of 14 congeners

In the animal studies the authors report PCB levels as sum of 10 congeners, among these ten, nine are included in the 14 congeners which are usually used in the human health studies. And since these nine are those that occur in the highest ratios, the sum of PCB-10 only deviates slightly from the sum of PCB-14.
The table 4.3.28 above shows that provisional calculated intakes of PCB and chlordanes exceed the Canadian TDI's. The DDT and hexaclorobenzene guidelines are not close to TDI values, but beta HCH is 25% of TDI which means that some fraction of the study group exceeds the TDI.
Pie graphs are shown below to illustrate the relative contribution by food items to POP intakes (PCB and DDT) it is obvious the seal blubber followed by whale blubber are the main contributors to the intake of lipophilic organic contaminants, Figures 4.3.17 and 4.3.18.

These calculations are based upon animal contaminant levels and human diets on the in the South West of Greenland, and as yet we do not have comprehensive animal data available to perform similar calculations for East

and North Greenland. However, provisional data show that the PCB content in seals from East Greenland (Ittoqqortoormiit) is more than double that in West Greenland, and that DDT content is more than 50% higher.
The results from dietary surveys from East Greenland 2000 are shown in tables 4.17-4.20 and figures 4.3.2-4.3.8. These surveys show that polar bear is consumed in both Ittoqqortoormiit (30 gram/day) and Tasiilaq (10 gram/day). Contaminant levels for Svalbard polar bears (AMAP 1998) indicate that just one gram of polar bear fat a day (15.000-31.000 microgram PCB/gram) would increase the PCB intake by more than 75% compared to the table above (4.28). It is therefor evident that on the East coast of Greenland the consumption guidelines for PCB are strongly exceeded.

Dietary surveys are very difficult to conduct and especially difficult regarding accurate answers about portion sizes. It is therefor relevant to validate intake estimates by other methods or sources. According to the official catch statistics (Piniarneq 2001 in Hansen 2001), the following meat weights are available to the Greenland population of 55000 persons.
(Among these 13.000 Danes probably do not eat much seal and are excluded from the calculations and it is assumed that the 28.000 sleighdogs eat the waste, bones, skin offal, and some blubber)

Table 4.3.29. Official catch statistics and meat availability in Greenland 1998 (Piniarneq 2001, Hansen 2001). Reported intakes in parenthesis. (Pars 2000)

Species	Total annual catch in 1000 kg	Available catch per Greenlander/year	Available meat per Greenlander/day= 40% of catch
Ring seal	4100		
Harp seal	5800		
Hooded seal	1270		
other seals	500		
seals, total	11670	277 kg	304 g (120 g)
Minke whale	1400		
Beluga	900		
Narwhale	1200		
whale, total	3500	83 kg	92 g (42 g)
polar bear	200 minimum	30 kg *	34 g* (22 g)**
Danish, imported meat, beef, pork, lam, poultry	3400	59 kg	162 g (114 g)**

* Only eaten in four districts Ittoqqortoormiit, Tasiilaq, Nanortalik and Qaanaq areas, about 6500 people (Greenland Statistical Yearbook 2000-2001).** Mean reported intake on the East Coast (This report, table 4.3.20)

The above table shows the “available” seal meat per Greenlander per day to be over 300 grams. This shows that the estimates of seal and whale intakes used in the calculations above, a total of 120g seal products, and 42 g whale products per day, are not over estimations, probably the opposite. Therefor the estimated exposure from contaminants can considered to be conservative.

And the real situation may be much more serious. The numbers also indicate that the natural resources are plentiful and a considerable amount of meat may be wasted.

Although provisional all the calculations above point to the same conclusion that the contaminant contents of mercury, cadmium, PCB and chlordanes in the major local food items and the total diets are above guideline levels. These results are consistent with the guideline exceedances for human blood levels of mercury and PCB aroclor presented in table 4.3.17, which show exceedances in all parts of Greenland but at a much higher level at the East coast that at the West coast.
The exceeding percentages are also high in Uummanaq, North West Greenland.

Figure 4.3.13. Relative contribution of local food items to dietary exposure from total mercury. Southwest Greenland calculated from dietary survey (Pars 2000) and animal contaminant data (Johansen et al 2003, previous chapter 3)

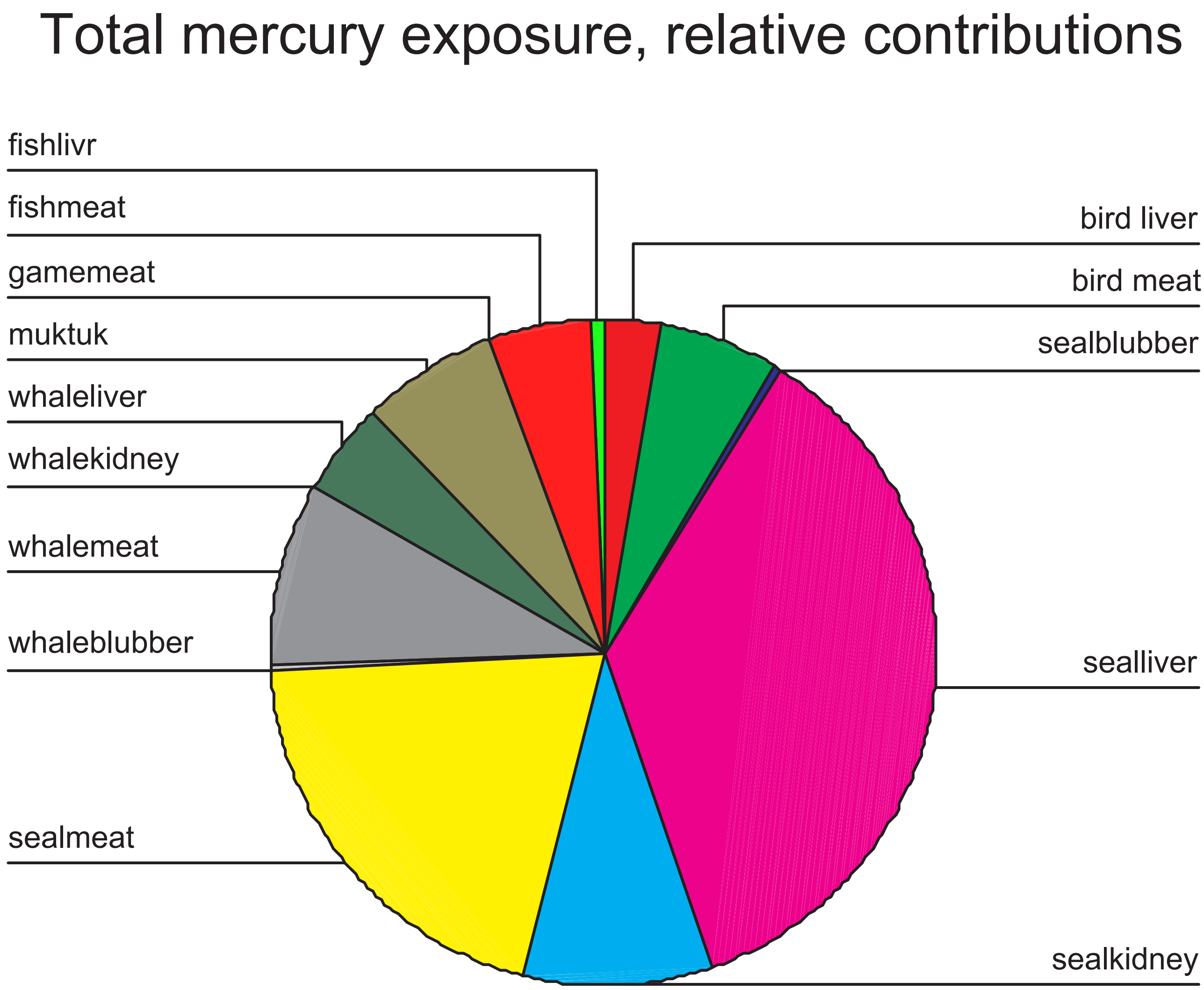


Figure 4.3.14. Relative contribution of local food items to dietary exposure from bioavailable mercury. Southwest Greenland calculated from dietary survey (Pars 2000) and animal contaminant data (Johansen et al 2003, previous chapter 3)

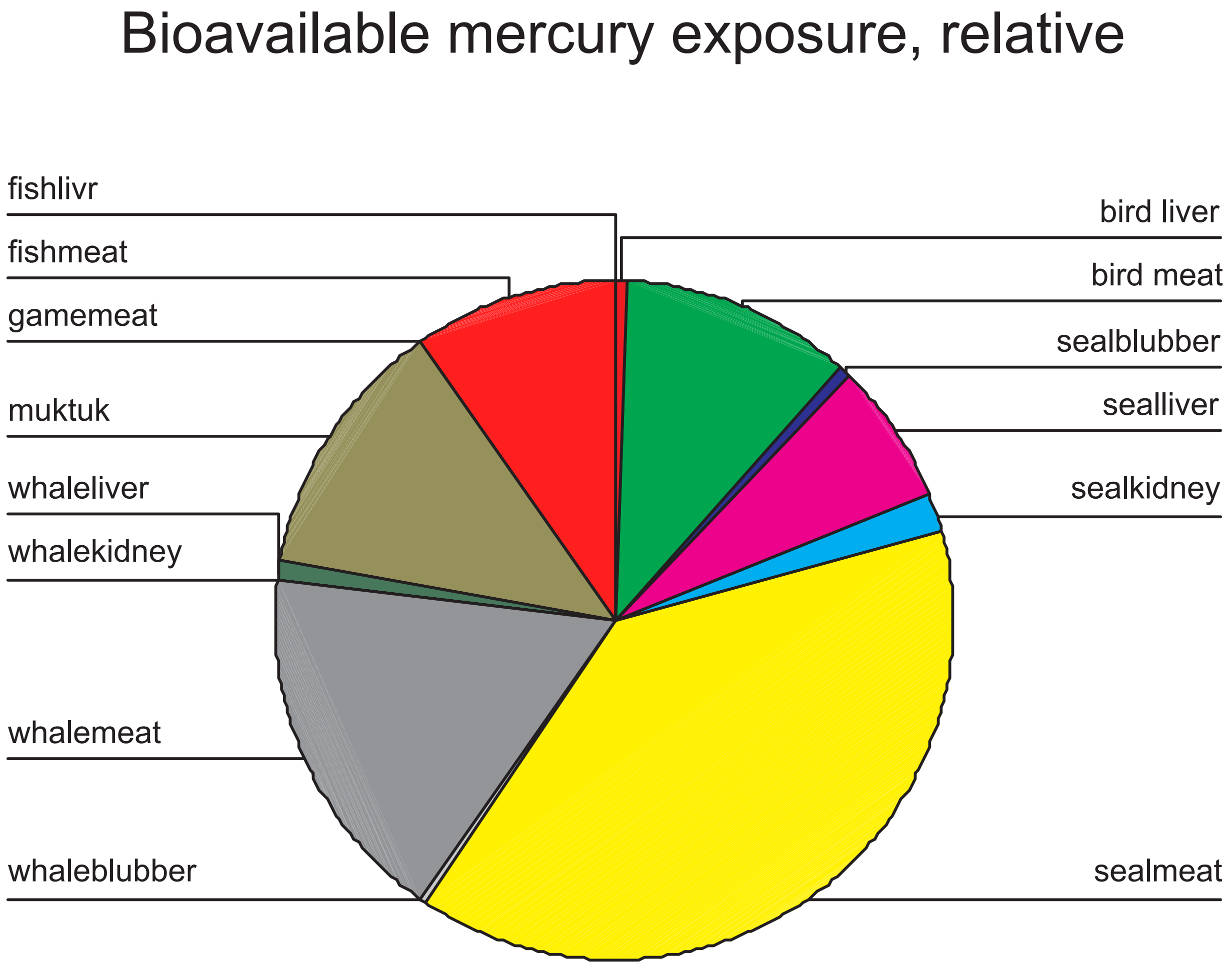


Figure 4.3.15. Relative contribution of local food items to dietary exposure from cadmium, Southwest Greenland calculated from dietary survey (Pars 2000) and animal contaminant data (Johansen et al 2003, chapter 3)

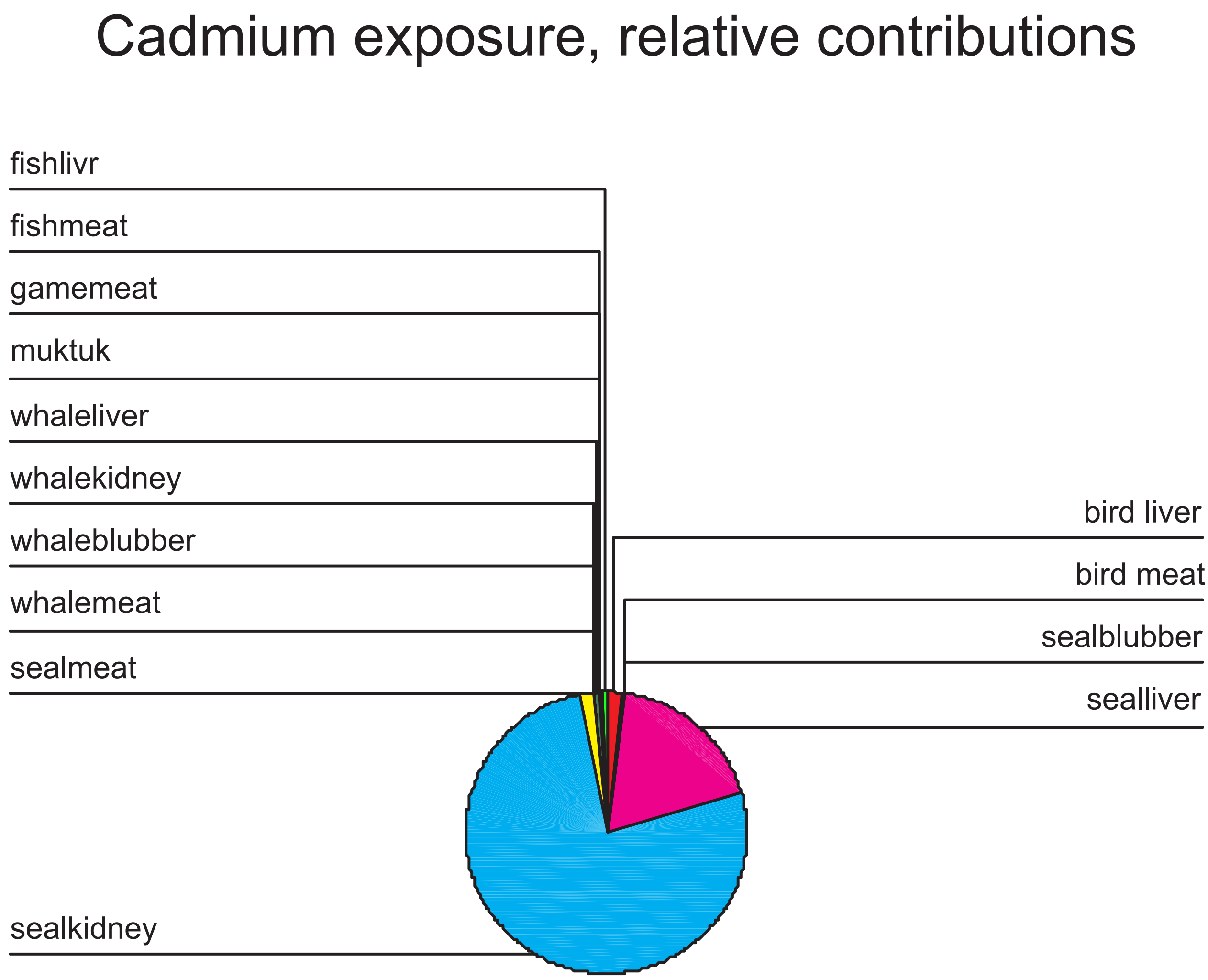


Figure 4.3.16. Relative contribution of local food items to dietary intake of bioavailable selenium Southwest Greenland calculated from dietary survey (Pars 2000) and animal contaminant data (Johansen et al 2003, chapter 3)

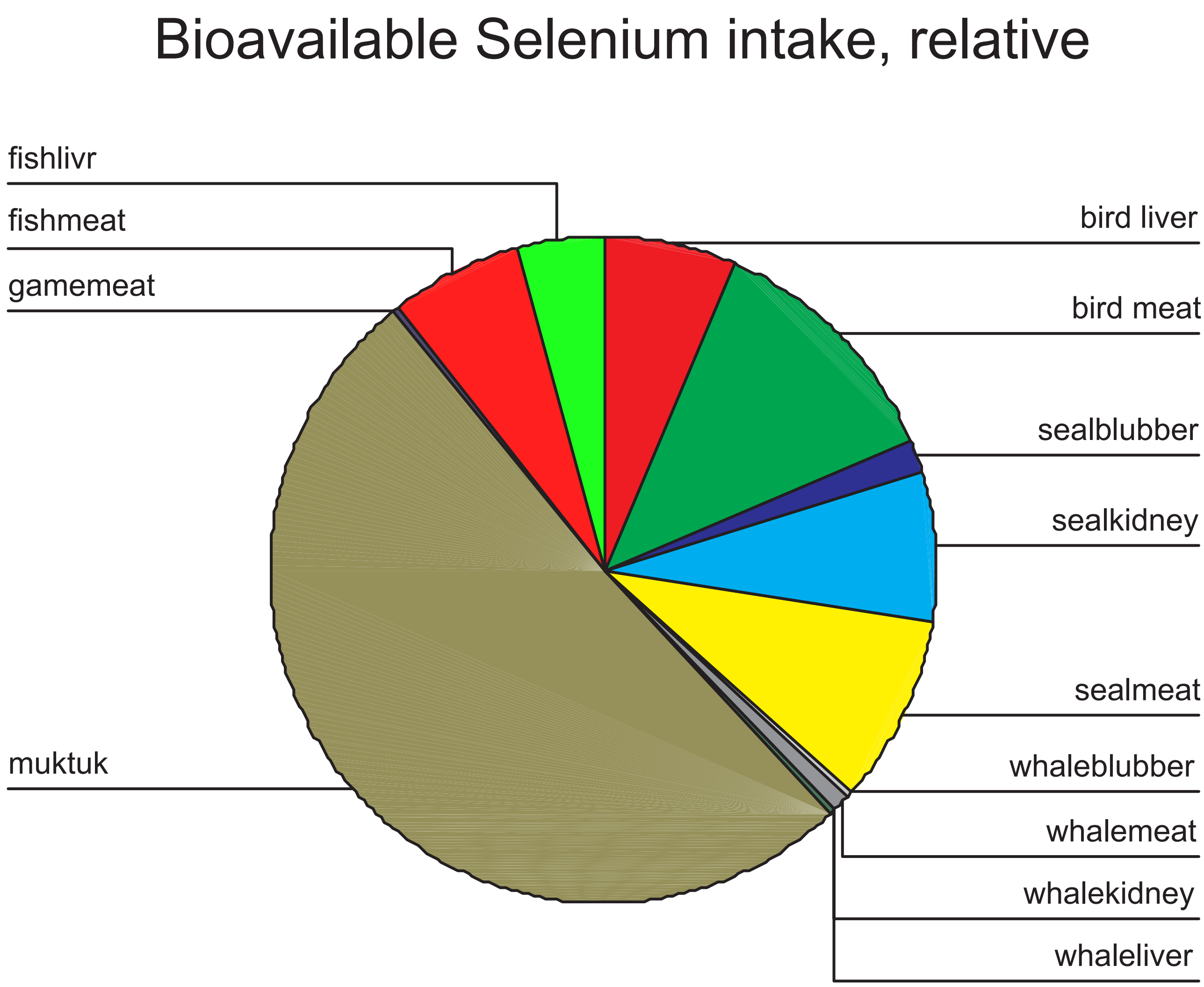


Figure 4.3.17. Relative contribution of local food items to dietary exposure from DDT. Southwest Greenland calculated from dietary survey (Pars 2000) and animal contaminant data (Johansen et al 2003, chapter 3)

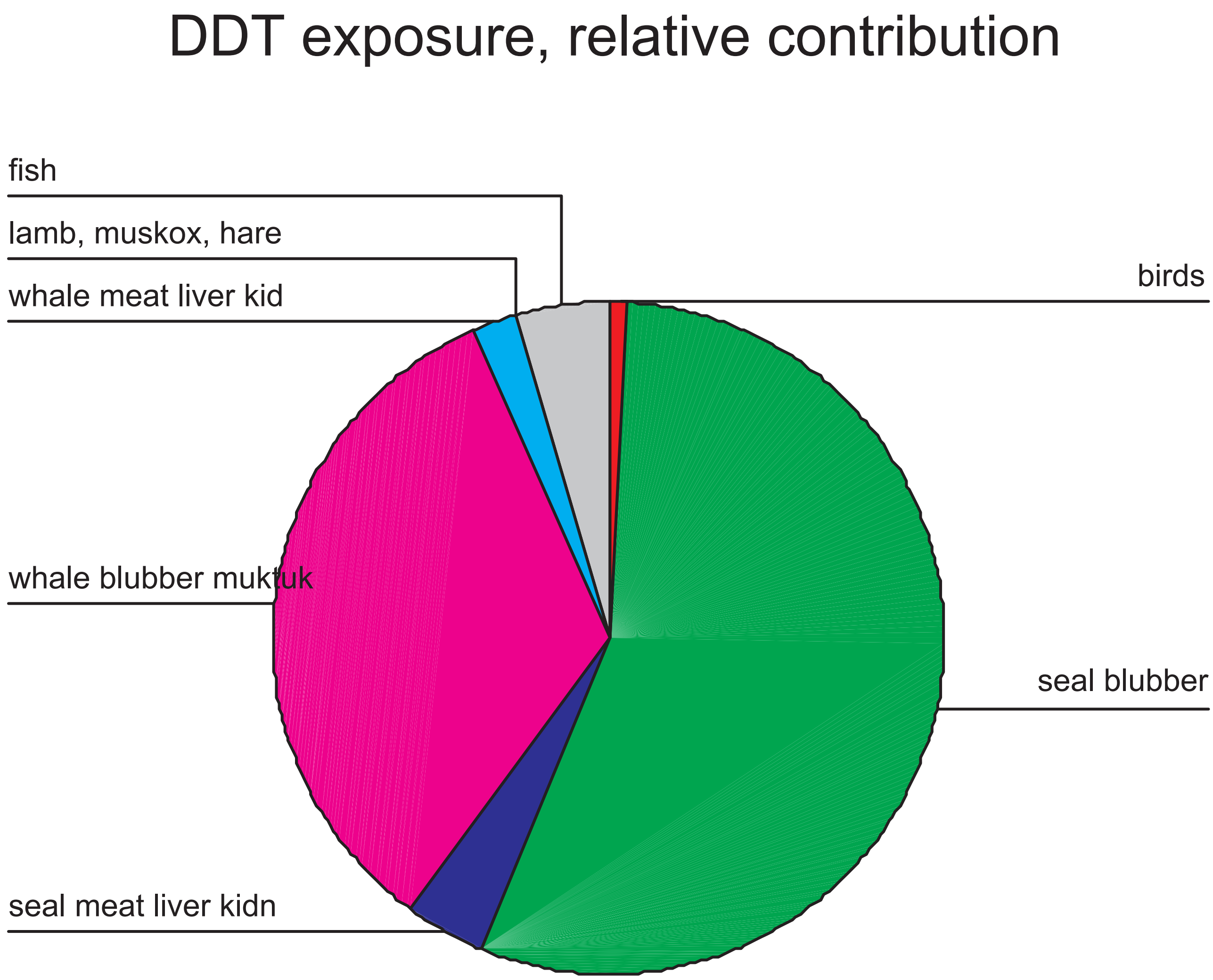
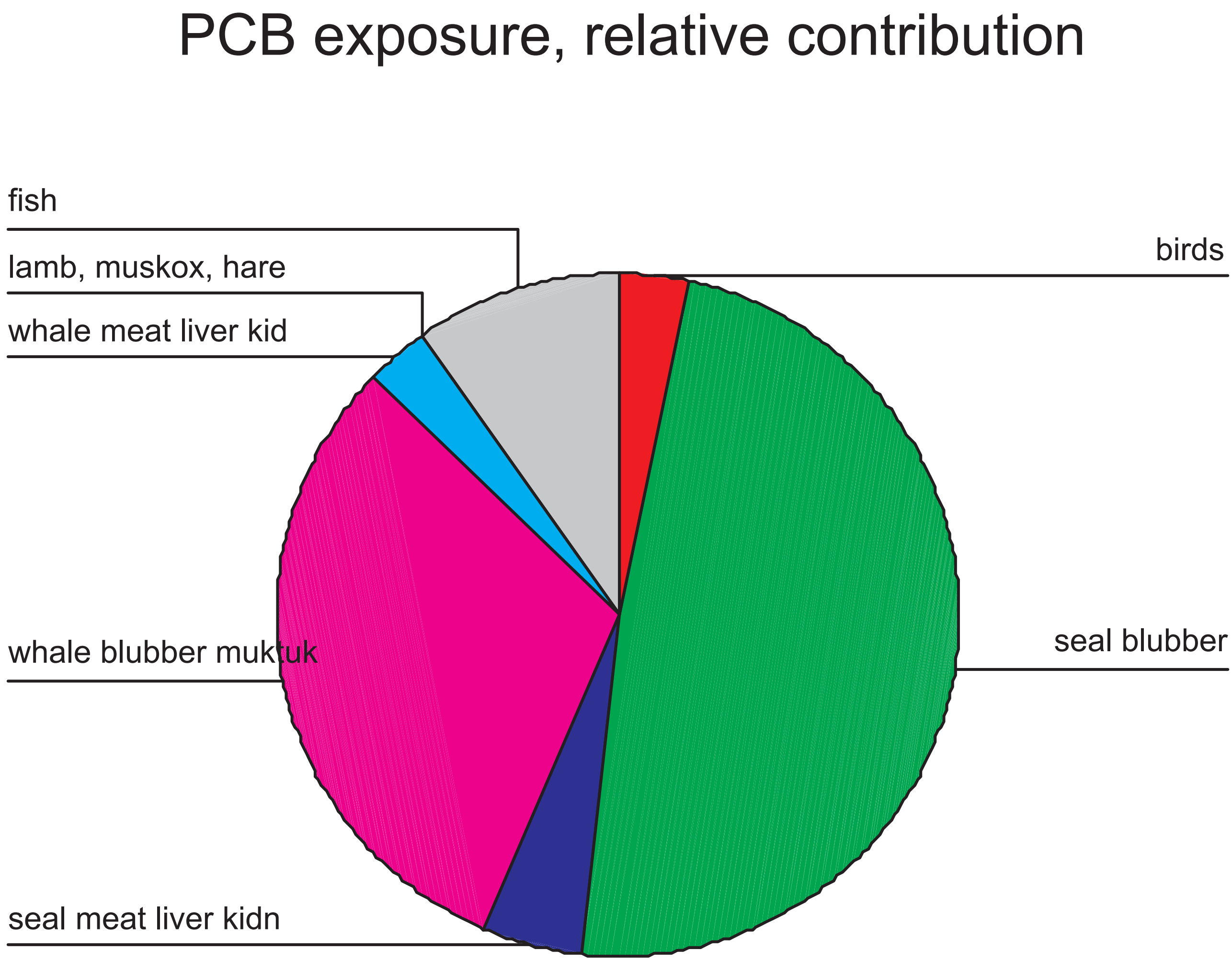


Figure 4.3.18. Relative contribution of local food items to dietary exposure from PCB Southwest Greenland calculated from dietary survey (Pars 2000) and animal contaminant data (Johansen et al 2003, chapter 3)



4.4 Summary

The AMAP Human Health programme in Greenland has monitored persistent organic pollutants and heavy -metal contaminants as blood levels among several population groups in Greenland during 1997-2001. The general protocol for the sample collection and analyses are in accordance with the program agreed upon by the international Human Health Expert Group in 1992 and later revisions. The programme has been approved by the Ethic Committee for Scientific Studies in Greenland.

The first phase of this programme was carried out from 1994-96. During the interim phase in 1997 heavy metals were not measured

The primary target group were pregnant women and infants, from 1999 these were supplemented with men and non-pregnant women of fertile age to obtain larger and more representative population samples.
In addition to blood contaminants, dietary markers (Selenium and fatty acids) were also determined and questionnaires supplied information regarding demographic, anthropometric and lifestyle factors (smoking and dietary habits).

4.4.1 Heavy metals

In both pregnant women, non-pregnant women and men the same general picture was drawn regarding blood levels of total mercury (Hg), cadmium (Cd), and lead (Pb). The lowest geometric mean blood levels of mercury were found in Nuuk (4.5 microgram/litre) slightly higher levels were recorded in Disco Bay (12.5 microgram/litre) and the East Coast (10.5-26.0 microgram/litre) and the highest in Uummanaq (52.0 microgram/litre). These mean blood levels were also reflected in the number of samples which exceeded the US-EPA guidelines for blood mercury of 4.4 microgram/litre. Among pregnant women in Nuuk 44% exceeded the guideline and in all other population groups 80-100% exceeded the guideline value. Also the 20 microgram/litre, WHO guideline value was exceeded by more than 25% in all groups (except among 8 pregnant women from Ittoqqortoormiit).

Mean cadmium and lead blood levels were only moderately high. The Cd levels ranged from 0.66 microgram/litre in Tasiilaq to 1.65 microgram/litre among men in Ittoqqortoormiit. The higher Cd levels reflected the smoking levels among the subgroups. The Cd levels among smokers in Uummanaq was found to be double as high as among non-smokers.
The Pb levels ranged from 23.8 microgram/litre among pregnant women in Tasiilaq to 70.7 micrograms/litre among men in Ittoqqortoormiit, again the level of smoking may have influenced the level. The Pb guideline value of 100 microgram/litre was exceeded only by low percentages of blood samples among these the highest were 14 % in Uummanaq and 10% in Ittoqqortoormiit.

4.4.2 Organochlorines

The geographical pattern of blood levels of persistent organic pollutants was slightly different from the pattern of heavy metals. The highest general blood concentrations of POPs were found in Ittoqqortoormiit especially among men. This was first shown in the geographical pilot study collected in 1997 and the levels were confirmed by measurements among larger population samples in 1999-2000.

Hexachlorophene, betaHCH and Toxaphenes were relatively evenly distributed geographically but chlordanes , DDTs and particularly PCBs were at very high levels in Ittoqqortoormiit, in fact the PCB levels were about 3-4 times higher than in the other locations, and should be considered the highest measured among Arctic populations (AMAP International report, Human Health 2002)

The mean blood levels of PCBs were also consistent with the number of blood samples exceeding the Canadian guideline values for PCB-Aroclor1260.
In all locations except Disco Bay and Nuuk (1999) 93-100% of blood samples exceeded the 5 microgram/litre "Level of Concern" for pregnant (and fertile) women and among men in Ittoqqortoormiit 60% of samples (1997) and 43%(2000) exceeded the 100 microgram/litre guideline "Level of Action"

4.4.3 Dietary Markers

4.4.3.1 Fatty acids
The ratio of plasma fatty acids (n-3/n-6) indicates the relative consumption of traditional and imported food of which a high n-3/n-6 ratio indicates a high intake of traditional food (of marine origin). The ratio was highest in Nanortalik (0.66) and Uummanaq (0.60) and lowest in Nuuk (0.21). However it was also relatively low among men in Ittoqqortoormiit (0.27) year 2000.

4.4.3.2 Selenium
Whole blood selenium was also highest in Uummanaq namely 354 microgram/litre and lowest in Nuuk (140 microgram/litre). A high Selenium level indicates a high intake of meat from marine animals and in particular of muktuk.

4.4.4 Dietary surveys

A dietary survey by semi quantitative food frequency questionnaire performed among 190 persons on the East Coast showed that the relative intake (weight) of traditional food was 25-30%, and slightly higher in the North, Ittoqqortoormiit, than in the South, Tasiilaq. The food was more versatile in Tasiilaq both concerning composition of traditional food which contained more fish and of imported food, which contained more fruit and vegetables. The mean value of the total intake of traditional food was about the same as found in a previous study on the West Coast (Pars 2000). Thus the total intake of traditional food can therefor not be considered different between East and West Greenland although there were various differences in composition. One of the more important differences was that polar bear is consumed frequently on the East coast but is not common on the West Coast except in the north.

4.4.5 Dietary exposure from contaminants

Calculations using dietary survey data and animal contaminant data showed that seal blubber was the major contributor and whale blubber the second contributor of all the lipophilic organic pollutants, in reality all the pesticides and PCBs measured in the programme. Using information on the relative bioavailability of metals in different anaimal tissues it was furthermore calculated that seal-(and whale meat) were the main contributors of methyl mercury and that seal kidney was the predominant contributor of cadmium. Comprehensive contaminant data were not available from the east coast but the higher levels of PCB and DDT in ring seals (chapter 3) were consistent with the higher blood levels found in human beings.

4.4.6 Predictors of high contaminant levels

Multiple linear regression analyses of results from Disko Bay 1994-97, the geographical survey 1997 , Uummanaq 1999, and the latest results from the East Coast 2000 showed the main predictors of high blood levels of persistent organic pollutants to be:
age, smoking (cotinine), and high n-3/n-6 ratio indicating high intake of traditional seafood, also district was a major determinant.
Whereas gender itself was not a predictor , lifestyles, particularly smoking, but also traditional food intake varied between the two sexes and therefor exposure was sometimes higher among men than among women

4.4.7 Time trends.

In Ummanaq the mean blood level of mercury increased significantly between 1979 and 1999, whereas the mean blood levels of Pb had dropped significantly among men in Uummanaq since1979 and among men and women in Tasiilaq since 1981.
Previous measurements of organic pollutants were not available and the time period within the AMAP study was too short and the material insufficient to detect any possible time related changes in organic pollutant levels.

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5 The Faroe Islands. Sociocultural environment, lifestyle, health and contaminant exposure

By Pál Weihe, Maria Dam and Árni Olafsson

5.1 Settlement Sructure

The Faroe Islands are situated in the North Atlantic 430 km south-east of Iceland, 600 km west of Norway and a good 300 km north-west of Scotland, in the same time zone as Britain. The distance to Copenhagen, the capital of Denmark, with which the Faroe Islands have constitutional links, is about 1,300 km.

Of the 18 islands, 17 are inhabited. The total area is 1,399 sq.km, and the largest island is Streymoy (373.5 sq.km) with the capital, Tórshavn. The distance north-south is 113 km and east-west 75 km. The land averages 300 m above sea level. The highest point is 882 m.

The islands are of volcanic origin and are part of the North Atlantic basalt region extending from Ireland to Greenland. The Ice Age glaciers formed an archipelago of mountains, deep valleys and narrow fjords and straits.

The climate is oceanic: humid, changeable and windy. In Tórshavn the temperature in the coldest month averages 3 C and in the warmest 11 C. The shortest day is 5 hours and the longest 19 1/2 hours.

There are no woods, but plenty of grassland. A mere 6% of the land is under cultivation while the rest is reserved for the grazing of 70,000 sheep and some cattle and horses. Birds are plentiful, especially sea birds, but other animal life is sparse. In the seas around the Faroe Islands the meeting of the warm Gulf Stream and cold northern currents rich in nutritional matter, results in rather stable ocean temperatures, between 5 and 10 C, favouring fish and animal life.

The population on 31 December 2001 was 46,996 after a tenfold increase in the preceding two centuries. The birth rate is high by European standards, 1.5% in 2000. With a mortality rate of 0.7% the natural increase in population is 0.8%. A modest net emigration of earlier decades was replaced by a certain net immigration in the 1970´ies and 1980´ies. The early nineties saw a massive emigration, the population 1990-95 declining by 7.2%. Since 1996, however, there has been a modest net immigration.

The pattern of settlement is characterised by a large number of densely populated communities differing greatly in size. There are about 100 villages and towns, of which the largest is Tórshavn with its 16,000 inhabitants including the suburbs. Second largest is Klaksvík with 4,600 inhabitants.

Since 1948 the Faroe Islands have had a special autonomy status within the Kingdom of Denmark, viz home rule, seeking a balance between, on the one hand, the national uniqueness of the Faroe Islands and, on the other, maintenance of the union with Denmark.

The Faroese Home Rule authorities have the legal and administrative competence in those areas, which have been taken over as special Faroese affairs. The Faroe Islands have their own flag, bank notes and stamps and also a special passport.

The economy of the Faroe Islands is overwhelmingly dependent upon fisheries. Fishing, fish farming and fish processing account for a quarter of the gross factor income and almost 100% of exports. Other industries are to a great extent suppliers to the fishing industry. The remaining industries are, like the public sector, highly dependent on proceeds derived from the fishing industry. The Faroese economy is vulnerable to fluctuations in the size of the fish catch, fish prices, exchange rates and the prices of vital import products, including oil.

5.2 Language and Culture

The Faroese language is a Nordic language, closely related to Icelandic and to the dialects of Western Norway. After the reformation (c. 1540) Danish became the written language for official purposes, and Faroese went out of use in writing, but was retained as a spoken language and as a carrier of a rich "oral literature" in the form of stories and notably ballads, sung with the traditional Faroese ring-dance. In the 19th century a new written Faroese language was created on an etymological basis. After decades of political strife the Faroese language was permitted as the language of instruction in the schools (1937) and as legal language (1948). In 1998 157 books were published in Faroese, of which 96 originally Faroese and 61 translations. 5 newspapers are published, appearing from 1 to 5 times a week.

The Faroese Broadcast (founded 1957) uses Faroese only. In the Faroese Television (established 1984) only part of the material is in Faroese.

There is a rich theatrical and musical life based upon amateur interest, however supported by an increasing number of professional instructors. A number of records, tapes and CD's with Faroese music have appeared. The visual arts have a strong position. In Tórshavn the Museum of Art (Listaskálin) has a permanent collection of Faroese art. Many towns and villages have "community houses" as centres for artistic, cultural and civic activities.

The most popular sport is football. The Faroese national team have since 1990 participated in international tournaments such as the qualification rounds for the European and the World Championship. A special Faroese sport is competition rowing with boats of the traditional Faroese type.

5.3 Lifestyle

Wages are generally lower than in Denmark, and so are unemployment benefits. In the Faroe Islands, notably fishermen are used to having an income, which fluctuates in keeping with fish catches and prices. There is also a strong tradition for labour mobility, both geographically and between occupations. In the early nineties with high unemployment many Faroese went abroad to work, notably on foreign fishing vessels and in construction, but many of them are slowly drifting back again into the Faroese labour market. Due to freight costs, small units, and high indirect taxation, prices are generally higher in the Faroes, apart from books which are free of VAT, and agricultural produce, which can be bought at world market prices due to the status of the Faroe Islands outside of the Common Agricultural Policy of the EU. Nevertheless most people in the Faroese towns and villages live in fairly good and spacious, brightly painted, centrally heated houses, with most of the gadgets or conveniences considered necessary to day, including TV, video and home computer, and with a car in the garage.

The numbers of smokers is the adult population is not known in detail. However, according to a school survey in 9th grade in 1999, 38% of fathers smoke daily and 42% of the mothers. The number of daily smokers among pupils in 9th. grade has declined in recent years: In 1996 37% were smoking daily, in 1997 31%, in 1998 26% and in 1999 23%.

With regard to alcohol consumption, the statistics is based on sales figures. These figures indicate that the consumption in the Faroes is in the lower end of the Nordic range. The annual average alcoholic beverages in litres of pure alcohol per capita aged 15 years and over in 1990'ies was around 7 in the Faroes, 12 in Denmark and 14 in Greenland. Accordingly, the number of treatment periods/discharges from hospital for alcoholic liver diseases is low in the Faroes.

The diet is dominated by marine food, e.g. cod, haddock and halibut. Seabirds are consumed in the season, especially fulmar, puffin and guillemot. However, all types of Scandinavian food items are available in the supermarkets. A part of the traditional diet consists of pilot whale meat and blubber. The pilot whale is a small whale found in large schools in the North Atlantic, the Mediterranean and a closely related species in the Pacific Ocean. The Faroese pilot whale catch is a traditional, communal, non-commercial hunt aimed at meeting the community's need for whale meat and blubber.

The pilot whale catch proceeds as follows: A school of pilot whales, observed near the coast, is driven into a fjord and beached, preferably on a flat stretch. Only a limited number of beaches are approved for whaling. The whales are killed by a stab in the neck with a special knife. If the beaching is unsuccessful the whale is fastened by a special hook so that it can be killed in shallow water. It all looks quite dramatic, but each animal is dealt with so fast that the pain is brief. The authorities distribute the meat and blubber according to traditional rules, the main rule being equal shares for all the inhabitants of the district. No export takes place.

The pilot whale is not a threatened species. As a "small cetacean" the whale is not covered by the regulations of the International Whaling Commission (IWC). Working jointly with the IWC, ICES (the International Council for the Exploration of the Sea) and NAMMCO (North Atlantic Marine Mammal Co-operation Organisation), - Faroese and international scientists keep a close watch on the size of the whale population. The most recent scientific estimate is that there are approximately 780,000 animals in the North East Atlantic. The annual catch fluctuates with oceanic conditions, but the long term average catch of approximately 1,000 animals, corresponding to only a small fraction of the annual natural rate of increase, is sustainable.

Sometimes the Faroese authorities receive protests, occasionally concluding in threats of a trade boycott, which are often based on exaggerated or misleading descriptions of the whale catch. It is the position of the Faroese authorities that a sustainable harvest of pilot whales occurring in the waters around the Faroe Islands is a legitimate activity. In fact it is one of the most ecological methods of producing meat at 62 degrees Northern latitude, and only one of several examples of sensible traditional utilisation of local resources, still practiced in the Faroes. Endeavours to deprive the Faroese people of their right to harvest this resource is seen to be in violation of the UN Covenants of 1966 on Human Rights. Should the scientists so recommend, the authorities will be prepared to limit the catches. Up to now, catches are only limited in order to avoid waste. Whenever the need for whale meat and blubber is considered to be met, a whaling ban is imposed in the district concerned.

The Faroese authorities have acknowledged animal welfare issues regarding the methods of catching the pilot whale. In connection with updating of the age-old rules laid down for the pilot whale hunt, the authorities have strengthened the animal welfare element, such as banning the harpoon and the whale spear and significantly reducing the use of hooks from boats. A veterinarian has been charged with the task of monitoring pilot whale hunts and implementing further improvements in killing methods. Furthermore the hunt is monitored through an international observer scheme. The Faroese do not believe that the pilot whale meat on their plate represents more animal suffering caused by humans than a similar amount of imported meat and are therefore not prepared to accept the demands for a ban on a catch which makes a larger contribution to the meat production of the islands than all the sheep and cattle put together and which covers about one quarter of the total meat consumption.

5.4 Disease pattern

The disease pattern in the Faroe Islands like in Greenland is primarily known from mortality statistics, statistics on notifiable diseases, and population surveys. Life expectancy at birth is high compared with other Nordic countries both among men (75.2 years) and women (81.4 years). Infant mortality is low (1.8 per 1,000 live births for 1996-2000).

The causes of death show the typical pattern of western industrialised countries, with about 40% caused by cardiovascular diseases and 30% cancer. Mortality from acute infectious diseases, suicides and accidents is unimportant.

The occurrence of hepatitis B and C and HIV infections is very low. In 2000 no new cases were recorded. The number of diagnosed cases of tuberculosis is low, but possibly increasing if the figures from year 2000 indicate a trend.

A major fall in the incidence of the traditionally sexually transmitted diseases, gonorrhoea and syphilis, has been seen over the last two decades. In recent years there were no notified cases of syphilis.

5.5 Health Care

In 1995, the Danish Act concerning central administration of the health care was introduced at the Faroe Islands. The Danish Act concerning the medical officers etc. also applies on the Faroe Islands. The Faroe Islands Act concerning health care came into force in 1996, and according to this Act the Faroe Islands' home rule sets out rules concerning tasks, benefits and administration.

The hospital structure and its organization, specialist fields and their organization as well as the primary health service and its organization largely follow Danish principles. The same applies to nursing homes, home nurses and home help as well as dental treatment.

The health sector consists of (year 2000):

- 90 Physicians, (27 general practitioners, 30 specialized physicians)
- 38 Dentists
- 366 Qualified nurses
- 3 Pharmaceutical divisions

There is a central hospital in the capital and two smaller hospitals in the northern and southern parts of the islands. Complicated cases are treated in Denmark. Social legislation is generally based on the Danish model.

5.6 Contaminants in Faroese subsistence food

There have not been any studies dedicated to elucidate the pollutant load carried by the Faroese subsistence food. However, from the results established as part of the Faroese AMAP project since 1997, and from the monitoring done by the Food and Environmental Agency, it is possible to give at least a preliminary sketch of the pollutants load in the subsistence food. In general, the selection of species and matrices studied in the Faroese AMAP program was governed by three criteria:

- the relevance of the species in the international AMAP context
- the relevance of the species in the Faroese subsistence food
- the suitability of the species as monitoring organisms

The latter criterion to a large extent is a question of whether the species are stationary in the Faroes or not. The species thus included in the Faroese AMAP program for Heavy Metals and Persistent Organic Pollutants (POPs) are not necessarily suitable as regular monitoring organisms, but they may have been included because of their role in the traditional diet. Some of the species, which are included in the AMAP program are analysed regularly whereas others may have been subject to occasional analyses.

The species of most relevance in the Faroese diet, which have been analysed in the AMAP program are: Long-finned pilot whale (*Globicephala melas*), fulmar (*Fulmarus glacialis*), cod (*Gadus morhus*), sheep (*Ovis aries*), hare (*Lepus timidus*), brown trout (*Salmo trutta*) and Arctic char (*Salvelinus alpinus*). The freshwater fish species, especially the Arctic char, though an important part of the diet in other northern communities, is of limited importance as food-item in the Faroes. First and foremost due to the limited abundance of Arctic char containing waters, and secondly due to the limited catch of these fishes, which are taken on a fishing rod by sports anglers only. Blue mussels and queen scallop have once been analysed for pollutants as a part of the AMAP Faroes program. These shellfish species are widely used as food. However, in the Faroes the consumption is very limited. Consequently analyses of these shellfish species are not included in the present overview.

5.6.1 Heavy metals

Most concern has been on the metals: Mercury, lead and cadmium. Most samples have been analysed for these metals. However, in some matrices also selenium has been analysed.

Lead concentrations have been shown to be generally low in the matrices analysed. Accordingly there is no special emphasis on these metals in the current analysis program. Mercury on the other hand, remains a priority metal because elevated concentrations are found in certain species, for instance the marine mammals, the seabirds and the freshwater fish. The analyses have been focused on total mercury (Hg) rather than methyl mercury (MeHg), therefore the actual amount of the latter is not known. Indications of the amount of mercury that is present in methylated form may be found in earlier studies. For instance the methyl-mercury fraction of the total mercury in pilot whale meat from 16 individuals in 1978 were found to be in the range 24 – 86%, averaging 52% of the 1.56 mgHg/kg (Juelshamn et al., 1987).

There are only a very few data on MeHg in seabirds eggs in the Faroes. However, results are available for a few fulmars' eggs, which were analysed along with some other seabirds' eggs from the Faroes in 1972. They contained 0.21 mgHg/kg, of which 73% was MeHg. This is in the lower end of the range (Dyck og Bloch, unpubl).

Table 5.6.1 Metals in terrestrial mammals, mg/kg ww.

Species	Year	Tissue	N	Hg	Cd	Pb	Se	Ref
Lamb	1997	Muscle	8	<0.02	<0.002	<0.020		Larsen & Dam, 1999
Lamb	1997	Liver	17	<0.02	0.05	0.09		Larsen & Dam, 1999
Sheep	1997	Liver	8	<0.02	0.17	0.14		Larsen & Dam, 1999
Sheep	1997	Liver	8	<0.02	0.069	0.074		Larsen & Dam, 1999
Hare, male	1999	Liver	Pooled sample	0.03	0.28		0.56	Olsen et al., 2001
Hare, young	1999	Liver	Pooled sample	0.06	0.09		0.62	Olsen et al., 2001

An overview of concentrations of heavy metals in terrestrial mammals is given in Table 5.6.1. Mainly liver samples have been analysed. Unfortunately, the part of these animals that are most commonly consumed by humans, the muscles, are only rarely analysed. The reason for this is that the monitoring of pollutants in the species as such has been the focus rather than the study of the transfer of pollutants to humans.

Table 5.6.2 Mercury in Freshwater fish muscle, mg/kg ww.

Species	Location	Age/size	Year	N	Hg	Ref
Brown trout	Fjallavatn	Small	1997	19	0.23	Larsen & Dam, 1999
Brown trout	Fjallavatn	Large	1997	9	0.36	Larsen & Dam, 1999
Brown trout	Leitisvatn	<25 cm	1997	16	0.3	Larsen & Dam, 1999
Brown trout	Leitisvatn	>25 cm	1997	7	0.35	Larsen & Dam, 1999
Arctic char	Leynavatn	7.8 yr <25cm 131 g	1998	15	0.18	Dam, 1999
Arctic char	Mýranar	7.2 yr 559 g	2000	5	0.14	Olsen et al., 2001
Arctic char	Mýranar	555 g	2001	8	0.23	Olsen et al., 2001

Mercury in two freshwater fish species is listed in Table 5.6.2. Overall, these mercury levels are in the higher end of those reported (for instance in the AMAP Assessment Report 1998). However, as earlier mentioned, freshwater fish is not likely to make up a large part of the fish intake in the Faroes, since marine species are so easily available. Therefore, the major vectors for mercury transport into the human food chain from subsistence food are presumably those listed in Table 5.6.3 Please note that sculpins are not part of the subsistence diet in the Faroes. These data were included merely because this species is used for food in other countries and is an important AMAP indicator species for the marine area. Shag liver in particular, is not to be regarded as a food item either, but shag muscle is. Unfortunately, muscle samples have not been analysed, but liver data are included to give an indication of the exposure levels. Although the actual intake of these subsistence food items are not known, it may be assumed from abundance data that fulmars are more frequently eaten than shag. Eggs of selected seabirds are also eaten, but there are hardly any data on metal concentrations in eggs at present.

Table 5.6.3 Metals in marine species (fish, seabirds and mammals), in mg/kg ww.

Species	Tissue	N	Age/size	Year	Hg	Cd	Pb	Se	Ref
Cod	Muscle	25	3 yrs, 53 cm	1994	0.01				Stange et al.,1996
Cod	Muscle	44		1997	0.028				Larsen & Dam,1999
Cod	Muscle	10	2 yrs, 49 cm	2000	0.017				Heilsufrøðiliga Starvsstovan
Cod	Muscle	10	4 yrs, 65 cm	2000	0.026				Heilsufrøðiliga Starvsstovan
Cod	Liver	25	3 yrs, 53 cm	1994		0.07	0.004	1.03	Stange et al.,1996
Redfish	Muscle	25		1994	0.18				Stange et al.,1996
Sculpin	Liver	5	15-20	2001	0.07	0.1		1.48	Hoydal & Dam, in prep
Sculpin	Liver	5	25-32	2001	0.26	1.19		1.70	Hoydal & Dam, in prep
Fulmar	Liver	25	Fledging	1997	0.19	0.38	<0.15		Larsen & Dam,1999
Fulmar	Muscle*	10	Young birds	1999	0.13	0.28			Dam et al., 2001
Shag	Liver	36	All ages	1996	0.5	0.5			Dam, 1998
Grey seal	Muscle	20	Adult females	1993-95	0.8				Larsen & Dam,1999
Grey seal	Muscle	21	Young	1993-95	0.38				Larsen & Dam,1999
Pilot whale	Muscle	50	Mean all**	1999	1.53	0.19		0.59	Olsen et al., 2001
Tórshavn 14-3-99									
Pilot whale	Muscle	22	Mean all**	1999	1.99	0.25		0.66	Olsen et al., 2001
Vestmanna 8-9-99									
Pilot whale	Muscle	21	Mean all**	2000	1.60	0.26		1.64	Heilsufrøðiliga Starvsstovan
Tórshavn 9-9-2000									

* Concentrations have been calculated assuming a dw of 25%

** The weighed mean for all whales was calculated using the average distribution of the age and sex groups from the study in 1986-88 (Bloch et al., 1993)

5.6.2 POPs

Persistent organic pollutants have been widely found in samples from the Faroe Islands. The highest concentrations are normally found in the species from the marine compartment. In Table 5.6.4 some marker POPs are shown in selected species. The marker POPs are selected as the single isomer normally occurring in the highest concentration in their class of compounds. Thus CB 153, which makes up approx. 35-50% of the total-PCB in the bird eggs, is chosen as an indicator of PCB. Likewise, p,p´-DDE is chosen as an indicator for the DDT group. In pilot whales p,p´-DDE occurs in a ratio from 5.1 to 5.8 to the isomer, which occurs in next highest concentrations, which is o,p´-DDT (lowest among the young and highest among the adult males). For toxaphene, the Parlar 50, is shown. The values are all given lipid based. This way of presenting the data is appropriate in order to compare various species and various tissues.

Table 5.6.4 POPs in selected species from the Faroese environment, in µg/kg lipids.

Species	Tissue	N	Age/size	Year	% lipids	CB 153	pp-DDE	HCB	Par-50	Ref
Hare	Liver	3	Young	1999	1.75	6	7	64	Nd*	Hoydal et al., 2001
Hare	Liver	3	Adult males	1999	1.8	5	6	25	Nd*	Hoydal et al., 2001
Lamb	Liver	17		1997	8	8	3	12		Larsen & Dam, 1999
Lamb	Tallow	17		1997	88	6	4	5		Larsen & Dam, 1999
Sheep	Liver	8		1997	8.9	4	6	10		Larsen & Dam, 1999
Sheep	Tallow	8		1997	86	2	2	5		Larsen & Dam, 1999
Cod	Muscle	25	48 cm	2000	0.8	Nd	38	Nd	Nd	Heilsufrøðiliga Starvsstovan
Cod	Liver	24	58 cm	2000	54.8	25	43	17	27	Heilsufrøðiliga Starvsstovan
Redfish	Liver	25	42 cm	1994	24	113	278	39		Stange et al., 1996
Sculpin	Liver	15	25 cm	2000	6.2	1500	2048	39	129	Mikkelsen et al., 2002
Guillemot	Eggs	10	Eggs	2000	12	243	1132	304	38	Heilsufrøðiliga Starvsstovan
Gull (L.fuscus)	Eggs	10	Eggs	1999	8.2	1797	2006	214	198	Heilsufrøðiliga Starvsstovan
Fulmar	Eggs	10	Eggs	2000	8.2	1532	1277	568	203	Heilsufrøðiliga Starvsstovan
Fulmar	Liver	25	Fledging	1997	6.5	292	338	86		Larsen & Dam, 1999
Fulmar	Fat	25	Fledging	1997	86.9	432	585	121		Larsen & Dam, 1999
Fulmar	Muscle	10	Young	1999	3.4	3343	4762	523	187	Dam et al., 2001
Fulmar	Fat	10	Young	1999	63.4	5795	6810	738	327	Dam et al., 2001
Fulmar	Fat	5	Adults	1998	67.1	10137	20843	995	844	Dam et al., 2001
Grey seal	Blubber	13	Adult females	1993-96	89	885	544	29	22	Dam, 2001
Grey seal	Blubber	3	Adult males	1993-96	87	6724	3033	14	39	Dam, 2001
Pilot whale	Blubber	173	Young	1997	86.0	3700	10171	479	5587	Dam & Bloch, 2000
Pilot whale	Blubber	193	Adult females	1997	86.4	1800	3919	220	1110	Dam & Bloch, 2000
Pilot whale	Blubber	54	Adult males	1997	89.1	4100	11995	361	2174	Dam & Bloch, 2000

* Not detected at 5 µg/kg lipids

The highest concentrations, lipid based, of CB 153 and p,p´-DDE are found in subcutaneous fat from adult fulmars. The most comprehensive study of fulmars was designed to enable calculation of the total body burden of pollutants in these birds, commonly consumed in the Faroes (Dam et al., 2001).

5.6.3 Dioxins

The dioxin and non-ortho PCB concentration are known in a limited number of samples from sheep, lamb, cow's milk, guillemots' eggs, cod liver and pilot whale (Mikkelsen et al., 2002). Table 5.6.5 summarises the results of these analyses. Like with the "common" POPs, the higher concentrations are found in the marine compartment. The dioxin concentration in guillemots' eggs is high in particular. The very high proportion of "dioxin-toxicity" originating from the non-ortho PCBs (CB 77, 126 and 169) is remarkable, especially found in cod. Again guillemots' eggs contain high concentrations of these PCBs.

Table 5.6.5 Dioxin and non-ortho PCB in Faroese biota.
Units are pg/g lipids of International Toxic Equivalents for PCDD/PCDF and for non-ortho PCBs those of Ahlborg et al., 1994 were used.

Pg/g lipid	Lamb	Sheep	Cows milk	Cod	Guillemot	Pilot whale	Pilot whales
Age/sex	Both sexes	Female		40 - 70 cm	Eggs	Adult males	Adult females
Yr sampling	1999/2000	1999/2000	1999	2000	2000	1996	1996
Tissue	Tallow	Tallow	Milk	Liver	Eggs	Blubber	Blubber
N	32	32	5	20	10	8	19
% lipid	90	90	3.4	51.1	14.6	83	79
I-TEQs PCDD/PCDF	1.67	0.90	0.47	1.15	66.0	10	12.9
TEQs non-ortho PCB			0.33	6.30	139	36.51	40.59
Sum TEQ			0.79	7.45	205	46.5	53.5

Note, in case of not detectable quantity, the TEQ is calculated as 0.5*LD*TEF.

5.6.4 Flame retardants

Polybrominated diphenylethers have been analysed in pilot whales only. The earliest study of a school sampled in 1996 indicated very high levels of PBDE in pilot whales (Lindström et al., 1999). In this school, the levels of total BDE just exceeded 3,000 ng/g lipid in the juvenile males and females. The levels were just above 1,000 ng/g lipid in adult females; in the adult males the total BDE was 1,600 ng/g lipid. The dominating isomers were Te-BDE #47 and Pe-BDE #99, at approx. 1,700 ng/g lipid and 600 ng/g lipid in the juveniles respectively. Other penta- and hexa-brominated isomers occurred in comparable high levels. Later analyses of samples taken in subsequent years have not given as high concentrations of BDE as in this 1996 school. Comprehensive studies of the predominant POPs in pilot whales have revealed large inter-school variation. This seems to be the case for the brominated flame-retardants too.

5.7 References

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6 The Human Health programme in the Faroe Islands 1985-2001

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6.1 Introduction

Research on prenatal exposure to seafood contaminants and the potential effects on the foetus has been performed in the Faroes since 1985. This research has been carried out as a cooperation between the Department of Occupational and Public Health in the Faroese Hospital System and the Department of Environmental Medicine of the University of Southern Denmark. In addition to funding from the Danish Environmental Protection Agency and the Danish Medical Research Council, substantial support has been obtained from the U.S. National Institutes of Health and the European Commission.

In this report we will present preliminary results of studies financed by Arctic Monitoring and Assessment Program, under the following headings:

- "Effects of marine pollutants on the development of Faroese children" including 656 deliveries from December 1997 to February 2000. A description of the cohort characteristics, exposure to contaminants, obstetric optimality, neurological optimality and associations between exposures and potential effects will be presented. (6.2)

- "Dietary Survey of Faroese Women in the Third Trimester of Pregnancy" including 150 women October 2000 to October 2001. A description of contaminant levels in blood and main characteristics of the Faroese diet will be presented. (6.3)

- "Exposure to Seafood Contaminants and Immune Response in Faroese Children". The study is not yet finished, but the results of this study will be available in the near future. (6.4)

- "Exposure to POPs, 1985-2001" In this concluding section we will present exposure data from the above mentioned project as well as from other projects previously reported elsewhere. (6.5)

6.2.1 Introduction

Consumption of marine food in preference to other food is generally considered to be healthy. But different contaminants such as persistent organic pollutants (POP) and heavy metals – in this case methyl mercury – might outweigh the advantages. The Faroese are known to be heavily dependent on seafood. Thus the exposure to some pollutants is very high in this population. Of special concern for the Faroese population are the following substances:

Organochlorine compounds, such as polychlorinated biphenyls (PCB) and chlorinated pesticides (4,4´-DDT, and its most stable daughter compound 4,4´-DDE, trans-nonachlor, ß-HCH, HCB), have long been problematic in the environment for a number of reasons. Many of them (like DDT) have endocrine activity, therefore called hormonally active agents (HAAs). The term organochlorine refers to chemical compounds that have a chlorinated hydrocarbon structure; that is, they are formed from atoms of hydrogen, carbon, and chlorine. Although their effect may be much weaker than the body's natural hormones (like oestrogens, androgens, and thyroid hormones), they are nonetheless suspected of disrupting the endocrine system, resulting in harmful effects like reproductive and developmental defects. In humans, an association between breast cancer risk and PCB and DDT concentrations in mammary adipose tissues or plasma lipids could be shown in epidemiological studies (Dewailly et al., 1994). They are suspected to promote the progression of certain hormonally responsive tumors of the breast and uterus, especially DDT, β-HCH, HCB. According to animal research, organochlorines may be able to modulate immune response. Most of the substances have been banned for years, but due to their longevity in the environment, PCB, dieldrin, DDT, chlordane, aldrin, kepone, mirex, endrin, and toxaphene still constitute a public health problem. Human exposure to these contaminants is mainly through the consumption of food, particularly food caught in contaminated waters.

Polychlorinated biphenyls (PCBs) are divided into two main classes of congeners, the ortho-substituted and the non-ortho-substituted, which differ in their toxicology. The number of chloride atoms in the ortho-position of the two phenyl rings of the PCBs is responsible for the strength of the dioxin-like effect of the respective congener: the fewer the atoms in the ortho-position, the higher the dioxin-like toxicity. Thus, the planar or non-ortho congeners (IUPAC-numbers 77, 126, and 169) have a higher dioxin-like toxicity than the mono-ortho congeners (IUPAC-numbers 105, 114, 118, 123, 156, 157, 167). The toxic effect of PCBs and dioxins is mediated through binding to the cytosolic arylhydrocarbon (Ah)-receptor (Poland et al., 1992). The toxicity of the di-ortho PCBs (IUPAC-numbers 138, 153, 170, 180) depends on different mechanisms that are still being explored.

4,4'-dichlorodiphenyltrichloroethane (DDT) was used as an insecticide in agriculture. Nowadays it is banned in Europe, but it is still important in countries with serious mosquito borne disease problems such as malaria.

4,4'-dichlorodiphenyltrichloroethene (DDE) is the most stable daughter compound of DDT. DDE itself is persistent and bio-accumulating. Both substances accumulate in fatty tissue. DDT can mimic the effects of oestrogen, and DDE can be anti-androgenic (AMAP, 1997).

Trans-nonachlor is a breakdown product of a mixture of different compounds, called chlordane, which is used as pesticide. It has major effects on the liver, the nervous system, and the immune system. It is also a probable human carcinogen.

Hexachlorobenzene (HCB) is a by-product in the production of a large number of chlorinated compounds. It was also used as a fungicide.

Hexachlorocyclohexanes are a group of compounds that are primarily used as pesticides. The most toxic form, gamma-hexachlorocyclohexane, is also called lindane. Due to its persistence, beta-hexachlorocyclohexan (β-HCH) usually is measured (AMAP, 1997). Effects of HCB and β-HCB are similar to those of the other mentioned pesticides (see the paragraph about trans-nonachlor), they all are excreted via breast milk.

An overview of the range of effects of organochlorines is given here:

- adverse neurobehavioral effects, neurotoxic effects (Seegal et al., 1992).
- Ah-receptor mediated effects are growth reduction (body weight reduction)
- immunologic effects are suspected (Tryphonas, 1998), but available data are inadequate to support any definitive conclusion (Committee on Hormonally Active Agents in the Environment, 2001)
- because of their structural similarity to steroid hormones they may interfere with endocrine function, such as thyroid function (Porterfield, 2000) and reproductive system (some PCB congeners showed a weak estrogen-like effect (Toppari et al., 1996); several hydroxy-PCB congeners exhibit oestrogen-receptor antagonistic effects (Committee on Hormonally Active Agents in the Environment, 2001); 4,4´-DDE acts as a weak antiandrogenic agent (AMAP, 1997).

Musk xylene, a synthetic aromatic substance, is often used in fragrances and soaps as a substitute for natural musk. It belongs to the group of nitromusk compounds. The main environmental intake of musk xylene occurs via consumption of fish and drinking water as well as the use of body care and perfumed household products. Musk xylene is stable against biological and chemical degradation and is highly lipophilic (Kafferlein et al., 1998). A genotoxic risk for humans has been assumed (Mersch-Sundermann et al., 1996).

Methylmercury (MeHg) is a well-established neurotoxicant that can cause serious adverse effects on the development and functioning of the human central nervous system (Harada, 1995; Grandjean et al., 1997). Methylmercury exposures to women of childbearing age are of great concern because a foetus is highly susceptible to adverse effects (CDC, 2001), even for low-dose exposure (Committee on the Toxicological Effects of Methylmercury, 2000). Methylmercury inhibits the growth of the foetal brain and the migration of neurons from the embryological generation layer to the final destination in the brain. This causes microcephalus in severe cases, and lower exposures result in behavioral changes and reduced cognitive and motor abilities. Methylmercury interferes with microtubule formation, cell division, and neural protein synthesis, all of which could explain the effects described above (WHO, 1990). Epidemiological studies have therefore applied neurobehavioral tests as outcome parameters. Using domain-related neuropsychological tests in the Faroes study, a doubling of prenatal methylmercury exposure was associated with a delay in development of 1-2 months at age 7 years. This delay corresponded to about 10% of the standard deviation of the test results. Thus, the children were generally healthy, subtle neurodevelopmental effects were associated with increased mercury exposures (Grandjean et al., 1997).

There is also evidence that exposure to MeHg can have adverse effects on the cardiovascular system (blood-pressure regulation, heart-rate variability, and heart disease) even below MeHg exposure levels, which were found to be associated with neurodevelopmental effects (Committee on the Toxicological Effects of Methylmercury, 2000). Regarding cardiovascular toxicity at low-level methylmercury exposures, a Finnish population study showed that increased exposure from fish constituted a risk factor for cardiovascular mortality in adults (Ashby et al., 1990). Children with mercury poisoning often have increased heart rate and blood pressure (Sørensen et al., 1999).

The toxicological effects of methylmercury can, therefore, be summarized thus: carcinogenicity, genotoxicity, immunotoxicity, negative effects on the reproductive system, renal toxicity, cardiovascular effects, and neurotoxicity with a specific emphasis on the developing central nervous system.

To further evaluate the effects of prenatal exposure of the foetus to mixture of marine pollutants, a study was initiated in the Faroe Islands. As study design a prospective longitudinal cohort study was chosen.

Samples were collected of maternal serum at week 34 of pregnancy (last antenatal consultation at the hospital), umbilical cord blood and serum, maternal hair at parturition, and breast milk on days 3-5 post-parturition (prior to mother and child were being discharged from hospital). Nutritional habits were recorded by questionnaire (number of whale meat dinners per month during pregnancy and before pregnancy; number of fish dinners per week; ingestion of blubber with whale meat or fish). The infants were examined neurologically at about 2 weeks of age. The results of the methyl mercury levels in maternal hair and the determination of organochlorines levels in breast milk are presented. These values, which are known to correlate very well with the concentration of the pollutants in maternal and cord blood, are presented below. The effects of the pollutants on the neurological status of the infants and on the infants' on the anthropometric data are analyzed.

The purposes of the study are:

1. to document the current Faroese level of prenatal exposure of chemical substances originating from marine pollution, i.e. methylmercury, organochlorines, and hormone disrupters;

2. to relate the exposure to the mothers´ dietary history;

3. to compare the exposure to marine pollutants with the exposure data, available from the cohort of 1,022 newborns in 1986-87 and estimate whether the exposure has changed;

4. to investigate whether prenatal exposure to these pollutants is related to potentially harmful effects on health, especially the function of the central nervous system and malformations of the sexual organs; and

5. to establish a birth cohort with well-documented exposure to environmental pollutants, which can be examined later on for delayed negative effects of environmental pollution on health.

6.2.2 Methods

6.2.2.1 Subject recruitment

Women who intended to deliver at the Central Hospital in Tórshavn were invited in the last trimester of pregnancy by letter to participate in the project. If they agreed, around week 34 of pregnancy (co-inciding with the last antenatal consultation at the hospital) a 50 ml blood sample was collected by phlebotomy for determination of organochlorine concentration and estrogen-like substances. In connection with the delivery, cord blood and serum, and a sample of maternal hair (100 mg) were taken. Before mother and child were discharged from the maternity ward (between day 3 to 5) a sample of breast milk was collected. Blood and milk samples were stored at minus 80° C. At approximately two weeks of age (adjusted for complete 40 weeks of gestation), the infants were examined according to the neurological optimality schedule (Prechtl, 1977). At that time all relevant obstetric data, information about smoking and alcohol consumption, as well as important socioeconomic data about the mother were recorded. A second milk sample was collected where possible. In the second half of the cohort, nutritional habits were recorded on a questionnaire filled in by a project assistant when the mother came for the neurological examination of the infant. Birth weight of the infant was recorded by the midwives. Weight at the neurological examination was measured by the examining physician on electronic baby scales, corrected to the nearest 10 grams. The infant´s length was measured on a length board to the nearest 5 mm, and its head circumference was measured using a standard tape, corrected to the nearest mm. The Ethical Committee of the Faroe Islands approved the study protocol. Written informed consent was obtained from each mother.

6.2.2.2 Dietary questionnaire

The dietary questions included those previously used about the number of whale meat dinners and dinners with blubber per month during pregnancy, and before pregnancy, but we also recorded the estimated portion weight per meal, and number of other occasions where dried blubber or whale meat was eaten. The number of fish dinners per week, and the number of fulmar (*Fulmarus glacialis*) and other sea birds consumed per month, as well as the consumption of other meat (chicken and livestock) were recorded. To determine the awareness of possible hazards associated with whale meat, blubber and seabirds, the mother was asked whether the consumption of the respective food items remained the same during pregnancy, was reduced / increased somewhat or much. For whale meat and blubber, the estimated intake during the whole pregnancy was computed by multiplying the number of meals per month by 9 and then by the average weight of the portions consumed.

6.2.2.3 Exposure variables

6.2.2.3.1 MeHg in maternal hair

For mercury analysis, a hair sample of at least 100 mg (total thickness equivalent to a match stick; total length at least 6 cm) was cut with a pair of scissors close to the root from the occipital area; the hair was tied with a cotton string and saved in a small, marked envelope. Taking in account the delay before mercury appears beyond the hair root and the growth rate of scalp hair, a hair sample of this length will mainly represent the exposure during the first and second trimesters of pregnancy (Grandjean et al.,1999).

Mercury analysis took place at the Trace Element Laboratory, Odense University, using a Perkin-Elmer atomic absorption spectrometer 5100 with a fluid injection system. A volume of 250 µl of digested sample is then transferred to another Minisorp tube, and 2 ml of saturated KMnO4 (Merck) in 3% H2SO4 (Merck) is added. The tubes are sealed with perforated parafilm (American Can Company, Greenwich, CT) and agitated before incubation in a 75° C warm water bath for 30 min. After cooling, excess potassium permanganate is reduced by careful addition of 250 µl saturated hydroxylamine hydrochloride (Merck). The solution is agitated carefully until clear. Each digested sample is prepared and analyzed in duplicate. Mercury results in µg may be converted to nmol by multiplying by 5.0.

6.2.2.3.2 Organochlorines, pesticides, and musk xylene in breast milk

6.2.2.3.2.1 Collection, storage, and transport of samples

While the mother was still at the hospital, a sample of transitional milk was collected directly into acid-rinsed 250 ml polyethylene bottles (Kartell, Einasco, Milano, Italy) and then frozen at -80° C.

6.2.2.3.2.2 Laboratory procedure for organochlorines

Milk analysis was performed in the Institute of Environmental Toxicology, Flintbek/Kiel, Germany (Dr. Heinzow) for hexachlorobenzene (HCB), ß-hexachlorocyclohexane (ß-HCH), dichlorodiphenyltrichloroetane (4,4'-DDT), dichlorodiphenyldichloroethene (4,4'-DDE), trans-nonachlor, musk xylene, and polychlorinated biphenyl congeners (IUPAC number 105, 118, 138, 153, 156, and 180). The sum of the levels of PCB-138, 153, and 180 makes up about 50% of the total PCB congener mixture consumed by Faroese people. Thus ΣPCB was calculated as twice the sum of the congeners 138, 153, and 180. Samples were analyzed by gas chromotography as perviously described (Brock et al,. 1996). Aldrine and Mirex were used as internal standards and added to 4 ml of a thoroughly mixed aliquot of the milk sample. Following solid-liquid-phase extraction with Florisil (Merck) and iso-hexane and elution with iso-hexane / dichloromethane (80 / 20, v / v), the eluate was evaporated with a vacuum-rotation evaporator just to dryness. The residues were reconstituted in a final volume of 2 ml iso-hexane and transferred to an autosampler vial. Analyses were performed by high-resolution gas chromatography on a Varian 3400 gaschromatograph equipped with an autosampler, a 30m DB-5 capillary column and an electron capture detector. The specific congeners were identified and quantified by comparison with response and retention time of calibration standards for each analyte of interest. At a fat content of 3% the detection limits were 0.003 µg/g lipid for DDT, 0.006 µg/g lipid for musk xylene, and 0.005 µg/g lipid for the different PCB-congeners and the other substances. For each 8 analyte-runs, one blind sample and one pool-sample were included for internal quality control. The lipid content of the samples was determined by means of the photometric Merckotest 3221 (Merck) for total lipids. Values below the detection limit were substituted by 0.0015 µg/g lipid.

6.2.2.4 Neurological Optimality Score (NOS)
At an age of approximately two weeks (adjusted for a gestational age of 40 complete weeks) the infants underwent a neurological examination. The Groningen Neonatal Neurological Examination systematically records major indicators of neurological function, such as posture, motility, general, muscle tone, responses, tendon reflexes, other reactions, reactivity, and stability of behavioral status during the examination. The technique for the examination of the children is a comprehensive age-specific examination as described by Prechtl (Prechtl, 1977). It has proven to be predictive of later major and minor neurological dysfunction. The neurological findings were summarized into a clinical diagnosis (normal, suspect and abnormal). A neurological optimality score (NOS) is generated, defined as the number of optimal items from a list of 60 items which were considered to be representative of the neurological condition (Touwen et al., 1980). Furthermore, two subscores were calculated according to the literature (Huisman et al., 1995), one for muscle tone (postural tone cluster score with a maximum number of 17 points) and one for reflexes (reflex cluster score, maximum: 22 points).

6.2.2.5 Confounders / covariates
Many factors are known to have an impact on growth and neurological development. Their effects have to be taken into account when analyzing the changes of anthropometric data, gestational age, neurological outcome, and others that are suspected to be caused by contaminants in food.

In the preliminary analyses (bivariate correlation) several different groups of confounders and covariates could be identified (see also table 6.2.1):

- factors in connection with the neurological examination, such as the identity of the examiner, the date of the examination (higher NOS toward the end of the examination period), time of examination (better scores for infants examined later in the day), and the interval between last meal and examination (lower scores seen too soon after a meal);
- gender, gestational age, age at neurological examination;
- condition during and after birth (for example Apgar score, transfer to special care unit, neonatal icterus)
- maternal- / paternal factors (educational status of parents, profession- /- occupation of parents, consumption of nicotine and- /- or alcohol during pregnancy; cf. 6.2.2.5.2 OOS)

Table 6.2.1 Possible confounders for NOS, for the whole cohort and for subcohort

Confounder / covariate	Pearson (P), or Spearman correlation coefficient (S), or T-test (as applicable)		P value (two-tailed)	
	All children (N=500)	Subcohort B (N=233)	All children (N=500)	Subcohort B (N=233)
Duration of gestation (in days)	(P) 0.004	(P) 0.008	0.921	0.908
Birth weight (in g)	(P) 0.025	(P) –0.080	0.575	0.222
Percentile of birth weight*	(S) 0.026	(S) –0.144	0.565	**0.027**
Corrected age at NOS (in days)	(P) -0.060	(P) -0.108	0.180	0.099
Apgar 5 minutes	(S) 0.042	(S) 0.033	0.345	0.616
Neonatal illness (no / yes)*	(T) –0.738	(T) 0.102	0.461	0.919
Head circumference (OFC) at NOS	(P) –0.067	(P) –0.120	0.135	0.068
Percentile of OFC at NOS*	(S) –0.113	(S) –0.147	**0.012**	**0.025**
Body length at NOS	(P) 0.083	(P) –0.054	0.065	0.414
Percentile of body length at NOS*	(S) –0.114	(S) –0.147	**0.011**	**0.025**
Icterus at NOS (no / yes)	(T) 1.569	(T) 0.491	0.117	0.624
Examiner (A / B)	(T) 9.473	---	**<0.001**	---
Date of examination	(P) 0.159	(P) 0.151	**<0.001**	**0.022**
Time (during day) of examination	(P) 0.080	(P) 0.083	0.081	0.215
Interval between meal and examination	(P) 0.244	(P) 0.135	**<0.001**	**0.045**
*Stability of states (no / yes)**	(T) –3.902	(T) –1.962	**<0.001**	0.090
Maternal age	(P) 0.029	(P) –0.140	0.513	**0.033**
BMI	(S) -0.058	(S) –0.161	0.193	**0.014**
Smoking of mother during pregnancy*	(S) -0.070	(S) 0.005	0.118	0.938
Alcohol of mother during pregnancy*	(S) –0.075	(S) –0.050	0.093	0.448
Education of mother*	(S) –0.005	(S) 0.025	0.912	0.705
Education of father*	(S) –0.023	(S) –0.013	0.615	0.841
Level of father´s / parents´ occupation and profession*	[1](T) 1.906 [2](T) 2.386	(T) 2.667 (T) 3.524	0.057 **0.017**	**0.008** **0.001**
Parity	(S) 0.060	(S) –0.111	0.184	0.090
Early spontaneous abortions (no / yes)	(T) 1.888	(T) 1.437	0.061	0.152
Other non-obstetrical diseases during pregnancy (no / yes)*	(T) –2.199	(T) – 4.380	**0.034**	**0.003**
Obstetric Optimality Score	(P) –0.063	(P) 0.015	0.156	0.853

* For further details: see text
1 : T-value resp. significance level for correlation with father´s occupation / profession
2 : T-value resp. significance level for correlation with highest parents´ occupation / profession

Explanations:

- percentile of birth weight:

  0 <2.3%
  1 2.3%-5%
  2 6-10%
  3 11-50%
  4 51-90%
  5 91-95%
  6 >95%

- percentile of OFC (head circumference) and body length at NOS:

  0 <10%
  1 10-50%
  2 51-90%

3 >90%

- neonatal illness (information was taken from the Obstetric Optimality Score):

  0 no neonatal illness
  1 any kind of neonatal illness (feeding problems, infection, neonatal icterus, problems after birth requiring observation)

- stability of states:

  0 behavioral status during neurological examination stable
  1 behavioral status during neurological examination unstable

- smoking of mother (partner) during pregnancy (see 6.2.2.5.4)

- alcohol consumption of mother during pregnancy (see 6.2.2.5.3)

- education of mother / father (see.6.2.2.5.5)

- father´s / parents´ occupation and profession (low / high) (see 6.2.2.5.5)

- other non-obstetric conditions during pregnancy: information was taken from the questionnaire for the Obstetric Optimality Score (OOS).

6.2.2.5.1 Examiner

There were three different examiners involved in the examination: US functioned as supervisor in the beginning of the study and therefore examined only a few children. Two experienced paediatricians A and B performed the examinations. The scoring of the neurological examination is known from the experience of other study groups to vary somewhat between examiners as individual judgment must be exerted, when performance of the infant is borderline. Therefore the dependence of the result of the neurological examination in form of the NOS of the two main examiners was tested. The children seen by examiner A reached a significantly higher score than the rest of the group (see 6.2.3.2.1). When ever necessary and applicable, the data analysis was done for the combined group as well as for the two subcohorts A and B.

6.2.2.5.2 Obstetric Optimality Score (OOS)

Obstetric data were evaluated according to the obstetric optimality list, as described by Touwen (Touwen et al., 1980).The list used in this study consisted of 73 items that measure socioeconomic status and pre-, intra-, and immediate post-partum conditions (for a complete list and criteria for optimality see Table 6.2.21 in the appendix). The items were completed using information recorded in the hospital records as well as that given verbally by the mother. For several items (such as marital status at time of delivery, participation in parenthood course, education of mother’s father) no information was available. By counting the number of items that fulfilled the preset criteria for optimality (Prechtl, 1980), the Obstetric Optimality Score (OOS) was calculated.

6.2.2.5.3 Alcohol during pregnancy

Two separate analyses were done to examine the influence of maternal alcohol consumption on the growth and the neurological outcome of the infant. Two different scoring lists were used: dichotomized as “no alcohol at all” versus “any amount of alcohol during pregnancy” and an ordinal variable. The possible answers were:

0 no alcohol at all
1 alcohol less than once per month
2 alcohol about once per month
3 alcohol few times per month
4 alcohol about once per week
5 alcohol 2 to 3 times per week
6 alcohol 4 to 5 times per week
7 alcohol nearly every day

Where necessary (e.g. for linear regression model) the information about alcohol was dichotomized into “no alcohol during pregnancy” and “yes, alcohol during pregnancy”.

6.2.2.5.4 Smoking of mother and / or partner
For the registration of smoking habits of mother or mother´s partner during pregnancy five categories were used:

0 no smoking at all
1 1-5 cigarettes / day
2 6-10 cigarettes / day
3 11-15 cigarettes / day
4 16-20 cigarettes / day
5 >20 cigarettes / day

As for “alcohol during pregnancy”, the information about smoking was also dichotomized into “no smoking during pregnancy” and “yes, smoking during pregnancy”.

6.2.2.5.5 Education / profession / occupation of parents
Education of parents was categorized into:

0 no elementary school examination (yet), i.e. less than nine years of schooling
1 nine years of schooling
2 ten years of schooling including secondary school (HF-prógv)
3 12 years of schooling (FHS)
4 13 years of schooling with university entrance qualification (studentsprógv / hægri handelsskúlaprógv)

Scoring of profession / occupation of parents which was done by the Faroese staff using these classes:

0 under training
1 unskilled worker
2 short theoretical education / training
3 apprenticeship finished
4 middle long theoretical education
5 long theoretical education

To calculate certain correlations, the higher of the two scores of the education of mother and father were chosen. To obtain a dichotomized variable, education was divided into the following two groups:

0 only basic school exam (max. 10 years in school)
1 more than basic school exam (more than 10 years in school).

For profession and / or occupation, a dichotomized variable was used with the following subdivision:

0 score for mother´s / father´s occupation / profession was 0-3
1 score for mother´s / father´s occupation / profession was 4 or 5

6.2.2.6 Statistical methods
All statistical analyses were performed using the Statistical Package for the Social Sciences, version 10.0 (SPSS for Windows 10.0).

Quantitative data are described by their arithmetic means, and the standard deviation. In some cases the 10^{th}, the 90^{th} percentile and the range are also included. For variables with skewed distribution such as contrations of exposure data, maternal body mass index (BMI), and most dietary variables, geometrical means with spread factor (geometric standard deviation) were computed to normalize the distribution and to obtain a better statistical fit. For these data log 10-transformed values were used in parametric tests. Percentage values are used to describe the distribution of qualitative variables.

Mean differences in group comparisons were calculated by using the T-test for independent samples. For proportions chi-square analysis was used to determine differences between groups.

Bivariate correlations between variables were tested by calculating the Pearson correlation coefficient in normally distributed data, and Spearman´s rho for rank orders. The statistical significance of correlations was determined by computing the p-values for the coefficients. For the correlation of several variables it became necessary to calculate partial correlation coefficients while controlling for major covariates (e.g. sex in the correlation between exposure data and NOS). For the sake of uniformity, only two-tailed significance levels were used.

Linear regression analyses were carried out for the main outcome variables birth weight and NOS. Items were chosen as covariates and tested if they were known as confounders from other studies or if it appeared plausible that they might function as confounders.

6.2.3 Results

6.2.3.1 Description of subjects
During the period of cohort formation a total of 1,152 children were born alive in the National Hospital in Tórshavn. These included one set of triplets and 16 pairs of twins, thus leaving 1,117 singletons, (7 pairs of twin were examined but not included in the cohort). In 1,019 births, the mother lived in the primary catchment area of the National Hospital (i.e. not the northern or southern islands). This area was the proposed catchment area for the project. A total of 608 of the infants were examined, giving an overall participation rate of 59.7%. This rate represents an underestimate, as inclusion required,

e.g. cord blood, thereby eliminating Caesarean section and births where complications prevented the midwife from taking a blood sample. Due to prematurity, the data of 10 children were not used for analysis (4 children of 35 weeks of gestation, 6 children of 36 weeks of gestation), and 7 children were excluded because they were older than 5 weeks of corrected age at examination – an age when the used technique for the neurological examination no longer is valid. Eight infants were examined when only two days old (chronological age) when birth stress factors still influence heavily the result of the neurological examination. Therefore their data were not used for the analyses. The exclusions (for reasons other than incompleteness of exposure data) amounted to 25/608 or 4.1%. In addition, hair for mercury analysis and / or milk for analysis of organochlorines, pesticides, and musk xylene were in several cases not obtained in sufficient amount to allow chemical analysis. Thus the data of 500 mother-infant pairs remained for this preliminary report.

6.2.3.1.1 Infants: anthropometric data and other characteristics of the children in the study.

The most important information about the infants in the study cohort is displayed in the following two tables (table 6.2.2 and table 6.2.3).

Table 6.2.2 Description of infants

	Mean	Median	SD	Range
Birth weight (g)	3,743	3,750	473	2,450 – 5,400
Gestational age (completed weeks)	40.1	40	1.2	37 – 42
Gestational age (days)	283.2	283	8.0	260 – 300
Apgar score at 1 min	9.2	9	1.0	3 – 10
Apgar score at 5 min	9.9	10	0.4	6 – 10
Corrected age at NOS (days)	16.9	16	5.8	-1 – 34
Chronological age at NOS (days)	13.7	13	7.0	3 – 35

Table 6.2.3 Non-metric characteristics of infants

	N	Percent
Gender: male / female	267 / 233	53.4 / 46.6
Birth weight (small-for-dates / appropriate for gestational age / large-for-dates)	22 / 404 / 74	4.4 / 80.8 / 14.8
Head circumference at neurological examination: appropriate for age (small / appropriate for age / large) N = 499	6 / 385 / 108	1.2 / 77.2 / 21.6
Body length at neurological examination appropriate for age (small / appropriate for age / large /) N = 498	6 / 385 / 107	1.2 / 77.3 / 21.5

N = Number of infants where data are available

It is known that Faroese children are very large at birth (Olsen et al., 1985), but no specific growth charts for Faroese children are available. Therefore German (for birth weight) and British (for length and head circumference) charts were used as reference anthropometric data for the Faroese infants. The fact that only term-infants were included in the cohort explains why in the study cohort only 4.4% small-for-gestational-age children (by definition those who constituted the 10 lightest percent of a birth cohort), but 14.8% of large-for-date infants (instead of 10%) were found. The percentage of children with a head circumference or length above the 90th percentile was even higher.

Some more significant differences were identified between boys and girls in the study cohort:
Body temperature at the neurological examination was higher in boys than in girls (p-value: 0.014); the same was true for maternal age (p-value: 0.046) and parity (p-value: 0.024). The OOS was also slightly higher in girls (p-value: 0.062). The time between rupture of membranes and delivery was longer in boys (0.047). These observations may represent spurious findings, but possible links to endocrine disruption cannot be ruled out.

Clinical examination of the 267 boys revealed one boy with a unilateral undescended testis, for two boys the information about the testicles was missing. As an ultrasound examination was not carried out, the true number of cases may have been underestimated. Two children had a mild hypospadia. The concentration of all PCB-congeners, DDE, and DDT were in the lower range of the general distribution. For the small number of cases no statistical analyses were done.

Estimation of gestational age was based on the mother´s report of her last menstrual period. If the date of the last menstrual period had been unclear, then the expected date of delivery calculated by ultrasound examination of the foetus at approximately week 22 of pregnancy was used. The duration of a complete pregnancy was taken to be 280 days or 40 weeks. Prolongation or shortening of the period was expressed in days as well as in completed weeks of gestation.

6.2.3.1.2 Background data about the mothers and their partners
Of major interest is all information about the possible covariates of neurological outcome of the child and its growth that are associated with the family background data: maternal age, maternal smoking during pregnancy, maternal alcohol consumption during pregnancy, maternal medical history, and socioeconomic status. The distribution of maternal pre-pregnancy body mass index [weight in kg / (length in m)²] was skewed. Therefore BMI was log 10-transformed before using it in parametric analyses. For a summary of characteristics of the parents, see table 6.2.4 and table 6.2.5.

Table 6.2.4 Characteristics of the parents, part I (metric data)

	Mean	Median	SD	Range
Mother´s age (in years)	29.1	30	5.1	17 – 43
Mother´s weight (in kg)	64.4	63	10.3	43 – 106
Maternal height (in cm)	165.3	165	5.8	148 – 184
Body mass index BMI (in kg / m²)*	23.3	22.9	1.2	16.6 – 39.6
Weight gain during pregnancy	15.0	15.0	4.9	-2 – 32
Parity (number of previous pregnancies)	1.3	1	1.1	0 – 8
Obstetric Optimality Score (out of 73)	62.2	63	3.9	49 – 72

*: For skewed distribution of body mass index, geometric mean and spread factor are given in the table instead of arithmetic mean and standard deviation

Table 6.2.5: Characteristics of the parents, part II (ordinal data)

	N	Percentage
BMI of mother (low / optimal = 18.8 - 24.2 / high)	500	4.8 / 61.0 / 34.2
Alcohol during pregnancy (none / less than once or once per month / more frequently)	500	58.0 / 35.6 / 6.4
Smoking of mother (no / yes)	500	71.2 / 28.8
Smoking of father (no / yes)	497	61.4 / 38.6
Parity (0 / 1 / 2 / >2)	500	26.6 / 35.0 / 25.6 / 13.8
Mother´s nationality (Faroese / Danish / other)	500	96.4 / 2.0 / 1.6
Father´s nationality (Faroese / Danish / other)	498	96.2 / 2.8 / 1.0
Basic school education of mother[1]	500	1.0 / 1.4 / 13.0 / 84.6
Higher school education of mother[2]	500	27.4 / 34.4 / 19.8 / 18.4
Occupation / profession of mother[3]	500	8.6 / 28.0 / 9.4 / 27.0 / 22.2 / 4.8
Basic school education of father[1]	492	9.6 / 2.0 / 13.2 / 75.2
Higher school education of father[2]	493	67.3 / 21.5 / 4.7 / 6.5
Occupation / profession of father[3]	495	5.1 / 10.3 / 3.2 / 42.2 / 29.3 / 9.9

1: 7 years / 8 years / 9 years / 10 years or more
2: None / high school diploma / high school equivalent / commercial school (1 year)
3: Scoring of occupation of parents: no professional education completed or under training / unskilled worker / skilled worker / medium long training / longer training / university training; scoring of profession of parents: under education / unskilled worker / lower employee / middle class employee / independent middle class occupation / higher class occupation; for the item "occupation / profession of mother or father" the highest one of all four variables was selected

6.2.3.1.3 Possible selection bias in study cohort: Comparison of participating and non-participating mother-infant pairs

In the study period (1.1.1998 – 29.2.2000), 1,152 children were born alive in the National hospital. Infants who were born at the hospitals in Klaksvík or Tvøroyri and those, who were born in Tórshavn, but were living with their mothers on the northern islands (Borðoy, Viðoy, Kunoy, Karlsoy, Fugloy, and Svínoy) or on the southern island (Suðuroy) were not included in the cohort. However, one child from Klaksvík and one child from Sandvík (Suðuroy) were found to be misclassified. After exclusion of premature infants of less than 37 weeks of gestation, 1,074 singletons remained. To rule out selection bias for the children in the cohort, those infants of the eligible 1,074, who did not participate, were compared with those of the cohort examined (table 6.2.6). Information was obtained from the birth records that are used for official statistics. Children born by caesarian section or vacuum extraction (instrumental delivery) are underrepresented in the cohort due to the practical difficulties of collecting blood and hair samples under such circumstances.

As major differences between participants and non-participating mother-infant pair, maternal age and parity (younger mothers and those with less children) participated less often. The ratio of infants who had to be transferred to the neonatal intensive care unit was higher in the study group. The number of non-smoking mother is slightly higher in the study group. Although statistically significant, the differences were small and possibly of limited importance for the study.

Table 6.2.6 Comparison of participants and non-participants

	Cohort of 500 children	Non-participants (N=483)	Significan-ce
Sex (male / female)	267 / 233 (53.4% / 46.6%)	254 / 229 (52.6% / 47.4%)	N.s.
Birth weight (g)	3743 / SD 473	3686 / SD 478	N.s.
Length (cm)	53.4 / SD 2.1 (N=499)	53.2 / SD 2.2 (N=481)	N.s.
Gestational age (weeks)	40.1 / SD 1.2	40.1 / SD 1.3	N.s.
Apgar at 1 min.	9.2 / SD 1.0	9.1 / SD 1.1 (N=482)	N.s.
Apgar at 5 min.	9.9 / SD 0.5	9.9 / SD 0.4 (N=482)	N.s.
Pediatrician present at delivery (no / yes)	93.2% / 6.8%	93.6% / 6.4%	N.s.
Transfer to intensive care or observation (no/ yes)	97.6% / 2.4% (N=497)	94.6% / 5.4% (N=482)	**0.016**
Maternal age (years)	29.0 / SD 5.2	28.3 / SD 5.7	**0.038**
Parity (including this one)	2.3 / SD 1.1	2.1 / SD 1.1 (N=482)	**0.018**
Civil status of mother (married or living together with father of child / other)	92.4% / 7.6% (N=397)	91.6% / 8.4 (N=370)	N.s.
Smoking of mother (no / yes)	75.4% / 24.6% (N=491)	69.5% / 30.5% (N=469)	**0.043**
Complications during pregnancy (no / yes)	89.6% / 10.4%	85.5% / 14.5%	N.s.
Induction of labor (no / yes)	73.2% / 26.8%	71.2% / 28.8%	N.s.
Presentation at birth (vertex / other)	87.4% / 12.6%	86.3% / 13.7%	N.s.
Instrumental delivery (no / yes)	87.4% / 12.6%	85.1% / 14.9%	N.s.
Analgesia during delivery (none, acupuncture / more)	48.2% / 51.8%	46.0% / 54.0%	N.s.
Complications during delivery (no / yes)	88.4% / 11.6%	84.5% / 15.5%	N.s.
Color of amniotic fluid (clear / not clear)	88.6% / 11.4% (N=491)	88.2% / 11.8% (N=473)	N.s.

N.s.: Not significant (2-tailed $P > 0.05$)
If information was not available for all children, the number of cases is given in parenthesis.
For ordinal parameters mean and standard deviation (SD) are given.

According to the study protocol, only mothers, who reside in the Streymoy, Eysturoy, Vágar, and Sandoy, were invited to participate. Therefore only very few participants came from the other islands: one child from the southern islands (Suðuroy), one from the northern islands. These two children were subsequently excluded. Children from Eysturoy are over-represented in the study cohort, while those from Vágar participated significantly less then expected, possibly due to longer travel distances.

Table 6.2.7 Mother´s residence

Mother´s residence	Study cohort (N=500)	Non-participants (N=483)	Significance
Tórshavn[1]	51.0%	51.4%	N.s.
Streymoy[2] outside of Tórshavn area	15.4%	14.1%	N.s.
Vágar	3.6%	8.9%	**0.001**
Eysturoy	27.4%	21.7%	**0.039**
Sandoy	2.6%	3.9%	N.s.

1: Tórshavn, Argir, Hoyvík, Kaldbak
2: Vestmanna, Kvívík, Leynar, Nolsoy, Velbastaður, Kollafjørður, Hosvík, Hvalvík, Saksun, Haldarvík, Eiði, Oyrabakki, Streymnes, Koltur, Hestur

6.2.3.2 Covariates / confounders

6.2.3.2.1 Examiner

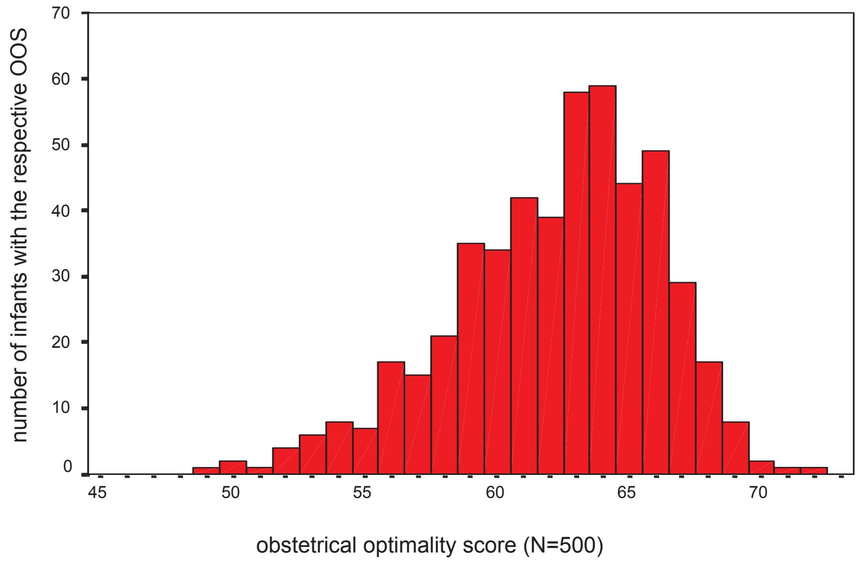
Three examiners were involved in the study: A, B and C. Only few examinations were done by C (5/500), A saw 262 and B 233 of the children. In order to correct for inter-observer differences, the examiner was included as an explanatory variable. The two subcohorts that were examined by pediatrician A and pediatrician B are analyzed here to look for substantial differences between the groups. All examiners were unaware of the exposure to harmful contaminant.

No significant objective differences could be identified between the two subcohorts. Comparison of the exposure data of the two subcohorts revealed no significant differences. However, some fifferences in NOS scores were seen (see section 6.2.3.7.1).

6.2.3.2.2 OOS (Obstetricl optimality score)

The mean of the OOS was 62.2 (out of 73) with a standard deviation of 3.9, the results for the OOS ranged from 49 to 72 points. The quartiles (P25, P50, and P75) were calculated to 60, 63, and 65 points.

Figure 6.2.1: Distribution of OOS



A higher OOS was achieved with prolongation of gestation (p-value for Pearson correlation: 0.036). Boys showed a tendency to lower OOS compared with girls (means in boys: 61.9, girls: 62.6; 2-tailed significance 0.062). Birth weight did not influence the OOS in this cohort.

Lower OOS (more risks and less favorable conditions during pregnancy and delivery) are connected with increasing maternal age, increasing parity, increasing weight of gravida, higher BMI, higher weight gain during pregnancy, and if mother and / or partner are smokers. Higher school education of father and / or mother (but not with profession or occupation of parents) and greater height of mother lead to a higher OOS. The magnitude of correlations reaching significance level between parental characteristics and OOS are shown in table 6.2.8.

Table 6.2.8 Significant correlations between parents´ characteristics and OOS

	Correlation coefficient (P=Pearson, S=Spearman)	P-value (2-tailed)
Maternal age	-0.202 (P)	<0.001
Weight of mother	-0.205 (P)	<0.001
Height of mother	0.110 (P)	0.014
Body mass index of mother (weight / height^2)	-0.250 (S)	<0.001
Weight gain during pregnancy	-0.089 (P)	0.046
Smoking of mother*	-0.141 (S)	0.002
Smoking of partner*	-0.188 (S)	<0.001
Parity	-0.159 (S)	<0.001
Mother´s school education*	0.199 (S)	<0.001
Father´s / partner´s school education*	0.200 (S)	<0.001

* : For scoring: see 2.5.3, 2.5.4 resp. 2.5.5

6.2.3.2.3 Alcohol during pregnancy

The older the mother, the higher is the consumption of alcohol during pregnancy (p=0.005). With increasing height of mother, alcohol is also consumed more often. Astonishingly, a significant positive correlation was found between alcohol and gestational age (Spearman´s rho 0.109, p=0.015), i.e. more alcohol leads to higher gestational age! Mean of length of gestation for teetotalers was 282 days, for children of mothers, who consumed alcohol, 284 days (level of significance for t-value: 0.011). However, consumption of alcohol during pregnancy is correlated with a higher score for mother´s school education, occupation and profession (p<0.001 for all of them). The same is true for the father´s education (p<0.001) and less so for profession (p=0.020). Parents who are not Faroese drink more alcohol (significance of result of T-test is <0.001). The amount of alcohol consumption is positively correlated with more legal abortions (p=0.001) and more late spontaneous abortions, i.e. during 16-28th gestational week (p<0.001). Note must be taken that the alcohol consumption levels in this population are quite low. On the other hand, the NOS of infants of mothers who consumed alcohol during pregnancy is lower, but not significantly different to that of children of teetotaler mothers (p-value for Spearman´s rho: 0.093). When analyzing some of the specific items of the NOS, it was shown that tremor intensity and tremor amplitude increased with higher consumption of alcohol (p<0.05). Although possibly of limited importance due to the limited alcohol intake, these tendencies have to be kept in mind in further analyses of the data.

6.2.3.2.4 Smoking of mother and / or partner
A clear negative correlation was seen between birth weight (p=0.003), body length at NOS (p=0.019), and OOS (p=0.002) with smoking of mother. As could be expected, intrauterine growth retardation in one of the previous pregnancies (Fischer´s exact test: 0.008) or in the present one (Chi-square: 0.005) was highly significantly correlated to maternal smoking. A higher Apgar score at one (p=0.007) and five minutes (p=0.045) is found in children of smoking mothers, the same is true if the father is a smoker but with an even higher significance (Apgar one minute: p=0.002, Apgar five minutes: p=0.029). Maternal smoking is correlated with more overshooting movements (significance of F<0.001) during the neurological examination. Passive smoking of mother (i.e. partner´s smoking) is significantly correlated to muscular hypertonia of the infant (significance of F: 0.023) and with the diagnosis of "opisthotonus" in the infant (0.012). The conclusion of the neurological examination was more frequently described as "suspect" if both parents were smokers (Fischer´s exact test: 0.027). The NOS itself was not significantly correlated to the smoking-status of the parents. Given the known effects of maternal smoking, the prevalence of smoking in these mothers, and the types of associations identified, smoking appears to be an important covariate.

6.2.3.2.5 Education, profession, and occupation of parents
6.2.3.2.5.1 Description
For distribution of parental education, profession and occupation: see section 6.2.3.2.

6.2.3.2.5.2 Effects of education, profession, and occupation of parents
A higher score for the profession or occupation of one of the parents led to a higher birth weight and a higher percentile of birth weight as well as higher percentiles of length and head circumference at NOS. Duration of gestation and Apgar-score are unaffected by educational and / occupational status of parents. Reduced smoking of the pregnant mother and father are significantly correlated with a higher school education (p=0.002 / p<0.001), higher occupation (p=0.017 / p=0.021) and profession (p<0.001 / p=0.004). These anticipated associations support the need to consider all of these covariates together.

6.2.3.2.6 Nationality of parents
Faroese mothers are younger (significance of T-test 0.017) and have a lower pre-pregnancy body weight (0.042). The birth weight of infants of Faroese mothers as compared with infants of non-Faroese mothers is significantly higher (difference of the mean more than 230g, significance of T-test 0.002). The same is true for the percentiles of head circumference and body length at neurological examination (significance of F: 0.007 resp. 0.008 This may be partially explained by the fact that Faroese mothers smoke less then non Faroese mothers (p=0.032). On the other hand their partners are more frequently smokers if their nationality is not Faroese (p=0.022). Faroese mothers are more often teetotaler than mothers of other nationality (<0.001). The Apgar-score of their children after one minute is significantly higher (0.020).

6.2.3.3 Dietary questionnaire
In this paragraph, the result of the analyses of the 262 dietary questionnaires are presented. Only a few of the questionnaires were filled in by the mothers themselves; most were filled in by a project assistant, who questioned the

mothers, thus helping to ensure uniformity of scoring. A summary of the results is given in table 6.2.9 and table 6.2.10.

Table 6.2.9 Dietary habits of mothers during pregnancy, part I

	N	Mean	Median	Standard deviation	P 25	P 75	Range
Total number of meals with whale meat per month	261	1.8	1	1.9	0	3	0 – 8
Total whale meat during pregnancy (in g.)	217	326	100	438	0	600	0 – 2400
Number of meals with blubber per month	256	1.4	0	2.7	0	2	0 – 18
Total amount of blubber during pregnancy (in g.)	238	90.8	0	293	0	100	0 – 3600
Number of other meals with dried whale meat	257	0.6	0	1.9	0	1	0 – 18
Number of other meals with dried blubber	258	1.6	0	3.5	0	1	0 – 18
Number of fish meals per week	256	2.1	2	1.1	1	3	0 - 5
Number of meals with fulmar during pregnancy	258	1.2	0	2.8	0	1	0 – 27
Number of meals with other seabirds during pregnancy	257	1.7	1	4.8	0	2	0 – 36
Number of other meals with meat per week*	253	3.3	3	1.2	3	4	1 – 6

* Normal distribution, the distribution of all other variables was skewed

For those who ate whale meal during pregnancy (N=120), the geometric mean of the total amount was 427g, with a spread factor of 2.4g. For those who ate blubber (N=83), the geometric mean of the total amount of blubber, consumed during pregnancy, was 151 (spread factor 2.5). For the other data with a skewed distribution, the geometric mean of those, who ate the food item, was:

- number of other meals with dried whale meat during pregnancy 1.6 (spread factor 1.9),
- number of other meals with dried blubber during pregnancy 2.4 (spread factor 2.7),
- number of fish meals (per week) 1.8 (spread factor 1.8),
- number of meals with fulmar during pregnancy 1.9 (spread factor 2.2),
- number of meals with other seabirds during pregnancy 2.0 (spread factor 2.3), and
- total number of meals with any seabird during pregnancy 2.5 (spread factor 2.5).

6.2.3.3.1 Dietary habits and parental characteristics

Here, the correlation between parental characteristics and diet was examined as an important way to identify possible predictors of dietary habits. No significant correlation was found between mother´s age, height, weight, or BMI with dietary habits during pregnancy.

Women who ate more whale meat meals during pregnancy reported abortion in late pregnancy (16-28 weeks) more often (significance of t-value of independent samples test: 0.012).

The lower the parents' education, the more whale meat and blubber were consumed. Father's education is further correlated to the number of fish meals: the higher the level of education, the less fish meals were eaten by the mother during pregnancy. In interpreting this information, it must be kept in mind that the Faroese authorities have issued advisories regarding whale consumption, and that the impact of such recommendations may be related to the subjects educational level.

The more alcohol the mother consumed during pregnancy, the more meals with dried whale meat she ate (significance of Spearman´s rho: 0.019). Maternal smoking during pregnancy (dichotomized into "yes" or "no") is strongly correlated with eating blubber or whale meat on two consecutive days (2-sided significance for Fischer´s exact test; 0.009 and 0.024, respectively) and a similar tendency was seen for the smoking of the partner.

Father´s nationality (Faroese or not) and mother´s fish consumption are significantly correlated with each other: if the father was Faroese, 2.1 fishmeals per week were reported compared to1.9 for a non- Faroese father (2-tailed significance for independent-samples T-test: 0.010), but no significant correlation was seen with mother´s nationality.

Again, these associations in general are quite in accordance with expectations and confirm the importance of considering these factors as covariates.

Table 6.2.10 Correlation between mother´s dietary habits during pregnancy of and parent´s education / profession / occupation

Spearman´s rho p-values (2-tailed significance)	Mother´s education	Mother´s occupation	Father´s education	Father´s occupation
Total amount of whale meat (N=217)	-0.199 **0.003**	-0.208 **0.002**	-0.266 **<0.001**	N.s.
Total amount of blubber (N=238)	-0.082 0.205	-0.184 **0.004**	-0.162 **0.013**	N.s.
Number of other meals with dried whale meat (N=257)	N.s.	0.115 0.066	N.s.	N.s.
Number of other meals with dried blubber (N=258)	0.192 **0.002**	N.s.	N.s.	N.s.
Number of fish meals per week (N=256)	N.s.	-0.105 0.095	-0.250 **<0.001**	N.s.
Number of other meals with meat per week (N=253)	N.s.	N.s.	0.122 0.054	N.s.
Change of usual consumption of blubber during pregnancy* (N=258)	N.s.	N.s.	N.s.	N.s.
Change of usual consumption of seabirds during pregnancy* (N=255)	N.s.	-0.117 0.063	N.s.	N.s.

* : Possible answers were "much less", "less", "the same", "more", and "much more"

6.2.3.3.2 Diet and present recommendations

"Women who intend to get pregnant during the next three months, women who are pregnant or those who are breastfeeding should not eat any whale meat at all. Livers and kidneys of whale should be eaten at all." The health authorities of the Faroes issued this advisory in 1998 (Heilsufrøðiliga Starvsstovan, 1998). The results of the questionnaires, all of which were completed after 1 January 1999, revealed that many mothers had either been unaware of the recommendations or had ignored them. More than 60% of women ate whale meat, and about 30% consumed blubber during pregnancy.

No difference could be seen between the number of mothers who refrained from whale meat or blubber meals in the first months of 1999 and in the last three months of the study (i.e. December 1999 and February 2000).

How many mothers reduced their consumption of whale during pregnancy? 71% of the mothers stated that they reduced the consumption of whale meat during pregnancy; 61% ate less blubber. Only very few of them increased the amount of whale meat, and no one ate more blubber during pregnancy than before. About 65% of the mothers who filled the questionnaire had eaten at least one meal containing seabirds; 20% had eaten fulmar for dinner on more than one occasion; 28% had eaten other species at least twice during pregnancy. These results suggest that the advisory has had a substantial effect, though it was by no means fully successful.

Table 6.2.11 Dietary habits of mothers during pregnancy, part II

	N	Number; percentage
No whale meat at all	261	97; 37.2%
No blubber at all	256	155; 60.5%
Consumption of whale meat during pregnancy: less / unchanged / more	259	184 / 74 / 1 71.0% / 28.6% / 0.4%
Consumption of blubber during pregnancy: ess / unchanged / more	258	158 / 100 / 0 61.2% / 38.8% / 0%
No fulmar at all	258	153; 59.7%
No other seabirds at all	257	128; 49.8%
No seabirds at all	256	89; 34.8%
Consumption of seabirds during pregnancy: Less / unchanged / more	255	50 / 203 / 2 19.6% / 79.6% / 0.8%

6.2.3.4 *Exposure Variables*

For their skewed distribution, the geometric mean and spread factor were calculated to characterize the concentration of exposure variables in maternal hair and breast milk. Very wide ranges of exposure data were found. The ratio of the highest to the lowest concentration of the substances are given in the column "max. / min." in table 6.2.12.

Table 6.2.12 Mercury (µg/g in maternal hair) and POPs (µg/g lipid in breast milk)

	Mean	Geometric mean	Spread factor	P25	P75	Min.	Max.	Max. /min.
Mercury	2.998	2.073	2.460	1.190	3.898	0.0200	32.72	1636
HCB	0.044	0.039	1.673	0.026	0.052	0.0090	0.256	28
β-HCH	0.023	0.020	1.623	0.015	0.027	0.0015	0.210	140
PCB-105	0.018	0.012	2.623	0.007	0.022	0.0015	0.109	73
PCB-118	0.082	0.059	2.280	0.037	0.105	0.0015	0.629	419
PCB-138	0.280	0.215	2.038	0.137	0.344	0.0150	3.147	210
PCB-153	0.372	0.287	2.019	0.183	0.460	0.0190	3.830	202
PCB-156	0.027	0.021	2.069	0.014	0.035	0.0015	0.164	109
PCB-180	0.208	0.160	2.058	0.100	0.262	0.0070	1.817	260
Σ PCB*	1.720	1.330	2.022	0.848	2.078	0.0820	17.59	215
4,4'-DDT	0.035	0.022	2.731	0.013	0.043	0.0015	0.482	321
4,4'-DDE	0.857	0.599	2.280	0.359	0.991	0.0590	11.35	192
Sum DDT+DDE	0.892	0.624	2.282	0.376	1.036	0.0610	11.83	194
Ratio DDT/DDE	0.042	0.037	1.662	0.028	0.053	0.0025	0.117	47
Trans-nonachlor	0.153	0.099	2.592	0.056	0.192	0.0050	1.889	378
Musk xylene	0.016	0.013	1.867	0.008	0.017	0.0015	0.297	198

* : 2.0 x PCB (138+153+180)

6.2.3.4.1 Mercury
The mean concentration of mercury in maternal hair was calculated to nearly 3 μg/g of hair, the geometric mean for the skewed distribution reaching only 2 μg/g. Ten hair samples (5%) exceeded the value of 10 μg/g MeHg, a limit previously thought to protect against clinical adverse effects. In 74 (14.8%) samples more than 5 μg/g was found. The range of the distribution was wide: the lowest samples containing not more than 0.02 μg/g, the one with the highest load nearly reaching 33 μg/g. Thus the ratio between the highest and the lowest concentration calculates to more than 1,600 (see table 6.2.12).

6.2.3.4.2 PCB / POPs
The few samples containing non-detectable levels of one of the POPs were given the concentration of 0.0015 μg/g for purposes of statistical analyses. This level corresponds to a concentration below the detection limit. For HCH, one sample was below detection limit; for PCB-105, 36 samples; for PCB-118, one; for PCB-156, seven; 4,4′-DDT, 16, and musk xylene, one.

The mean for the ΣPCB (twice the sum of PCB's 138, 153, and 180) was 1.7 μg/g lipid, and the geometric mean 1.3 μg/g lipid; 93 milk samples (18.6%) had a ΣPCB >2.5 μg/g. There were 10 samples being above a 6 μg/g limit

To get an impression of the extent of contamination of the breast milk of the Faroese mothers with persistent organic pollutants, the concentrations of the present cohort were compared to the reference values given by the German Federal Agency for the Environment (Institut für Wasser-, Boden und Lufhygiene, 1999) These values represent the 95^{th} percentile of the concentrations found in unselected breast milk sample in 1994 (N=1757). The limits for the two di-ortho congeners IUPAC number 180 and 153 were exceeded by more than one-third and nearly half of the Faroese samples, respectively (table 6.2.13).

Table 6.2.13 Concentrations of POPs in breast milk and German reference values

	German reference limit for breast milk samples	Number of samples exceeding this limit	Percentage of samples exceeding the limit
β-HCH	0.1 μg/g lipid	3	0.6%
HCB	0.3 μg/g lipid	0	0%
PCB-138	0.3 μg/g lipid	2	0.4%
PCB-153	0.3 μg/g lipid	228	**45.6%**
PCB-180	0.2 μg/g lipid	182	**36.4%**
Sum PCB*	1.2 μg/g lipid	209	**41.8%**
Sum DDT + DDE	0.9 μg/g lipid	2	0.4%
Musk xylene	0.33 μg/g lipid	0	0%

* : 1.64 x (PCB138 + PCB 153 + PCB 180) to compare with German summation of a limited number of congeners

As for mercury, the range for each substance was very wide. The ratio between the highest and the lowest concentrations varied between 28 for HCB and 420 for PCB-118 (table 6.2.12).

The ratio of DDT to DDE was calculated in order to obtain some information about the origin of dioxins: If the share of DDT is higher, it would suggest a recent exposure to DDT trough food contaminated by current use of DDT in nearby regions. If DDE dominates, this will indicate that DDT has accumulated in the food chain over a longer period, possibly from far-away sources (AMAP, 1997). For the mothers of the study group only very low values for the DDT/DDE-ratio were found, thus indicating no direct contact to DDT. With the ban of DDT in the region in effect, this was to be expected. Still, the continued presence of DDT many years after the ban in the EU suggests that current or recent use of DTT elsewhere adds to the marine contaminantion.

6.2.3.4.3 Correlations between exposure data

The six different PCB congeners measured in breast milk were all significantly correlated to each other (Spearman´s rho correlation coefficient >0.8 for most substances), therefore suggesting a common source for the contamination.

HCB, DDT, DDE, and trans-nonachlor also correlated very well with all PCB congeners: ΣPCB and HCB: r=0.85; ΣPCB and DDT: r=0.85; ΣPCB and DDE: r=0.88; ΣPCB and trans-nonachlor: r=0.93. However, methyl mercury and PCB congeners were related to each other to a much smaller degree (ΣPCB and MeHg: r=0.39). Also the correlation between the PCB-congeners and β-HCH was only weak (ΣPCB and β-HCH: r=0.28).

Musk xylene is correlated with DDE (p=0.042) and the sum of DDT + DDE (p=0.048). The higher the DDT/DDE-ratio the lower the concentration of musk xylene that was found in breast milk (p=0.017).

The DDT/DDE – ratio is higher in the milk of mothers with higher hair mercury, higher HCB, trans-nonachlor, PCB-105, PCB-118 (p<0.01 for all of them), and musk xylene (p=0.013).

Because the lipophilic contaminants originate form blubber and mercury from meat, the association demonstrate that mothers eating blubber are also likely to eat whale meat. However, in this regard the relatively short biological half-life of methyl mercury in the body (as compared to PCB and DDE) should be kept in mind.

The complete set of correlations can be found in table 6.2.22 in the appendix.

6.2.3.4.4 Parental characteristics and exposure values

Increased maternal age is significantly correlated with higher levels of β-HCH, HCB, all PCB-congeners, DDT, DDE, and trans-nonachlor (p-value <0.001). The association is likely due to accumulation of these persistent compounds with age. Higher parity also leads to an increase in mercury, HCB, all measured PCB-congeners, DDT, DDE, and trans-nonachlor (p-value for 2-tailed significance of Spearman´s rho for the correlation: <0.001 for each of them). However, when controlling for maternal age, the picture changes: while mercury still increased significantly (p-value <0.001), β-HCH decreased with parity (p-value <0.001). For most other substances weak negative correlations were found.

A significant positive correlation was found for pre-pregnancy BMI with ß-HCH, HCB (p-value 0.005 for Spearman´s rho), musk xylene, PCB-105, sum of the three measured mono-ortho PCB-congeners (PCB-105, PCB-118, and PCB-156), DDT, and DDE, and for maternal weight with HCB, β-HCH, PCB-105, PCB-118, DDT , DDE, and musk xylene. But the data analysis did not reveal a significant correlation with maternal height.

A negative correlation appeared for weight gain during pregnancy with mercury, ß-HCH, HCB, PCB-105, PCB-118, PCB-138, PCB-153, PCB-156, DDT, DDE , and trans-nonachlor.

Mercury in hair ($p=0.012$) and β-HCH ($p=0.003$) in breast milk were positively correlated with the mother´s consumption of alcohol during pregnancy. The geometric mean of all other measured contaminants was higher in mothers who confirmed any consumption of alcohol during pregnancy. The ratio of DDT/DDE in these mothers was significantly higher than the one in teetotalers ($P=0.020$).

Smoking was associated with lower concentrations of musk xylene, PCB-105 ($p=0.070$), and DDT while the concentration of the other pollutants increased with the number of cigarettes smoked by the mother.

The mothers were interviewed about complaints about previous fertility problems. Those who reported problems with getting pregnant had significantly higher PCB-118 ($p=0.049$), PCB-138 ($p=0.016$), PCB-153 ($p=0.026$), PCB-156 ($p=0.030$), PCB-180 ($p=0.034$), DDE ($p=0.040$), and trans-nonachlor ($p=0.050$) than those who became pregnant without problems or delay. Mercury was lower ($p=0.003$) in mothers who had troubles with infertility.

The data showed a tendency to a higher rate of spontaneous early abortions with higher concentrations of mercury ($p=0.050$), HCB ($p=0.083$), PCB-118 ($p=0.021$), PCB-105 ($p=0.015$), DDE ($p=0.018$), and DDT ($p=0.024$). Cases of late abortion, i.e. during 16th to 28th week of gestation, more frequently occurred at higher mercury concentrations ($p=0.034$). The same tendency was seen for β-HCH and HCB ($p=0.092$ and 0.097, respectively): higher contamination levels thus seem to increase the risk for abortions. On the other hand, age and parity may be important covariates that need to be concidered.

Because previous infertility and the number of abortions is strongly correlated with maternal age, the connection between both variables and the exposure data was analyzed once more after controlling for maternal age. The significant correlations remained unchanged. Solely the significance of MeHg as protection against infertility vanished. Further exploration of these issues seems indicated.

For the relation between contaminants and complications during parturitions significant correlations were found for: HCB ($p=0.027$), β-HCH ($P=0.005$), PCB-105 ($p=0.033$), PCB-118 ($p=0.037$), PCB-138 ($p=0.035$), PCB-156 ($p=0.026$), and DDE ($p=0.036$). For the cases where complications during child birth were recorded, the concentrations of pollutants uniformly was higher than for those with an uncomplicated birth.

Significant correlations (p-values for 2-tailed significance of Spearman´s rho are given in parentheses if they were ≤ 0.05 and ≥ 0.001, all other p-values were <0.001) were found between mother´s education, profession, and present occupation with the exposure parameters. Higher maternal education lead to lower mercury (0.047), higher β-HCH (0.001), PCB-105 (0.006), PCB-118 (0.007), PCB-138 (0.011), PCB-153 (0.005), PCB-156 (0.001), PCB-180 (0.001), DDT, DDE (0.007), trans-nonachlor (0.027), and musk xylene (0.034) is found with higher maternal profession; higher maternal occupation is significantly correlated with higher HCB (0.005), β-HCH, PCB-105 (0.012), PCB-118 (0.018), PCB-138 (0.009), PCB-153 (0.003), PCB-156, PCB-180, DDT (0.008), DDE (0.039), and trans-nonachlor (0.022).

If the same analyses were done for the father / the partner of the mother, the results were: higher school education of father is correlated with a lower MeHg in mother´s hair (0.016), with a lower HCB (0.020), PCB-105 (0.002), PCB-118 (0.003), PCB-138 (0.002), PCB-153 (0.005), PCB-156 (0.045), PCB-180 (0.026), DDE (0.008), and trans-nonachlor in mother´s milk; higher values of HCB (0.012), β-HCH (0.020), PCB-105 (0.023), PCB-118 (0.008), PCB-138 (0.015), PCB-153 (0.006), PCB-156 (0.010), PCB-180 (0.004), DDT, DDE (0.003), and trans-nonachlor (0.025) correlate significantly with a higher score for father´s profession, while for father´s occupation significant correlation could be found solely for β-HCH (0.011), PCB-118 (0.047), and DDT (0.003).

Overall, these associations perhaps reflect a lower educational level in subjects involved in whaling, perhaps also in the degree that governmental advisories are taken into regard. Further studies are needed to clarify these aspects and their associations with age.

When exposure data were inspected with respect to mother's nationality, contaminants were higher in the samples of Faroese women. Only β-HCH tended to be slightly lower in Faroese women ($p=0.129$). The differences in exposure were highly significant for all measured PCB-congeners, trans-nonachlor, and DDE (2-tailed significance of results of T-test for independent samples test: <0.001). These differences were not explained by confounding by maternal age, weight, BMI and / or parity. The impact of the father's nationality was much weaker and not significante.

Table 6.2.14 Summary of correlations between contaminants and parental characteristics

	Positive	Negative
Mercury in (mother´s hair)	Parity**, mother´s alcohol consumption during pregnancy*, mother is Faroese**	Teetotal mother*, father´s school education, weight gain during pregnancy*
ß-HCH (in breast milk)	Maternal age**, mother´s weight**, BMI**, mother´s alcohol consumption during pregnancy**, father´s profession*, father´s occupation*, previous infertility*, complication under birth**	Weight gain during pregnancy, teetotalling mother**, mother is Faroese**, weight gain during pregnancy*, OOS**
HCB (in breast milk)	Maternal age**, mother´s weight**, BMI**, father´s profession*, mother is Faroese*, parity**, complication under birth*	Father´s school education, weight gain during pregnancy**, OOS*
Σ PCB (in breast milk)	Maternal age**, parity**, father´s profession**, mother is Faroese**, previous infertility**, complication under birth*	Father´s school education**, weight gain during pregnancy**, OOS*
4,4´-DDT (in breast milk)	Maternal age**, mother´s weight**, BMI**, father´s profession**, father´s occupation**, mother is Faroese**, parity**, complication under birth*	Weight gain during pregnancy**
4,4´-DDE (in breast milk)	maternal age**, mother´s weight*, BMI**, parity**, father´s profession**, mother is Faroese**, previous infertility*, complication under birth*	Father´s school education**, weight gain during pregnancy*, OOS*
Trans-nonachlor (in breast milk)	Maternal age**, parity**, father´s profession*, mother is Faroese**, previous infertility**	Father´s school education**, weight gain during pregnancy*, OOS**
Musk xylene (in breast milk)	Mother´s weight**, BMI**	

**: Correlation is significant at the 0.01 level (two-tailed).
* : Correlation is significant at the 0.05 level (two-tailed).

6.2.3.5 Correlations between exposure variables and diet

In this section, the association between dietary habits is examined with regard to contamination with particular pollutants.

The highest correlation between mercury in mother's hair and food was found for the number of meals containing whale meat. But also blubber consumption, the number of fish meals per week, and the number of fulmars eaten during pregnancy showed a very close correlation to hair mercury of the mother (table 6.2.23). However, these dietary habits were also intercorrelated.

HCB, DDT, DDE, and trans-nonachlor were very closely correlated with the consumption of blubber and fulmar. The concentration of these pollutants also increased significantly with the consumption of whale meat and the meat of other seabirds. The amount of DDT ingested with blubber seems to be higher than that of DDE resulting in a significant increase of the DDT/DDE-ratio in the milk of these mothers (table 6.2.23). A detailed assessment of the

contribution of these dietary items will depend on data on pollutant concentrations in these items.
Concentrations of PCB-105, 118 and 138 in breast milk are very well correlated to the consumption of any form of whale products (meat or blubber, dried or fresh) and the number of fulmars eaten during pregnancy. The consumption of blubber (dried or fresh) and fulmars seem to best predict the concentration of the PCB-congeners 153, 156, and 180 in breast milk, while whale meat is only a minor source of these congeners (table 6.2.24).

No significant positive correlation was observed between any kind of food mentioned on the questionnaire and β-HCH or musk xylene.

The consumption of which food leads to a significant change of the load with the different pollutants? Information to the question is collected in table 6.2.15. Dried blubber and fulmar seem to be the two sources that add the highest number of contaminants in significant amount. Not all possible foods containing the measured pollutants were registered in the questionnaire. More information about the sources of the contaminants may be revealed by further research.

Table 6.2.15 Correlations between dietary habits and exposure variables

Dietary habit	Positive correlation with harmful substances (unless otherwise: indicated)
Number of whale meals	Hair mercury**, HCB, PCB 118, PCB 105**, PCB 138, DDE, DDT**, t-nonachlor**
Total amount of whale meat	Hair mercury**, PCB 118, PCB 105, DDE, DDT**, t-nonachlor**
Number of blubber meals	PCB 118, PCB 105, PCB138, ΣPCB**, DDE, DDT*, ratio DDT/DDE, t-nonachlor**
Estimated total amount of blubber	Hair mercury**, PCB 118, PCB 105, PCB 138, ΣPCB**, DDE**, DDT**, ratio DDT/DDE, t-nonachlor**
Number of other meals with dried blubber	Hair mercury**, PCB 118**, PCB 153, PCB 105, PCB 138**, sum of PCBs, DDE**, DDT**, ratio DDE/DDT, t-nonachlor**
Number of fish meals per week	Hair mercury**, PCB 105, PCB 118, DDT, DDE, t-nonachlor
Meals with fulmar	HCB, PCB 118**, PCB 153**, PCB 105**, PCB 138, PCB 156**, PCB 180, ΣPCB, DDE, t-nonachlor**
Meals with other seabirds	HCB, PCB 118, PCB 105, DDT
Number of other meals with meat per week	**Negative** correlation to: hair mercury**, HCB, HCH

** Correlation is significant at the 0.01 level (2-tailed); all other correlations were significant at the 0.05 level.

6.2.3.6 Dependent variables, part I: Anthropometric data, gestational age, and gender

6.2.3.6.1 Anthropometric data of infants

6.2.3.6.1.1 Description

A wide range of birth weight was found with a Gaussian distribution. Boys were heavier than girls at birth, they were longer, and had a bigger head circumference (length and head circumference were measured at the neurological examination). The differences of all three measurements between both sexes were highly significant (p-value <0.001) (table 6.2.16).

Table 6.2.16 Anthropometric data (mean, SD, second line in each cell: range of parameter)

	All infants	Boys (N=267)	Girls (N=233)
Birth weight in g (N=500)	3743 ± 473 2450 - 5400	3827 ± 505 2450 - 5400	3647 ± 415 2650 - 5100
Length at NOS in cm (N=499)	54.3 ± 1.9 47 – 60	54.8 ± 1.9 47 - 60	53.7 ± 1.7 50 - 59
Head circumference at NOS in mm (N=498)	370 ± 12 340 – 401	373 ± 11 342 - 401	366 ± 11 340 - 395

6.2.3.6.1.2 Correlations

6.2.3.6.1.2.1 Correlations of anthropometric variables and gestational age with parental attributes

The birth weight of infant was positively correlated with BMI of the mother (p=0.002), weight gain during pregnancy (p=0.048), mother´s weight (p <0.001), mother´s height (p <0.001), mother´s age (p=0.020), parity (p <0.001), and the fact that the mother suffered from diabetes (persistent or gestational) (p=0.013). A reduction of birth weight was linked to maternal smoking (p=0.003) and arterial hypertension (p=0.041). The analyses about a correlation between the metric data (mother´s weight, height, BMI, age, parity, and weight gain during pregnancy) were repeated while controlling for gestational age in days. The results remained virtually unchanged.

Birth weight is higher in infants of Faroese mothers as compared to those of non-Faroese mothers (p=0.002). The head circumference of these infants was also bigger (p=0.033) while the difference in length did not reach significance.

No major difference in these correlations was seen between boys and girls.

Gestational age (in days) increased with a higher maternal weight (p=0.030). Alcohol consumption during pregnancy appeared to prolong gestation (p=0.011). Arterial hypertension already present before pregnancy (p=0.043) and hypertension early in pregnancy (p=0.016) led to a shorter gestation. These tendencies are obviously affected by obstetric interventions.

6.2.3.6.1.2.2 Correlation of anthropometric outcome and gestational age to exposure variables

A positive correlation between all exposure variables and birth weight were observed except for β-HCH. A significant positive influence on birth weight was reached for PCB-105 and PCB-118, and the sum of the three measured mono-ortho PCBs (congeners 105, 118, and 156). To differentiate between possible effects of pollutants on birth weight, the data were re-analyzed while controlling for gender. As already mentioned, the birth weight of boys was significantly higher than that of girls (see table 6.2.16).The boys showed a high sensivity to HCB, PCB-105, PCB-118, and DDT, while for girls no significant effect of exposure variables on birth weight could be found (table 6.2.25 in the appendix). For boys a highly significant relation between the DDT / DDE-ratio and birth weight was seen: the higher the ratio, the higher the birth weight (p=0.003).

No new information was achieved if partial correlation coefficients were calculated while controlling for gestational age, maternal age, parity, and log10 of mother´s BMI.

Effects of exposure on head circumference measured at the neurological examination were weak. (table 6.2.26 in the appendix). If the analysis for the correlation between head circumference at neurological examination and exposure data was repeated after controlling for corrected age at neurological examination, a significant positive influence of MeHg, PCB- 105, and PCB-118 was seen for the whole cohort, while only PCB-105 increased the head circumference in boys (table 6.2.27). When taking the percentile of head circumference, the impact of all measured contaminants is greater in boys. HCB, PCB-118, 105 and 138, sum of the three mono-ortho PCBs, DDT, and trans-nonachlor reached significant levels of correlation. In girls no significant correlations between either head circumference – controlled for age – or percentile of head circumference at NOS and exposure data were found (table 6.2.28 in the appendix).

For the complete cohort, no significant correlation was found between length at NOS and exposure data. All correlations were, however, positive except for β-HCH which gave a weak negative correlation (table 6.2.29 in the appendix). After further controlling body length for corrected age after expected date of delivery at neurological examination, for maternal height and weight, parity, and for log 10 of PCB-105, the relation between length and exposure data became more clear: HCB, β-HCH, DDT, and DDE significantly decreased the length (table 6.2.30).

6.2.3.6.1.2.3 Linear regression model for calculation of birth weight

All the identified major factors influencing birth weight were used to create a linear regression model. The log10-transformed values of PCB-105 and ΣPCB served as independent variables. Gestational age (in days), maternal height, weight, and parity were introduced as covariates. As further important factors for birth weight, sex, Faroese and non-Faroese mother, mother with and without diabetes mellitus, and smoking of mother during pregnancy were added. For a summary of the model see table 17. The R^2 for the model was 0.274 (adjusted R^2 0.259).

Table 6.2.17 Linear regression for birth weight (in grams)

	Unstandardized coefficient B	Standard error of B	Significance for T	95%-confidence interval for B
(Constant)	-2984	839	<0.001	-4633 – -1335
Gestational age (days)	18	2	<0.001	13 – 22
Height of mother (cm)	9	3	0.006	3 – 16
Weight of mother (kg)	5	2	0.012	1 – 9
Primipara (no / yes)	-256	42	<0.001	-339 – -173
Log10 PCB 105	242	78	0.002	87 – 396
Log10 PCB 153	-315	108	0.004	-527 – -103
Gender (male / female)	-188	37	<0.001	-260 – -115
Smoking/non-smoking mother	-110	41	0.008	-191 – -28
Non-Faroese / Faroese mother	351	103	0.001	148 – 554
Diabetes of mother no / yes	155	65	0.018	27 – 283

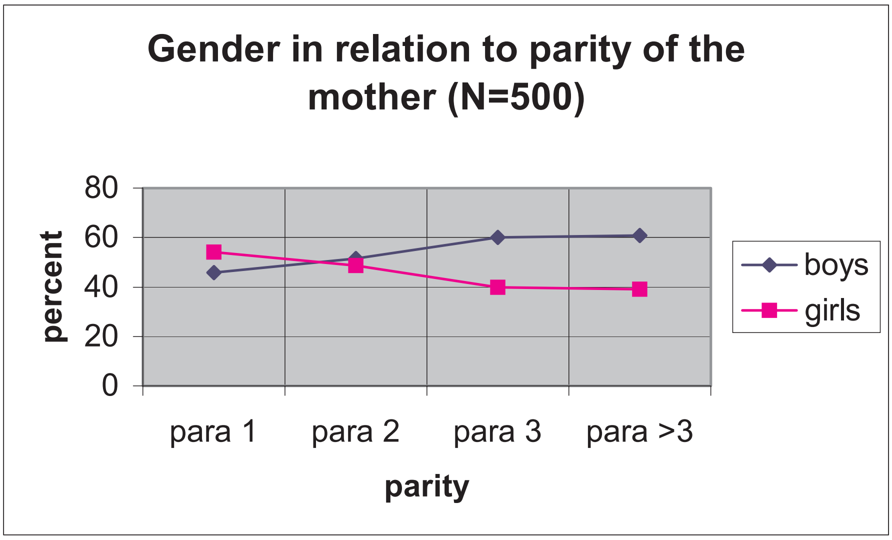
Unstandardized regression coefficients can be used to calculate the change of birth weight (in grams) per unit change in each variable, e.g. if gestation is one day longer, the birth weight can be expected to be 18g higher. For the log10-transformed exposure variables, a 10-fold change will cause a change of birth weight in the magnitude of the correlation coefficient, i.e. a plus of 221g for a 10-fold increase in PCB-105 and a minus of 315g for ΣPCB. The results shown indicate that several factors impact on birth weight. The effect of PCB congeners in different directions may be a statistical phenomenon due to collinearity, but it is also possible that PCB congeners may exert different effects.

6.2.3.6.2 Gestational age

Duration of gestation was mostly influenced by maternal condition during the present, but also during former pregnancies: Arterial hypertension in the first trimester of pregnancy as well as any complication during a previous pregnancy led to a significantly earlier delivery (4 resp. 2 days). Other non-obstetrical disease during the present pregnancy (excluding diabetes, epilepsy, hypertension, and heart diseases) was also correlated with a significant shortening of gestation (mean of gestation for healthy mothers: 284 days, for those with disorders: 280 days; $p=0.039$). Previous spontaneous abortion (one or more) resulted in a shorter gestation for the child: 284 days if no abortion was reported, 282 days for any number of early abortions <16 weeks ($p=0.025$). The same difference in duration of gestation was found for primiparae versus women with at least one previous birth ($p=0.031$). For the next pregnancies (third or more deliveries) a significant additional shortening of gestation was found ($p=0.024$). Exposure variables were only weakly associated with gestational age.

Figure 6.2.2: Distribution of sex for parity

$R^2=0.9$



6.2.3.6.3 Sex

Mothers of boys were about one year older than those of girls ($p=0.046$). This might explain why all measured contaminants were found in a slightly higher concentration in boys except for β-HCH that was higher in girls. None of the differences reached significance level. Since parity is also known to be of major influence on the load of contaminants, the infants were grouped after parity of mother. The sex distribution shows a higher ratio of girls for primipara (opposed to general experience which predicts a higher ratio of boys) and it changes after the second pregnancy to the expected distribution. To confirm this strange finding, the sex of all infants with known parity and who were born in the Tórshavn hospital during a period of 28 months

(15.11.1997 to 15.3.200, N=1251) were analyzed, but the result remained unchanged (R^2 of trend line was 0.89). (Fig. 6.2.2). It is still unclear wheter this tendency is accidental or related to some form of selection bias.

6.2.3.7 Dependent variables: neurological outcome

Analysis of neurological outcome in relation to exposure variables is divided in the results for the neurological optimality score (NOS) and the analysis of further neurological signs which were measured as a part of the neurological examination such as abnormal high or low muscle tonus, reduced amount of spontaneous movements (hypokinesia) and so on.

6.2.3.7.1 Neurological outcome, part I: NOS

In general the total score of the NOS became higher towards the end of the examination period (correlation between date of examination and NOS highly significant, p-value for the Pearson correlation was <0.001). For the first 250 infants the mean of the NOS was 49.6 points out of a maximum of 60 points, for the second half of the children 50.3.

6.2.3.7.1.1 Description of results

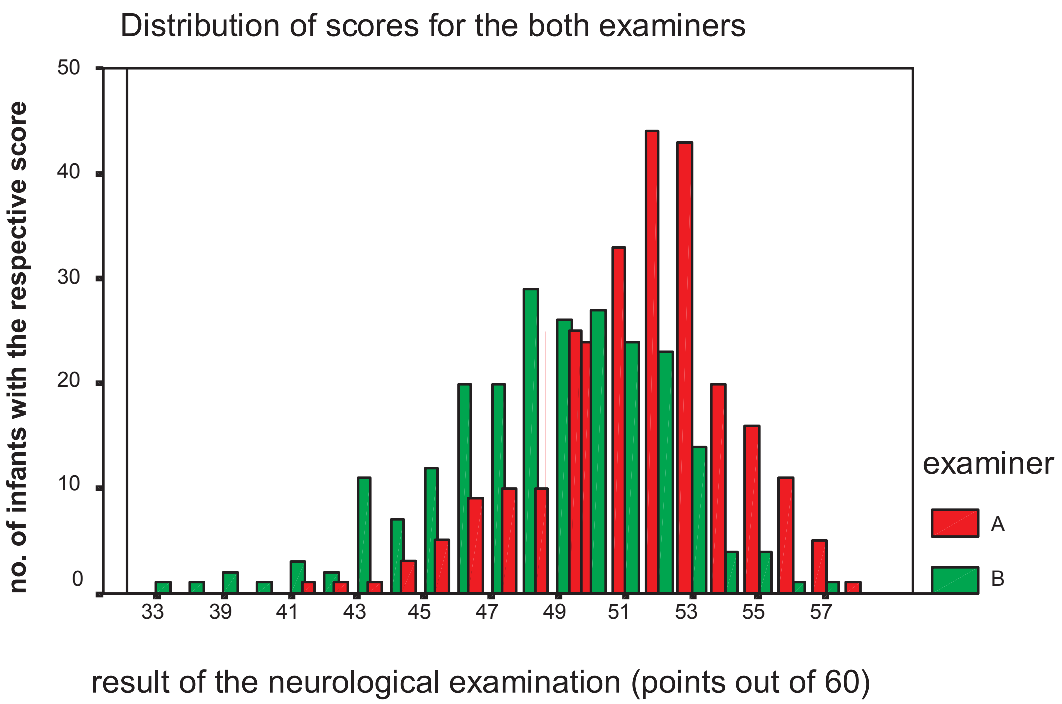
Most of the children, i.e. 368 or 73.6% were examined at the optimal age for the neurological examination (between 10 and 21 days after the expected date of birth). A total of 33 children (6.6%) were younger than 10 days, and 99 (19.8%) older than 3 weeks (see figure 6.2.4 in the appendix). This variation in age is obviously an effect of scheduling problems for mothers not reciding in Tórshavn.

The examination started in four children directly after the last meal. The largest interval between last meal and examination was 5 hours. The majority of children (323 /467 or 69.2%, for 33 infants this value was unknown) was seen between 1½ and 3 hours after the last meal.

262 children were examined by pediatrician A, 233 by pediatrician B. The remaining 5 infants were seen by pediatrician C. The mean as well as the median of the sum score was 50 (out of 60) with a standard deviation of 3.6. The child with the lowest score archived 33 points, the highest score was 58. P10 was 45, P25: 48, P75: 52, P90: 54. For 8 infants (1.6%) the clinical diagnostic classification was suspect, none of the infants were considered abnormal. The clinical diagnosis sorted after examiner were: 262 / 262 children seen by A were normal, 226 / 233 children seen by B were normal, 7 abnormal. C examined 5 children, one of them was classified as suspect.

As already mentioned in paragraph 6.2.3.2.1, the result of the NOS was significantly higher in infants, examined by A. The distribution of the scores given by the two main examiner can be seen in figure 6.2.3.

Figure 6.2.3: Distribution of Neurological Optimality in dependence of examiner (A/ B)



6.2.3.7.1.2 Association / correlation with parental / gestational data

A negative correlation of NOS was found with the percentile of head circumference (p=0.012) and percentile of length (p=0.010), i.e. infants with a larger head or longer length scored lower. In the subcohort of infants seen by B the large-for-gestational-age infants (percentile of birth weight >90) had a significantly lower NOS than infants with a birth weight that was small or appropriate for gestational age (p=0.021).

Parental smoking (sum of score for maternal and partner´s smoking during pregnancy) is correlated to a less favorable diagnosis of NOS (suspect or abnormal result of neurological examination) (p=0.036).

The higher the score for mother´s education (or the higher one of the scores for parents school education) the more likely was the diagnoses "normal" in the summary for the neurological examination (p=0.034; for parents´ education, 0.009). If the result of NOS in infants whose parents had a higher level of profession or occupation (see paragraph 6.2.2.5.5) were compared to those with a lower level of profession or education, there was a significant decrease in NOS (p=0.017).

In the B-subcohort, infants who were large-for-gestational age (birth weight >P90) had a significant lower result in the neurological examination (mean of NOS for large-for-gestational age infants: 47.2, appropriate- or small-for-gestational age: 48.7; p=0.021). This findings will be further analysed, and regard will be taken of the potential risk of birth complications associated with large birth size.

6.2.3.7.1.3 Correlation of NOS with exposure data
An increase in concentration of 4,4'-DDT in breast milk led to a less favorable NOS diagnosis, i.e. more frequently a suspect result was given (p=0.026). No other significant correlations between exposure and NOS could be found in the complete group.

In the children examined by B, clear correlations of the NOS with the exposure data were seen: PCB-118, PCB-105, DDT, and trans-nonachlor led with high significance to a lower NOS. Also HCB, PCB-138, PCB-180, and DDE caused a reduction of NOS, the connection between NOS and contaminants being significant (p<0.05). For full detail of correlation coefficients and level of significance: see table 6.2.18.

Table 6.2.18 Correlation of NOS with exposure data, differentiated for examiner

	All children (N=500)		Subcohort B (N=233)		Subcohort A (N=262)	
	Spearman´s rho	P-value	Spearman´s rho	P-value	Spearman´s rho	P-value
Methylmercury	-0.061	0.174	-0.094	0.151	-0.013	0.838
HCB	-0.064	0.151	-0.206**	**0.002**	0.077	0.214
β-HCH	-0.020	0.651	-0.101	0.125	0.038	0.543
Musk xylene	-0.019	0.664	-0.077	0.244	0.028	0.657
PCB 118	-0.033	0.457	-0.176**	**0.007**	0.104	0.094
PCB 153	-0.036	0.428	-0.150*	**0.022**	0.093	0.135
PCB 105	-0.079	0.077	-0.220**	**0.001**	0.064	0.303
PCB 138	-0.018	0.682	-0.143*	**0.030**	0.114	0.066
PCB 156	-0.006	0.894	-0.107	0.103	0.118	0.057
PCB 180	-0.030	0.497	-0.150*	**0.022**	0.109	0.078
ΣPCB	-0.028	0.535	-0.151*	**0.022**	0.107	0.083
Sum of MO-PCB&	-0.035	0.432	-0.173**	**0.008**	0.106	0.088
4,4'-DDE	-0.027	0.545	-0.158*	**0.016**	0.099	0.111
4,4'-DDT	-0.082	0.066	-0.210**	**0.001**	0.061	0.323
Trans-nonachlor	-0.023	0.603	-0.170**	**0.010**	0.124*	**0.046**

* : Significant correlation (2-tailed significance)
** : Highly significant correlation (2-tailed significance)
& : Sum of three mono-ortho PCBs (105+118+156)

The correlation between NOS and exposure data were also calculated while controlled for corrected age at neurological examination, for environmental temperature, for interval since last meal, and for weight gain of mother during pregnancy. Boys reacted more strongly in respect to their neurological performance to the PCB-congeners, to DDT, DDE, and trans-nonachlor. For HCB, a highly significant negative correlation with the NOS was found in boys while the substance had no apparent influence in girls. The significant negative effect of β-HCH in boys converted in girls into a significant positive factor for the NOS. Mercury acted as a weak positive factor on NOS in boys while it decreased the performance in girls, nearly reaching significant level of correlation. The complete list of correlations and p-values can be found in table 6.2.31 in the appendix.

6.2.3.7.1.4 Linear regression model for calculation of NOS

The list of influences on the neurological status of a newborn infant is long. Therefore models that show the effects of prenatal contaminants on the neurological presentation have to be very complex. They will include many factors. The summary of one model using multiple linear regression is presented in table 6.2.19. As in table 6.2.17, the change of one unit of a variable will cause a change of the NOS in the magnitude of the respective Beta-coefficient (for log10-transformed variables, a change with the factor 10 of the variable will cause a change of one unit of the NOS). R^2 was 0.221, adjusted R^2 0.198. For the children examined by B another model was constructed which gave a R^2 of 0.273 (adjusted R^2: 0.228), see table 9.2.7 in the appendix. If in this subcohort only the boys were tested, the R^2 came up to 0.566 (adjusted R^2 0.514) while the same model did not fit for girls again suggesting that different mechanism are responsible for the performance in boys and girls.

Table 6.2.19: Linear regression model for NOS (for children seen by A and B)

Model summary

	R	R^2	Adjusted R^2	Standardized error of the estimate
All children	0.556	0.309	0.284	2.99
All boys	0.595	0.354	0.311	2.99

	Unstandardized coefficients		Standardized coefficients	Significance		Collinearity statistic (tolerance)
	Beta	Standard error	Beta	♀+♂ (N=495)	♂ (N=266)	
Constant	44.73	3.960		**<0.001**	**<0.001**	
Examiner (A /B)	-2.776	0.336	-0.392	**<0.001**	**<0.001**	0.732
Date of examination	0.001	0.001	0.092	**0.030**	---*	0.927
Interval of examination to last meal (min)	0.006	0.003	0.087	0.063	0.136	0.755
Stability of states (no / yes)	3.063	0.500	0.256	**<0.001**	**<0.001**	0.944
Time between rupture of membranes and birth (min)	-0.027	0.019	-0.060	0.153	0.241	0.955
Apgar score at 5 minutes	0.691	0.327	0.089	**0.035**	**0.033**	0.938
Neonatal illness (no / yes)	0.486	0.364	0.056	0.182	0.113	0.940
Level of higher one of parents´ profession or occupation (low / high)	-0.902	0.308	-0.128	**0.004**	**0.003**	0.873
Mother´s age (years)	0.067	0.032	0.098	**0.035**	**0.010**	0.770
Maternal weight (kg)	-0.031	0.015	-0.091	**0.032**	---*	0.913
Weight gain during pregnancy (kg)	-0.044	0.031	-0.062	0.148	---*	0.918
Early abortions (no / yes)	-0.676	0.342	-0.082	**0.049**	**0.010**	0.959
Other non-obstetrical disease of mother (no/yes)	1.178	0.651	0.076	0.071	0.177	0.931
Log10 of PCB 156	4.370	1.758	0.386	**0.013**	**0.048**	0.069
Log10 of PCB 180	-5.168	1.757	-0.460	**0.003**	**0.028**	0.067
Log10 of β-HCH&	---	---	---	---	**0.008**	---
Log10 of musk xylene&	---	---	---	---	**0.032**	---

* : Not in model for boys
& : Not in model for all children

It is noteworthy that two PCB congeners caused effects in different directions. Colliniarity problems limit the validity of this findings. However, in conjunction with the associations with birthweight, the possibility exists that dioxin-related PCB congeners have toxic potentials that differs from other PCBs.

6.2.3.7.1.5 Correlation between diet during pregnancy and neurological status at 2 weeks

For the combined cohort no relation between the result of the neurological examination and one of the recorded dietary habits could be shown. However, the reflex cluster score improved with a higher number of meals with dried blubber and the total amount of blubber, consumed during pregnancy, but the consumption of fulmar led to a reduction of the score. Seabirds but not fulmar caused a significant reduction of the postural tone cluster score (table 6.2.10).

When the analyses were repeated for the subcohort of children examined by A and the one seen by B, the results did not differ much. Additionally a highly significant correlation was found between the number of fish meals per week and the NOS (p=0.008) for subcohort B. Diverging from the result of the combined cohort, the girls examined by B showed a very strong reduction of the reflex cluster score with an increasing number of meals with or total amount of blubber (p=0.007 and 0.008).

Table 6.2.20 Spearman´s rho and p-values (if p-value was ≤0.10)

	NOS	Reflex cluster score	Postural tone cluster score
Number of whale meals during pregnancy (N=261)	N.s.	N.s.	N.s.
Total amount of whale meat (in g) consumed during pregnancy (N=217)	N.s.	N.s.	N.s.
Number of blubber meals (N=256)	N.s.	0.117 0.063	N.s.
Total amount of blubber (in g) (N=238)	N.s.	0.140 **0.030**	N.s.
Number of other meals with dried whale meat (N=257)	N.s.	0.110 0.079	N.s.
Number of other meals with dried blubber (N=258)	N.s.	0.212 **0.001**	N.s.
Number of fish meals per week (N=256)	N.s.	N.s.	N.s.
Number of meals with fulmar (N=258)	N.s.	-0.139 **0.026**	N.s.
Number of meals with other seabirds (N=257)	N.s.	N.s.	-0.153 **0.014**
Total number of seabirds (N=256)	N.s.	-0.136 **0.029**	-0.172 **0.006**
Number of other meals with meat (per week) (N=253)	N.s.	N.s.	N.s.

6.2.3.7.2 Neurological outcome, part II: other neurological signs

6.2.3.7.2.1 Hypokinesia

Interval between last meal and neurological examination and severeal exposure variables weakly increased the probability to get the diagnose “hypokinesia” in the summary of the neurological examination. A higher concentration of mercury leads apparently to more activity: the diagnose “hypokinesia” was given less frequently (p=0.119; for boys only 0.038). PCBs, 4,4´-DDE, and trans-nonachlor showed stronger effects in girls. For details: see table 6.2.33 in the appendix.

6.2.3.7.2.2 Postural tone cluster score

Significantly lower results of postural tone cluster score were achieved by children with icterus at neurological examination (mean for the children without icterus: 8.2 versus 6.5 for those with icterus; p=0.001. In children of Faroese mothers, the tone cluster was significantly lower than in those of foreign mothers (mean 8.1 versus 9.1; p=0.034). No influence of the father´s nationality was found. A significantly higher postural tone cluster score (p=0.020) was found in infants who needed transfer to the neonatal ward for observation or treatment directly after birth (muscle hypertonia caused by mild asphyxia?).

When testing all boys, a negative influence on the result of the postural tone cluster score of all measured PCB-congeners, DDT, DDE, HCB, β-HCH, and trans-nonachlor was seen. For girls the tonus cluster score increased with increasing β-HCH (Spearman´s rho 0.132, p-value 0.045), the same was true for the PCB-congeners, HCB, dioxins, trans-nonachlor. For mercury a mild negative correlation with the tonus score of girls was found (p=0.212). Testing the partial correlations for postural tone cluster score (controlled for corrected age at neurological examination, environmental temperature, interval to last meal, and weight gain), for the combined cohort a very weak negative influence of all substances was found. The separate analysis of boys and girls revealed obvious differences in their reaction to the exposure variables: while mercury was negatively correlated to the tone score in girls, all other substances slightly improved the result. In boys, for all contaminants a negative correlation to the tone cluster was seen, the strongest the one with PCB-118 (p=0.105). The negative influence of mercury on the tonus in boys was much weaker than in girls.

If only the tone of the legs was tested in the B-subcohort a significant negative influence of MeHg could be shown for the whole group (p=0.021) as well as for the girls (p=0.032). No clear influence of exposure data on the muscle tonus of the legs in the children examined by A.

6.2.3.7.2.3 Opisthotonus

Pediatrician A never found opisthotonus in the infants examined, so only the subcohort B was used. Children with the diagnosis “opisthotonus” had significantly lower levels of PCB- 118 (p=0.030), PCB-153 (p=0.012), PCB-138 (p=0.015), PCB-156 (p=0.024), PCB-180 (p=0.012), DDE (p=0.019), and trans-nonachlor (p=0.028) in breast milk. In girls the apparent preventive effect of the named pollutants against the diagnose “opisthotonus” was stronger than in boys.

6.2.3.7.2.4 Reflex cluster score

When the complete cohort was analyzed, all of the POPs except musk xylene showed a weak negative influence on the reflex cluster score. When the correlation was controlled for corrected age at NOS, environmental temperature, interval to last meal, and maternal weight gain during pregnancy the negative correlation between β-HCH and HCB with the reflex cluster score became significant (p=0.029 and 0.031). As for the postural tone cluster score the separate analysis of boys and girls revealed differences in their reaction to the exposure variables: Mercury was positively related with the reflex cluster score in boys, but negatively in girls. The observed negative correlations between all of the POPs in boys were much stronger (especially for DDT) than in girls.

The bivariate correlation of the reflex score with the contaminants were also tested for the two subcohorts. For the subcohort A a positive correlation between reflex score and all exposure data, including mercury was found, but none of the correlations reached significance (all p-values >0.10). An uniform negative relation between all exposure data and the reflex cluster score were found in the children examined by B. Beside mercury and musk xylene the correlations were significant for β-HCH, PCB-118, PCB-153, PCB-138, PCB-180, and trans-nonachlor (see table 6.2.34 in appendix).

6.2.3.8 Different reactions in boys and girls

Here a short summary of the diverging reactions on the different pollutants in boys and girls will be given. First the effects on growth are discussed. Then the results of the neurological examination in dependence of gender follow.

PCB-105 had the strongest impact on birth weight, length and head circumference. In boys, the positive correlation between the concentration of this congener in breast milk was much higher than in girls. When the exposure of the other pollutants was controlled for PCB 105, all visible influences were still greater in boys: percentile of head circumference increased more with higher concentrations of contaminants than in girls; length was reduced more (except for DDT which affected girls more than boys) by all pollutants in boys.

Mercury had a "positive" influence on the NOS in boys, an adverse one in girls. β-HCH led to a lower NOS in boys, to higher one in girls. In both cases the correlation was a significant one. HCB didn't influence the neurological outcome in girls, while in boys a significant negative influence was observed. The negative impact of all tested PCB-congeners (IUPAC numbers 105, 118, 138, 153, 156, and 180) was much weaker in girls than in boys. The same was true for DDE, DDT, and trans-nonachlor.

The diagnosis "opisthotonus" was given less frequently with higher exposure to contaminants. This effect was stronger in girls than in boys, but musk xylene in girls leads to opisthotonus in girls, while seemingly preventing it in boys.

Reflex cluster score improved with increasing maternal hair-mercury in boys, while becoming lower in girls. All other contaminants showed a stronger negative impact on reflex cluster score in boys, especially DDT and β-HCH.

The correlation of hypokinesia with pollutants was more marked in girls for all measured PCB congeners, for DDE, DDT, and trans-nonachlor. On the other hand, boys tended more frequently to obtain the diagnosis "hypokinesia" with higher β-HCH and musk xylene.

A list of the observed differences in the neurological outcome in boys and girls is given in table 6.2.35.

6.2.4 Discussion

In considering the findings of the present study, the complexity of the exposure situation must be appreciated. More than 200 PCB-congeners exist. The number and position of the chlorine is responsible for the toxicity of a particular congener. Usually sums of PCB-congeners were used. They were introduced to reflect the total toxicity – including dioxin-like effects – of a certain mixture by adding few of the measurable congeners. But the mixtures found in seafood will vary depending on the sources. Therefore, the special effects of particular congeners such as PCB-105 reported here, might easily have been overlooked. The same difficulty arises for some of the other POPs where only few substitute substances are measured. Other, until now unknown substances might accompany the POPs in whale products, fish, or other specific food (seabirds) eaten by Faroese mothers. Thus the measured substances could function as a surrogate variable for the unknown substance. If the concentrations of the measured and the surrogate substance are not strongly correlated, interpretation of results becomes difficult. Some other habits, dietary or otherwise, which were not recorded in the present study, might also be the origin of an exposure which causes results that contradict the conclusions of other studies. Only further research, especially the examination of the effect of the particular PCB-congeners, will help to resolve these problems.

6.2.4.1 Characteristics of parents, life style factors, dietary habits of mothers and exposure data

Several correlations between maternal attributes and the load of POPs have been described in the literature:

The positive correlation of the concentration of all substances with maternal age was already reported in 1984 (Fein et al., 1984). In Germany, values for contaminants in a 40-years old primipara are about 1.5 to 2.0 higher than in a 20-year old mother of a first child (Institut für Wasser-, Boden- und Lufthygiene des Bundesunweltames, 1999). There is a simple explanation for this phenomenon: the amount of organochlorines in body fat increases with age because of continuous human exposure to low levels and long biological half-lives of these chemicals (Schade et al., 1998; Vartiainen et al., 1998). In our cohort, maternal age was highly significantly correlated to all of the organochlorines.

Higher age and higher parity are connected with each other. While some authors found a negative correlation of exposure data to parity (Fein et al., 1984), in another Faroese cohort increased parity or age were associated with slightly increased mercury concentrations in cord blood and hair (Weihe et al., 1996). In a Finish study, PCB concentrations in human milk in primiparae increased with age (Vartiainen et al., 1998). Breast-feeding of previous children can result in a decrease of body fat depots and it constitutes an important route of excretion for persistent organochlorines; the same is true for previous pregnancies (Fein et al., 1984; Schade et al., 1998). Not knowing how long the mothers nursed their children and lacking any information about weight gain or loss of weight during these period(s), exposure data were analyzed for the present cohort with respect to maternal age and parity. Not all of the organochlorines were reduced by a higher number of pregnancies and thus – for most of the Faroese mothers will nurse their infants for at least half a year – longer total period of breast-feeding.

Higher pre-pregnancy BMI was strongly correlated with an increase in many of the pollutants measured in breast milk in our cohort. Post-pregnancy BMI was measured in other settings and found to be a significant predictor of the likelihood of having higher concentrations for the sum of DDT and DDE, HCB, and ß-HCH while leading to lower concentrations for PCB levels (Schade et al., 1998). Mothers who were more highly exposed to PCB had a lower weight gain during pregnancy than non-exposed women (Fein et al., 1984). For the Faroese mothers, a negative correlation could be shown between weight gain and mercury in mother´s hair and most of the tested other POPs (β-HCH, HCB, DDT, DDE, and trans-nonachlor) in breast milk. A higher weight gain during pregnancy may lead to a dilution of POPs previously accumulated, thus giving lower concentrations of the named contaminants in breast milk. To answer this question in detail the mother´s load with pollutants has to be known before pregnancy.

The influence of alcohol consumption during pregnancy on the reduction of mercury concentrations in mothers is well known (Weihe et al., 1996; Dunn et al., 1981). However, mercury in hair in this study increased significantly with mother´s consumption of alcohol during pregnancy. Because of the low alcohol intake levels, this association is likely to be spurious and not an indication of toxicokinetic interactions. In German and Canadian breast milk samples consumption of spirits (alcoholic beverages) led to an increase of ß-HCH and HCB (Schade et al., 1998; Dewailly et al., 1996). The reason for the relationship is not clear. Alcohol abuse can induce chronic liver damage, which may in turn reduce the biotransformation rate of the measured chemicals. Alternatively, alcohol could increase absorption of organochlorines by raising the solubility of the substances in gastrointestinal fluids. Another and more likely explanation could be that alcohol intake is related to specific eating habits, especially to a diet containing more fat (Schade et al., 1998). In the presented study, DDT was higher in alcohol-consuming mothers. Also the ratio DDT/DDE in these mothers was significantly higher than the one in teetotal mothers which either could be caused by the fact that the life style of mothers who consume alcohol leads to a higher ingestion of DDT or that the conversion to DDE is delayed by a hampered or changed metabolism. Mothers who drank alcohol reported a higher amount of whale meat, a higher number of meals with dried whale meat, and a lower number of fish meals per week consumed during pregnancy. This supports the hypothesis that alcohol consumption is related to a different diet, which increases their load of pollutants.

Smoking showed no significant association with organochlorine compounds in breast milk also reported by other authors (Schade et al., 1998; Vartiainen et al., 1998). According to Lackmann ΣPCB (also true for the all single congeners except PCB 180) and HCB increase in a smoking mother (more in active than in passive smoking mothers) (Lackmann et al., 2000). Again, any toxicokinetic impact is questionable.

The average dioxin and PCB concentration in human milk increased with the education of the mother (Vartiainen et al., 1998). The same was seen in the Faroese cohort while the mercury concentration in maternal hair decreased with higher education of the parents, and also most of the POPs were lower if the father had a higher school education. With higher occupation and / or profession of parents an increase of POPs was found as also described by Jacobson (Jacobson et al., 1990), probably caused by the highly significant positive correlation between maternal age and occupational or professional status of both parents.

Low score in school education and low score in mother´s occupation are correlated with a higher consumption of whale meat during pregnancy while no influence on the number of fish meals per week could be seen. There are two possible explanations for the observation: either the lower education led to an ignorance of governmental recommendation concerning the consume of whale products or the living place of the mother functioned as confounder for a lower school education and occupation on one side and a higher availability of whale meat on the other side. A connection of social data like school education or present occupation of parents with the place of mother´s residence was not yet possible.

That preference and availability of whale products influence the load with contaminants became clear when correlating nationality and exposure data: higher concentrations of nearly all contaminants were found in Faroese women who can be assumed to be used to the consumption of whale products and seabirds and to have a better access to both.

6.2.4.2 Non-neurological characteristics of the infants

An apparently positive influence of all pollutants on birth weight was seen. After splitting the PCB-congeners into the individual congeners that were measured in breast milk it became clear that mainly the mono-ortho congener PCB-105 increases the birth weight, while PCB-153 (a di-ortho PCB) leads to a significant reduction of birth weight. In boys, the changes in both directions were stronger than in girls. Additionally a negative effect of DDE, HCB, and trans-nonachlor could be shown. A negative effect of POPs, especially of PCB on birth weight corresponds to the experience of several other authors (Fein et al., 1984; Schade et al., 1998; Brouwer et al., 1995; Patandin et al., 1998). However, because of collinearity these effects may be difficult to disentangle. The linear regression model explaining birth weight resembles well the one for another Faroese cohort (Grandjean et al., 2001), but some additional factors influencing the birth weight could be identified: maternal weight, diabetes of mother, and mother´s nationality, the last one probably reflecting the preference or availability of some food items or the presence of other ingredients in the dietary which differ in native people and foreigners. Thus, in our previous study, we showed the strong effect of polyunsaturated fatty acids present in fish oil, but these parameters were not assessed in the present study.

For head circumference, the same pattern of positive influences (especially the significantly positive correlation with HCB, PCB-105, PCB 118, DDT, and trans-nonachlor were found. The length of boys measured at the neurological examination decreased in dependence of the concentration of β-HCH, HCB, PCB-153, PCB-156, and DDE. In girls no significant effects on birth weight and head circumference were seen; solely their length increased significantly with increasing concentrations of contaminants.

Possible mechanisms by which PCB-105, PCB-118, HCB, 4,4´-DDT, and trans-nonachlor may affect birth weight and head circumference may relate to a growth-hormone-like effect of the substances or in their effect similar to other hormones.

The effects of the contaminants as hormone active agents (DDE acting antiandrogenic, some of the PCB-congeners and DDT causing estrogen-like effects) might explain why reactions to the pollutants differ between boys and girls. Altogether the girls appear less vulnerable than the boys. The incidence of hypospadias and cryptorchism that might be a sequel of disturbances in the early development of male sex organs caused by hormone active agents was too low to be tested statistically.

No significant correlation between either diet or one of the pollutants and length of gestation was found in this study, but was reported in other studies in the Faroe and elsewhere (Fein et al., 1984; Grandjean et al., 2001). But the concentration of fatty acids in maternal or cord serum that are responsible for a prolongation were not available for this cohort.

Our data suggest a relationship between sex and parity as well as sex and concentration of contaminants: the higher the parity, the higher the percentage of boys. First pregnancies resulted in more girls than boys, after the second child the boys outweighed the girls. The proportion of boys increased with each pregnancy. This may confirm the findings of other authors: Mocarelli and Brambilla reported an excess of female offsprings of parents who were exposed to high concentrations of dioxin after the Seveso accident (Mocarelli et al., 1996). Brouwer et al (Brouwer et al., 1995), found fewer boys than expected born to fishermen wives from the Swedish East Coast, whose pooled blood samples were found to have higher PCB levels than those of the Swedish West Coast. PCB levels and the concentration of POPs in breast milk were lower in primi-parae in our study. Still more girls than boys were born to primi-parae. Probably not only dioxin but a mixture of several substances are responsible for this phenomenon.

6.2.4.3 Neurological outcome

The interpretation of the neurological results is made difficult by several potential obstacles: For the second half of the study period higher NOS scores were achieved. This might be caused by (1) a higher percentage of children examined by A (48.2% versus 57.6%) who tended to give higher scores for the examination during the later part of the study or (2) because both examiners increased their scores during the study. As already discussed above (6.2.3.2.) it is not easy to get comparable results for the NOS if different persons carry out the examination. Thus the cohort had to be separated for most of the analyses of the neurological outcome. Many other factors can be of major impact on the performance, some of them like environmental temperature and interval between last meal and examination could be identified. But there well might be some important unknown factors that change the result of the examination.

An overall negative correlations was found between all exposure variables and NOS for the complete cohort and the subcohort B. In the subcohort the correlation often reached significance level especially if controlled for gestational age. The most important substances that caused a reduction of the NOS were HCB, PCB-105 (as well as the sum of the three measured mono-ortho PCB-105, 118, and 156), trans-nonachlor, and 4,4-DDT. For the subcohort A mostly a positive influence of the substances on the neurological performance of the infant was found. Only the concentration of mercury in maternal hair (very weakly correlated) showed a negative effect on the neurological outcome of the newborn. A positive correlation between prenatal exposure to POP is against the experience from former studies (Committee on Hormonally Active Agents in the Environment, 2001; Huisman et al., 1995; Rogan et al., 1986; Steuerwald et al., 2000). Because the examination and the scoring for the NOS is a highly subjective, it has to be assumed that the explanation for the unexpected results in the subcohort A was caused by spurious variation. Unfortunately a regular interrater-reliability control or a control of the examination technique of the examiners, which could have helped to reduce differences, was not possible.

Postural tone cluster score was weakly reduced by most of the contaminants. This confirms the findings of other authors who also described a decrease of muscle ton with increasing concentrations of PCB (Huisman et al., 1995; Fein et al., 1984; Rogan et al., 1986). The impact of the pollutants on the reflex cluster score was stronger: for the subcohort B a highly significant negative correlation between reflex score all tested substances except MeHg and musk xylene was apparent. In other words: POPs led to a hyporeflexia in this group of infants. Rogan saw a negative influence of PCB on reflexes (Rogan et al., 1986). and DDE levels in breast milk as low as 4 μg/g lipid can suppress reflexes in newborns (AMAP, 1997). The eight infants who were exposed to such a high concentration of DDE in our study, had a lower reflex cluster score (and NOS) but the difference from the other infants did not reach significance. Mercury was positively associated with abnormal reflexes in boys, but not in girls (hyperreflexia). Hyperreflexia and exaggerated deep tendon reflexes were observed in boys with high mercury exposures during pregnancy, but the present study could not confirm this association (WHO, 1990).

As to the anthropometric results, the associations with the contaminants differed in boys and girls, e.g. β-HCH increases the probability for the diagnosis “hypokinesia”, but reduces it in girls (both correlations were not significant). After controlling for some of the covariates which were found to have an impact on the NOS (namely corrected age in days at the neurological examination, environmental temperature during examination, and log10-transformed maternal pre-pregnancy BMI), the NOS in girls was negatively related to mercury (in the B subcohort), but boys showed a weak positive correlation. On the other side a significant (in the B subcohort) an influence of nearly all other pollutants could be shown in boys while for girls no correlation of the same substances on NOS was seen. A possible mechanism that might explain the phenomen was mentioned in section 6.2.4.2.

6.2.4.4 Diet and exposure variables

As has been known for some time (Grandjean et al.,1992) the amount of whale meat consumed during pregnancy is the best predictor for maternal MeHg exposure. Blubber and to a much lesser degree fish may add some more mercury to the maternal load. Any form of blubber - dried or fresh – seems to be the major source not only for PCB but also for DDT, DDE, and trans-nonachlor. The consumption of fulmar showed positive correlations to PCB, DDT, DDE, and trans-nonachlor. High levels of PCB were already described to be most likely the effect a diet of sea mammals, fatty fish, and perhaps eggs from seabirds (AMAP, 1997). It is known that also other seabirds, especially those which eat fish, have high levels of PCB and DDT. The puffin is one of them, and it is frequently consumed in the Faroe. The contamination of migratory seabirds like the fulmar often originates from pollution of their wintering areas. The concentration of pollutants in the eggs of the birds often approaches the levels where effects like embryo deformities and failing of hatching might occur (AMAP, 1997). The questionnaire used did not ask about consumption of seabird eggs. However, of the seabirds eaten by the mothers, the correlation with fulmar exeeded those for other seabirds. Recommendations about the consumption of seabirds and eggs might be considered as a consequences of these findings.

The consumption of all different whale products – meat or blubber, fresh or dried – is interrelated, i.e. those who have access to whale products are likely to use them all. Those who eat fulmar tend also to eat other seabirds, but only the consumption of dried whale meat is significantly correlated to the number of fulmars eaten during pregnancy. Probably this is a sign of traditional lifestyle that leads to a very high exposure to the potentially harmful substances.

Fish meals as such seem to be less important when looking for the sources of contaminants. The number of fish meals correlates with mercury in maternal hair and milk, DDT, DDE, and trans-nonachlor. Of the PCB-congeners the concentration of PCB-105 and PCB-118 increased with the number of fishmeals per week, but not the other congeners.

High HCB-concentration resulted from the consumption of whale meat, blubber, and fulmar but not from fish. Musk xylene showed mainly negative associations. Again this might reflect a certain traditional life style that reduces the use and contact with preparation containing musk xylene.

Consumption of other meat, (e.g. chicken, lamb or beef), serves as a protective factor against the exposure of the infant and foetus by the potentially harmful substances as indicated by negative correlations with the pollutants.

Maternal smoking and smoking of partner is found more often in families where the mother reported that they had eaten whale meat and / or blubber on two consecutive days. This might suggest an overall unhealthy life style where recommendations for an optimal outcome of pregnancy are unknown or ignored.

6.2.4.5 Comparison of present exposure data with those from earlier studies
The geometric average of hair-mercury in about 1,000 Faroese women of children born in 1986 and 1987 was 4.3 μg/g, with 130 samples above 10 μg/g; the maximum was 39.1 μg/g. Only 5% of the Faroese women had hair-mercury concentrations below 1 μg/g (Grandjean, 1992). Compared to this cohort, slightly lower overall mercury concentrations were found in a second cohort that was created in 1994 and 1995 with geometric means of 4.1 μg/g (Steuerwald et al., 2000). In the present data a geometric mean of 2 μg/g was found. Now only 5% of the samples exceeded a concentration of 10 μg/g and 18% were below 1 μg/g. The highest load with a concentration of 32.7 μg/g did not differ much from the one reported for the earliest cohort. Thus mercury concentration has clearly decreased since the establishment of the first cohort, probably as result of changed recommendations for the population about the consumption of whale products.

Differences in the load with PCB are much smaller due to the longer half-lives of these compounds which despite of changed dietary habits will take longer time to decrease. For the second cohort (for the first cohort only PCB-levels in umbilical cord for half of the children were available) ΣPCB in breast milk from day 4-5 had a geometric mean of 1.52 μg/g lipid (total range 0.07-18.5

μg/g) (Steuerwald et al., 2000) which is nearly identically to the values resulting from this cohort (1.33 μg/g lipid with a total range of 0.08-17.6 μg/g lipid). However, as the analyses were conducted by the same laboratory, the slight decrease indicated may reflect a real change.

In the second cohort, DDE in maternal milk reached a geometric mean of 0.87 μg/g lipid, the interquartile range was 0.49 – 1.55 μg/g, with a total range of 0.05 – 13.7 μg/g (Steuerwald et al., 2000). If compared with the values of the present cohort, a slight decline in this contaminant as well was found, with 0.60 μg/g for the geometric mean, an interquartile range of 0.36 – 0.99 μg/g, and a total range of 0.06 – 11.35 μg/g.

Whether the described decline of MeHg, ΣPCB, and 4,4´-DDE is solely caused by the changed recommendation about the consumption of whale meat and blubber, a higher awareness of the population about the potential harm of whale-products especially for the foetus and young infant, or whether this is an effect of reduced load of the whales themselves after implementation of strict regulations and bans of some of the substances cannot be decided by these data. In addition, maternal age may be considered as a covariate, the mothers from cohort 2 now being about 5 years older at the time of the generation of the present cohort 3.

6.2.5 Conclusions

Marine food / traditional food provides many benefits: Marine mammals and fish are rich in polyunsaturated fatty acids. A diet high with PUFA has been associated with lower risk for heart disease. Whale skin and other marine foods are rich in selenium. Selenium may perhaps reduce the toxic effect of mercury, may increase the body's antioxidant defence, and may protect against cancer and possibly against heart disease. High levels of vitamin A are found in animal liver and blubber. In general, traditional diets therefore provide a strong nutritional base for health (AMAP, 1997). But the growing foetus is exposed to contaminants in the womb, and the levels in the mother´s body will determine its dose of persistent organic pollutants. By the time a woman knows that she 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. An important way to reduce fetal exposure to POPs is therefore to develop dietary advice for girls, women of child-bearing age, and pregnant women to promote the use of less contaminated local food to help reduce POP intake (AMAP, 1997).

Realizing the hazard resulting from the present contaminations and as a consequence of the findings of studies in the Faroes, new recommendations on the consumption of whale products were issued by the government in 1998. Adults should refrain from having more than one or two lunches of whale meat (corresponding to 300g whale meat each second week) or blubber per month. Girls and women should not eat blubber at all before the end of the reproductive period. Women who intend to get pregnant during the next three months, women who are pregnant or those who are breastfeeding should not eat any whale meat at all. Livers and kidneys of whale should not be eaten by anyone at all (Heilsufrøðiliga Stravsstovan, 1998). Whale meat contains about 1.9 mg/kg. i.e. much more than mercury levels in Faroese fish. This is the background for the above-mentioned recommendation for whale meat. Because of the beneficial effects of fish consumption, the long-term goal needs to be a reduction in the concentration of MeHg in seafood rather than a replacement of fish in the diet by other foods. In the interim, the best method of maintaining fish consumption and minimizing Hg exposure is the consumption of fish known to have low mercury concentrations (Committee on the Toxicological Effects of Methylmercury, 2000).

Another easy recommendation should be added for nursing mothers: while a higher weight gain during pregnancy leads to a reduction of the concentration of contaminants in the body, this advance has to be weighed against the higher incidence of complications during delivery, lower Apgar scores and other disadvantages of the maternal weight gain. A reduction of maternal weight during the lactation period leads to a very high concentration of all compounds in breast milk, and therefore should be avoided (Institut für Wasser-, Boden- und Lufthygiene des Bundesumweltamtes, 1999).

PCB and HCB have carcinogenic and teratogenic properties, and tumor-promoting properties if applied together with tobacco-specific carcinogens (Lackmann et al., 2000). Therefore tobacco smoking together with eating whale products and seabirds (probably also eggs of seabirds) should be strongly discouraged in the whole population.

Further effects especially those of the hormone active agents will have to be examined in some years.

6.2.6 Summary

Effects of prenatal exposure to methyl mercury and persistent organic pollutants originating from marine food were studied. Data collection took place during a two-year period and involved a cohort of 500 mother-infants pairs. Information about socioeconomic and obstetrical conditions and the dietary habits of the mother during pregnancy was recorded. As outcome parameters length of gestation, growth and sex were recorded. Neurological performance was tested at the adjusted age of about two weeks. Exposure was determined by analyzing maternal hair for mercury and transitional breast milk for persistent organic pollutants.

An adverse influence of these contaminants on the outcome variables could be shown. Differences in results in boys and girls are in agreement with the ability of several of the substances to mimic or disturb the function of sex hormones.

When comparing the exposure in the present study with previous established Faroese cohorts it could be shown that contamination with mercury now amounts to only half of the exposure 15 years ago. Concentration of POPs in breast milk were almost unchanged since 1994.

Further activities of health authorities are necessary to reduce the still high exposure of the population. In addition to whale meat and blubber, attention should also be paid to fulmars and perhaps also other seabirds as sources of exposure.

6.2.7 Appendix

6.2.7.1 Abbreviations

BMI	body mass index (weight [in kg] / height [in m]^2)
X^2	Chi-square
DDE	4,4'-dichlorodiphenyldichloroethene
DDT	4,4'-dichlorodiphenyltrichloroethane
FDA	Food and Drug Administration
HAA	hormonally active agent
HCB	hexachlorobenzene
ß-HCH	beta-hexachlorocyclohexane
Hg	mercury
IUPAC	International Union of Pure and Applied Chemistry
MeHg	methylmercury
NOS	neurological optimality score
OCC	organochlorine compounds
OFC	occipito-frontal circumference (head circumference)
OOS	obstetric optimality score
PCB	polychlorinated biphenyls
POP	persistent organic pollutants
ppb	parts per billion = 1 µg / kg = 1 ng / g
ppm	parts per million = 1 mg / kg = 1 µg / g
PUFA	polyunsaturated fatty acid
ΣPCB	(sum of PCB 138, 153 and 180) x 2

6.2.7.2 Tables

Table 6.2.21 List of items included in the Obstetrical Optimality Score

Variable	Criteria for optimality
A: Social background	
Education of partner[&]	More than elementary
Education of mother´s father*	More than elementary
Marital state at time of delivery*	Married (or permanently living together)
Parenthood course*	Participated in parenthood course
Race and nationality	[Not defined for the study cohort]
Education of mother[&]	More than elementary
Smoking of partner	Not smoking
Family history of congenital anomalies	No
Previous baby with congenital anomalies	No
Previous legal abortion	No
Height of mother	160 – 180 cm
Age of mother	20 – 31 years
BMI (weight / height^2) of mother	18.8 – 24.2
B: Non-obstetrical conditions during pregnancy	
Smoking of mother	No smoking during whole pregnancy
Illness first trimester	No
Surgical therapy during gestation	No
Family history of diabetes	No
Diabetes (including gestational) of gravida	No
Heart disease	No
Epilepsy	No

Hypertension (at or above 90 mm Hg diastolic)	No
Other disease	No
C: Obstetrical past history	
Preterm delivery	None
Late abortion (16-28 weeks)	None
Early abortion (<16 weeks)	Not more than one
Late fetal or neonatal loss	None
Caesarian section	None
Instrumental delivery	None
Hypertension in pregnancy	No
Placental abruption	None
Other complications	None
Placenta praevia	None
Intrauterine growth retardation	No
Parity	One
Previous infertility	No
Induction of ovulation	No
D: Obstetrical aspects of pregnancy	
Vaginal bleeding	No
Proteinuria	No
Pre-eclampsia	No
Acetonuria*	No
Anemia in mid-trimester (Hb < 6.8 mmol/l)	No
Anemia in third trimester (Hb < 6.8 mmol/l)	No
Early hypertension (diastolic pressure > 80 mm Hg)	No
Uncertain or unreliable date of last menstrual period	No
Weight gain during pregnancy	8 – 15 kg
Other complications e graviditate	No
Rhesus sensitization	No
E: Diagnostic and therapeutic measures	
Frequency of prenatal care	9 – 15 visits
Number of admissions including for delivery	One
Oral Glucose Tolerance Test carried out	No
Amniocentesis	No
Placental function tests, CTG etc.	*Yes*
Drugs prescribed or taken prior to 16 th week	No
Drugs prescribed or taken after 16 th week	No
Cerclage	No
F: Parturition	
Complications during labor	None
Instrumental delivery including caesarian section	No
Resentation at birth	Cephalic
Perineal lacerations	Episiotomy
Duration of first period	10 hours or less
Duration of second period	50 min or less
Amniotic fluid	Clear

Start of labor	Spontaneous
Augmentation	No
Time between rupture of membranes and birth	6 hours or less
Sedation or analgesia	None
G: Neonatal condition immediately after birth	
Duration of gestation	37 to 42 weeks completed
Birth weight	More than P10& or less than P95&
First cry	Immediately
Apgar score 1 minute	8 – 10
Apgar score 5 minutes	9 – 10
Congenital anomalies	None
Transferred to neonatal ward	No

* : No information available for this cohort, therefore always scored optimal
& : For further information, see text in chapter 2.5.5

Table 6.2.22 Correlation coefficients (Spearman) between different groups of persistent organic pollutants in breast milk

Spearman´s rho	Mercury	HCB	β-HCH	4,4'-DDT	4,4'-DDE	Ratio DDT/DDE	Trans-nonachlor	Musk xylene
PCB 105	0.383**	0.835**	0.374**	0.848**	0.786**	0.318**	0.828**	-0.003
PCB 118	0.341**	0.894**	0.427**	0.861**	0.879**	0.218**	0.929**	-0.030
PCB 138	0.274**	0.869**	0.435**	0.806**	0.914**	0.078	0.944**	-0.012
PCB 153	0.273**	0.872**	0.433**	0.779**	0.899**	0.054	0.920**	-0.019
PCB 156	0.236**	0.853**	0.469**	0.695**	0.811**	0.035	0.867**	-0.074
PCB 180	0.255**	0.834**	0.398**	0.714**	0.837**	0.032	0.887**	-0.034
ΣPCB	0.269**	0.869**	0.428**	0.777**	0.895**	0.056	0.927**	-0.020
Sum of three MO-PCB&	0.334**	0.907**	0.444**	0.850**	0.878**	0.200**	0.931**	-0.036
HCB	0.356**							
β-HCH	-0.021	0.589**						
4,4'-DDT	0.399**	0.802**	0.351**					
4,4'-DDE	0.317**	0.805**	0.379**	0.851**				
Ratio DDT/DDE	0.215**	0.222**	0.072	0.513**	0.037			
Trans-nonachlor	0.345**	0.859**	0.360**	0.864**	0.877**	0.881**		
Musk xylene	-0.009	-0.065	0.027	0.030	0.093*	0.091*	-0.030	

* : Significant at the 0.05-level (two-tailed)
**: Significant at the 0.01-level (two-tailed)
& : Some of the three measured mono-ortho PCB-congeners (IUPAC numbers 105, 118, and 156)

Table 6.2.23 Correlation coefficients (Spearman) between dietary habits and mercury (in mother´s hair) and different POPs (in breast milk) for all p-values ≤ 0.100. In the second line in each row, the p-values significance are given. Those reaching a significance level of 0.05 are written in **bold** numbers.

	MeHg (hair)	HCB	β-HCH	Musk xylene	DDT	DDE	Ratio DDT/DDE	Trans-nonachlor
Number of meals with whale meat (N=261)	0.571 **0.000**	0.116 0.061	N.s.	N.s.	0.177 **0.004**	0.125 **0.043**	N.s.	0.167 **0.007**
Total amount of whale meat (N=217)	0.556 **0.000**	0.136 **0.045**	N.s.	N.s.	0.214 **0.002**	0.152 **0.025**	N.s.	0.202 **0.003**
Number of meals with blubber (N=256)	0.362 **0.000**	0.221 **0.000**	N.s.	N.s.	0.313 **0.000**	0.248 **0.000**	0.160 **0.010**	0.307 **0.000**
Total amount of blubber (N=238)	0.355 **0.000**	0.252 **0.000**	N.s.	N.s.	0.342 **0.000**	0.275 **0.000**	0.170 **0.009**	0.328 **0.000**
Number of other meals with dried whale meat (N=257)	0.202 **0.001**	0.114 0.068	N.s.	N.s.	0.182 **0.003**	0.141 **0.024**	n.s.	0.122 0.051
Number of other meals with dried blubber (N=258)	0.215 **0.000**	0.158 **0.011**	N.s.	N.s.	0.367 **0.000**	0.291 **0.000**	0.228 **0.000**	0.284 **0.000**
Number of fish meals per week (N=256)	0.250 **0.000**	N.s.	N.s.	N.s.	0.147 **0.018**	0.138 **0.028**	N.s.	0.143 **0.022**
Number of meals with fulmar (N=258)	0.213 **0.001**	0.207 **0.001**	N.s.	-0.146 **0.019**	0.169 **0.007**	0.147 **0.018**	N.s.	0.234 **0.000**
Number of meals with other seabirds (N=257)	0.128 **0.040**	0.110 **0.079**	N.s.	N.s.	0.137 **0.028**	0.106 0.091	N.s.	0.116 0.063
Total number of meals with seabirds (N=256)	0.194 **0.002**	0.184 **0.003**	N.s.	N.s.	0.179 **0.004**	0.155 **0.013**	N.s.	0.213 **0.001**
Number of meals with other meat per week (N=253)	-0.174 **0.005**	-0.146 **0.020**	-0.142 **0.024**	N.s.	-0.104 0.100	-0.101 0.108	N.s.	N.s.

Table 6.2.24 Correlation coefficients (Spearman) and p-values between different PCB congeners and dietary habits during pregnancy (for p ≤ 0.1). In the second line in each row, the p-values for the two-tailed significances are given. Those reaching a significance level of 0.05 are written in **bold** numbers.

PCB-congener number	105	118	138	153	156	180	Σ PCB
Number of meals with whale meat (N=261)	0.162 **0.009**	0.126 **0.041**	0.121 0.051	N.s.	N.s.	N.s.	n.s.
Total amount of whale meat (N=217)	0.179 **0.008**	0.157 **0.021**	0.153 **0.025**	N.s.	N.s.	N.s.	0.109 0.109
Number of meals with blubber (N=256)	0.246 **0.000**	0.269 **0.000**	0.246 **0.000**	0.212 **0.001**	0.157 **0.012**	0.178 **0.004**	0.214 **0.001**
Total amount of blubber (N=238)	0.279 **0.000**	0.298 **0.000**	0.278 **0.000**	0.249 **0.000**	0.189 **0.003**	0.206 **0.001**	0.247 **0.000**
Number of other meals with dried whale meat (N=257)	0.140 **0.025**	0.137 **0.029**	0.129 **0.039**	0.132 **0.034**	0.108 0.085	0.101 0.106	0.122 0.050
Number of other meals with dried blubber (N=258)	0.231 **0.000**	0.258 **0.000**	0.239 **0.000**	0.196 **0.002**	0.145 **0.020**	0.166 **0.008**	0.203 **0.001**
Number of fish meals per week (N=256)	0.131 **0.037**	0.133 **0.033**	0.103 0.100	N.s.	N.s.	N.s.	N.s.
Number of meals with fulmar (N=258)	0.254 **0.000**	0.241 **0.000**	0.203 **0.001**	0.213 **0.001**	0.213 **0.001**	0.196 **0.002**	0.207 **0.001**
Number of meals with other seabirds (N=257)	0.172 **0.006**	0.176 **0.005**	0.111 0.076	0.127 **0.041**	0.115 0.066	0.114 0.068	0.117 0.060
Total number of meals with seabirds (N=256)	0.242 **0.000**	0.246 **0.000**	0.192 **0.002**	0.203 **0.001**	0.202 **0.001**	0.191 0.052	0.197 **0.002**
Number of meals with other meat per week (N=253)	N.s.	-0.118 0.061	N.s.	N.s.	-0.116 0.066	N.s.	N.s.

N : Number of answers that were available for analyses

Tables 6.2.25 –6.2.30

Bivariate / partial correlations between anthropometric data and exposure variables; p-values of significant correlations are written in bold letters

Table 6.2.25 bivariate correlation between birth weight and exposure data

Birth weight	Spearman´s rho			P-values		
	All infants (N=500)	Boys (N=267)	Girls (N=233)	All infants (N=500)	Boys (N=267)	Girls (N=233)
Mercury	0.062	0.073	0.016	0.168	0.235	0.807
HCB	0.076	0.144*	-0.009	0.088	0.019	0.891
β-HCH	0.004	0.043	-0.024	0.931	0.483	0.715
PCB-118	0.103*	0.159**	0.041	0.021	0.009	0.537
PCB-153	0.043	0.107	-0.026	0.334	0.082	0.690
PCB-105	0.141**	0.202**	0.073	0.002	0.001	0.269
PCB-138	0.053	0.112	-0.015	0.239	0.066	0.821
PCB-156	0.052	0.113	-0.040	0.250	0.066	0.830
PCB-180	0.046	0.110	-0.025	0.309	0.074	0.699
ΣPCB	0.047	0.110	-0.022	0.290	0.074	0.733
Sum of three mono-ortho PCB (105+118+156)	0.099*	0.157*	0.033	0.027	0.010	0.614
4,4'-DDT	0.080	0.163**	-0.019	0.074	0.008	0.767
4,4'-DDE	0.044	0.096	-0.013	0.328	0.119	0.848
Ratio DDT/DDE[&]	0.087	0.183**	-0.036	0.053	0.003	0.586
Trans-nonachlor	0.074	0.132*	0.004	0.100	0.032	0.951

* : Significant correlation (2-tailed significance)
** : Highly significant correlation (2-tailed significance)
& : Pearson correlation

Table 6.2.26 Bivariate correlation between head circumference and exposure data at NOS

Head circumference at NOS	Spearman´s rho			P-value		
	All infants (N=499)	Boys (N=267)	Girls (N=232)	All infants (N=499)	Boys (N=267)	Girls N=232)
Mercury	0.105*	0.099	0.073	0.019	0.108	0.267
HCB	0.057	0.126*	-0.011	0.206	0.039	0.872
β-HCH	-0.043	0.023	-0.082	0.343	0.708	0.213
PCB-118	0.067	0.111	0.048	0.136	0.071	0.466
PCB-153	0.027	0.068	0.005	0.541	0.267	0.940
PCB-105	0.098*	0.150*	0.067	0.029	0.014	0.313
PCB-138	0.036	0.075	0.015	0.422	0.220	0.918
PCB-156	0.021	0.052	0.000	0.642	0.396	0.995
PCB-180	0.036	0.068	0.013	0.421	0.269	0.846
ΣPCB	0.031	0.070	0.011	0.487	0.251	0.846
Sum of three mono-ortho PCB (105+118+156)	0.061	0.105	0.040	0.174	0.088	0.547
4,4'-DDT	0.058	0.101	0.039	0.194	0.101	0.558
4,4'-DDE	0.038	0.088	0.009	0.393	0.152	0.891
Trans-nonachlor	0.063	0.100	0.037	0.158	0.104	0.579

* : Significant correlation (2-tailed significance)

Table 6.2.27 Head circumference and exposure data: partial correlation, controlled for corrected age in days at NOS; for exposure variables, the log10-transformed values were used

Head circumference at NOS (controlled for age)	Partial correlation coefficient			P-value		
	All infants (N=499)	Male (N=267)	Female (N=232)	All infants (N=499)	Male (N=267)	Female (N=232)
Mercury	0.108*	0.099	0.077	0.016	0.109	0.244
HCB	0.065	0.100	0.017	0.147	0.105	0.802
β-HCH	-0.046	0.003	-0.075	0.305	0.690	0.255
PCB-118	0.100*	0.115	0.084	0.025	0.062	0.201
PCB-153	0.057	0.076	0.031	0.201	0.215	0.636
PCB-105	0.109*	0.142*	0.087	0.015	0.021	0.189
PCB-138	0.061	0.075	0.041	0.181	0.222	0.539
PCB-156	0.039	0.061	0.014	0.390	0.323	0.827
PCB 180	0.068	0.088	0.034	0.131	0.150	0.611
ΣPCB	0.061	0.079	0.036	0.172	0.189	0.590
Sum of three mono-ortho PCB (105+118+156)	0.089*	0.113	0.066	0.048	0.066	0.320
4,4'-DDT	0.070	0.077	0.058	0.121	0.211	0.379
4,4'-DDE	0.046	0.081	0.000	0.311	0.119	0.995
Trans-nonachlor	0.063	0.095	0.026	0.162	0.124	0.689

* : Significant correlation (2-tailed significance)

Table 6.2.28 Bivariate correlation between percentile of head circumference and exposure

Percentile of head circumference at NOS	Spearman´s rho			P-value		
	All infants (N=499)	Male (N=267)	Female (N=232)	All infants (N=499)	Male (N=267)	Female (N=232)
Mercury	0.059	0.043	0.073	0.189	0.482	0.266
HCB	0.094*	0.144*	0.036	0.036	0.019	0.589
β-HCH	-0.007	0.044	-0.055	0.883	0.477	0.401
PCB-118	0.125**	0.148*	0.099	0.005	0.015	0.131
PCB-153	0.081	0.107	0.055	0.072	0.082	0.405
PCB-105	0.162**	0.201**	0.115	<0.001	0.001	0.081
PCB-138	0.088*	0.110	0.065	0.050	0.072	0.323
PCB-156	0.072	0.106	0.037	0.108	0.085	0.578
PCB- 180	0.084	0.113	0.052	0.062	0.065	0.429
ΣPCB	0.084	0.110	0.059	0.060	0.073	0.370
Sum of three mono-ortho PCB (105+118+156)	0.122**	0.152*	0.089	0.006	0.013	0.176
4,4'-DDT	0.113*	0.140*	0.088	0.011	0.022	0.183
4,4'-DDE	0.079	0.105	0.054	0.079	0.088	0.417
Trans-nonachlor	0.103*	0.127*	0.077	0.021	0.038	0.245

* : Significant correlation (2-tailed significance)
** : Highly significant correlation (2-tailed significance)

Table 6.2.29 Bivariate correlation between body length and exposure data, all children

Body length at NOS	Spearman´s rho			P-value		
	All infants (N=498)	Male (N=267)	Female (N=231)	All infants (N=498)	Male (N=267)	Female (N=231)
Mercury	0.052	0.009	0.064	0.426	0.885	0.332
HCB	0.003	-0.009	0.006	0.945	0.882	0.928
β-HCH	-0.035	-0.046	-0.003	0.431	0.458	0.969
PCB-118	0.054	0.032	0.089	0.226	0.604	0.178
PCB-153	0.011	-0.018	0.052	0.813	0.765	0.436
PCB-105	0.062	0.043	0.093	0.170	0.486	0.160
PCB-138	0.032	-0.004	0.078	0.476	0.950	0.236
PCB-156	0.002	-0.041	0.053	0.970	0.504	0.421
PCB-180	0.015	-0.013	0.049	0.736	0.832	0.461
ΣPCB	0.017	-0.014	0.059	0.698	0.816	0.371
Sum of three mono-ortho PCB (105+118+156)	0.045	-0.017	0.085	0.316	0.779	0.199
4,4'-DDT	0.020	0.021	0.023	0.659	0.727	0.724
4,4'-DDE	0.001	-0.017	0.027	0.981	0.782	0.682
Trans-nonachlor	0.039	0.021	0.057	0.379	0.738	0.387

Table 6.2.30 Body length and exposure data: partial correlation, controlled for age at NOS, for maternal weight and height, for parity, log10 of PCB 105 - all children)

Body length at NOS	Partial correlation coefficients			P-value		
	All infants (N=498)	Male (N=267)	Female (N=231)	All infants (N=498)	Male (N=267)	Female (N=231)
Mercury	-0.017	-0.061	0.008	0.708	0.323	0.901
HCB	-0.128**	-0.165**	-0.100	0.004	0.008	0.133
β-HCH	-0.096*	-0.133*	-0.014	0.032	0.031	0.840
PCB-118	0.025	-0.021	0.060	0.574	0.735	0.372
PCB-153	-0.072	-0.127*	-0.009	0.108	0.039	0.890
PCB-138	-0.049	-0.109	0.023	0.274	0.079	0.729
PCB-156	-0.073	-0.150*	0.018	0.104	0.015	0.784
PCB-180	-0.038	-0.100	0.024	0.397	0.106	0.719
2 x sum of PCB (138+153+180)	-0.058	-0.117	0.009	0.189	0.059	0.894
Sum of PCB (138+153+156)	-0.064	-0.122*	0.005	0.158	0.049	0.936
Sum of three mono-ortho PCB (105+118+156)	-0.017	-0.063	0.029	0.705	0.109	0.660
4,4'-DDT	-0.097*	-0.089	-0.130*	0.032	0.153	0.050
4,4'-DDE	-0.115*	-0.140*	-0.107	0.011	0.024	0.107
Trans-nonachlor	-0.050	-0.046	-0.046	0.264	0.454	0.496

* : Significant correlation (2-tailed significance)
** : Highly significant correlation (2-tailed significance)

Table 6.2.31 Partial correlation between NOS and exposure data, cohort divided after sex (corrected for corrected age at NOS, environmental temperature, interval to last meal, and weight gain of mother during pregnancy)

	NOS (all infants) (N=500)		NOS (all boys) (N=267)		NOS (all girls) (N=233)	
	Partial Correlation Coefficient	P-value	Partial Correlation Coefficient	P-value	Partial Correlation Coefficient	Pp-value
Log10 MeHg	-0.031	0.518	0.056	0.392	-0.130	0.061
Log10 HCB	-0.098	**0.037**	-0.174	**0.007**	-0.005	0.940
Log10 β-HCH	-0.025	0.591	-0.161	**0.013**	0.161	**0.020**
Log10 musk xylene	-0.054	0.255	-0.037	0.568	-0.062	0.372
Log10 PCB 118	-0.078	0.097	-0.128	**0.049**	-0.024	0.725
Log10 PCB 153	-0.078	0.099	-0.119	0.068	-0.030	0.665
Log10 PCB 105	-0.101	**0.032**	-0.152	**0.019**	-0.044	0.525
Log10 PCB 138	-0.071	0.132	-0.116	0.075	-0.018	0.791
Log10 PCB 156	-0.042	0.372	-0.081	0.215	-0.001	0.985
Log10 PCB 180	-0.069	0.143	-0.112	0.086	-0.024	0.732
Log10 DDE	-0.084	0.075	-0.129	**0.047**	-0.032	0.649
Log10 DDT	-0.093	**0.049**	-0.140	**0.031**	-0.041	0.554
Log10 trans-nonachlor	-0.056	0.239	-0.093	0.155	-0.010	0.891

Table 6.2.32 Linear regression model for NOS (examiner B only)
Model summary

	R	R^2	Adjusted R^2	Standardized error of the estimate
For all children seen by ST	0.522	0.273	0.228	3.00
For all boys seen by ST*	0.752	0.566	0.514	2.39

	Unstandardized coefficients		Standardized coefficients	Significance		Collinearity statistic (tolerance)
	B	Standard error	Beta	♀+♂ (N=233)	♂ (N=131)	
Constant	56.84	7.444		**<0.001**	**<0.001**	
Corrected age at NOS (days)	-0.102	0.037	-0.172	**0.007**	**0.002**	0.949
Interval to last meal (min)	0.012	0.005	0.163	**0.009**	**0.042**	0.977
Environmental temperature (°C)	-0.391	0.276	-0.088	0.159	**0.001**	0.970
Stability of states (no / yes)	5.082	1.404	0.230	**<0.001**	**<0.001**	0.935
Level of higher one of parents´ profession/ occupation (low/ high)	-0.877	0.447	-0.128	0.051	0.138	0.879
Weight gain during pregnancy (kg)*	-0.038	0.040	-0.059	0.351	Not in model	0.944
Early abortions (no / yes)	-0.797	0.501	-0.102	0.114	0.051	0.909
Log10 of MeHg	1.125	0.595	0.140	0.060	**0.002**	0.688
Log10 of HCB	-3.155	2.179	-0.206	0.149	0.117	0.186
Log10 of PCB 105	-2.356	0.973	-0.286	**0.016**	**0.001**	0.269
Log10 of PCB 156	10.72	2.804	0.984	**<0.001**	**<0.001**	0.057
Log10 of PCB 180	-8.207	2.603	-0.787	**0.002**	**0.007**	0.059
Log10 of t-nonachlor*	---	---	---	---	0.312	---

* : Same model as for all children seen by B with trans-nonachlor instead of weight gain

Table 6.2.33 Correlation between hypokinesia and exposure data* (T-test)

Hypokinesia (no / yes)	All children (N=500)		All boys (N=267)		All girls (N=233)	
	T-value	Sig. (2-tailed) of t-value	T-value	Sig. (2-tailed) of t-value	T-value	Sig. (2-tailed) of t-value
Mercury	1.562	0.119	2.089	**0.038**	0.171	0.867
HCB	-0.648	0.517	-0.403	0.687	-0.518	0.605
β-HCH	0.014	0.989	-1.037	0.301	1.229	0.220
Musk xylene	-0.441	0.659	-0.683	0.524	0.022	0.983
PCB-118	-2.562	**0.017**	-0.975	0.330	-2.886	**0.012**
PCB-153	-2.436	**0.022**	-0.875	0.382	-2.430	**0.031**
PCB-105	-2.422	**0.023**	-1.024	0.307	-2.133	0.055
PCB-138	-2.389	**0.025**	-0.879	0.380	-2.484	**0.029**
PCB-156	-2.088	**0.047**	-0.756	0.450	-1.975	0.069
PCB-180	-2.422	**0.023**	-0.806	0.421	-2.615	**0.021**
ΣPCB	-2.461	**0.021**	-0.868	0.386	-2.562	**0.024**
Sum of three mono-ortho PCBs (105+118+156)	-2.472	**0.021**	-0.946	0.345	-2.659	**0.019**
4,4'-DDE	-1.726	0.085	-0.620	0.536	-1.840	0.067
4,4'-DDT	-2.754	**0.011**	-1.084	0.279	-2.450	**0.031**
Trans-nonachlor	-3.171	**0.004**	-1.669	0.120	-2.956	**0.011**

* : All exposure variable were tested as log10-transformed values

Table 6.2.34 Bivariate correlation between reflex cluster score and exposure data

Exposure variable	Complete cohort (N=500)		Subcohort B (N=233)	
	Spearman´s rho	p-value	Spearman´s rho	P-value
Mercury	0.034	0.447	-0.016	0.807
HCB	-0.045	0.315	-0.158	**0.016**
β-HCH	-0.087	0.053	-0.177	**0.007**
PCB-118	-0.044	0.325	-0.194	**0.003**
PCB-153	-0.038	0.402	-0.185	**0.005**
PCB-105	-0.024	0.593	-0.158	**0.016**
PCB-138	-0.038	0.396	-0.188	**0.004**
PCB-156	-0.036	0.422	-0.150	**0.022**
PCB-180	-0.042	0.351	-0.177	**0.007**
2 x sum of PCB (138+153+180)	-0.039	0.390	-0.187	**0.004**
4,4'-DDT	-0.015	0.745	-0.139	**0.033**
4,4'-DDE	-0.019	0.673	-0.167	**0.010**
T-nonachlor	-0.035	0.430	-0.180	**0.006**
Musk xylene	0.027	0.552	-0.042	0.523

Table 6.2.35 Summary of neurological effects, differentiated after sex

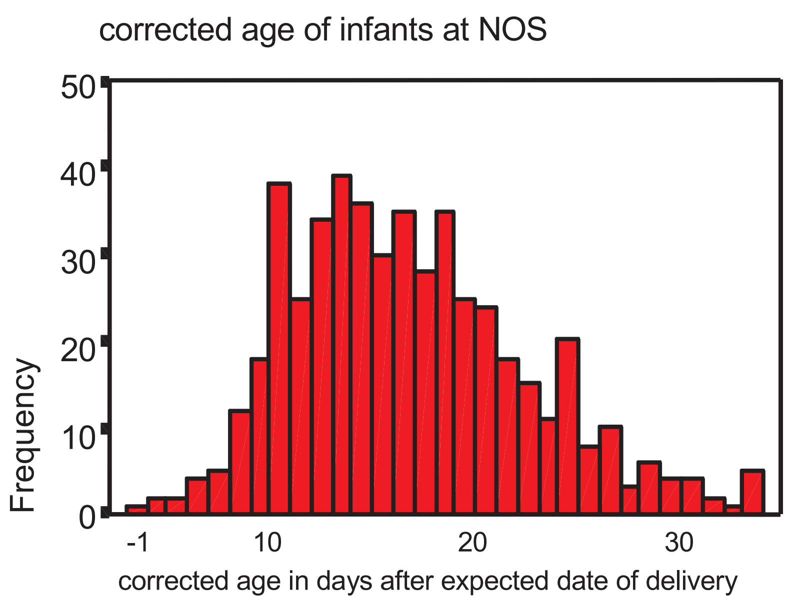
Contaminant	Effects in male	Effects in female
Mercury	NOS (↑) Reflex cluster score (↑) Tonus cluster score : 0 Much less hypokinesia ↓↓ More hyperkinesia (↑) Less opisthotonus (↓)	NOS ↓ Relex cluster score (↓) Postural tone cluster score ↓↓ No effect on hypokinesia Less hyperkinesia ↓ Much less opisthotonus ↓
HCB	NOS ↓↓ Reflex cluster score ↓ Postural tone cluster score (↓) More hypokinesia (↑) No effect on hyperkinesia Less opisthotonus (↓)	No effect on NOS Reflex cluster score: 0 Tonus cluster score: 0 More hypokinesia (↑) Hyperkinesia (↑) Less opisthotonus ↓
β-HCH	NOS ↓↓ Reflex cluster score ↓↓ Postural tone cluster score (↓) More hypokinesia (↑) More hyperkinesia (↑) Less opisthotonus (↓)	NOS ↑↑ Reflex cluster score (↓) Postural tone cluster score ↑↑ Less hypokinesia ↓ Less hyperkinesia (↓) Less opisthotonus (↓)
Musk xylene	NOS (↓) Reflex cluster score: no effect Postural tone cluster score (↓) More hypokinesia (↑) Less hyperkinesia (↓) Less opisthotonus (↓)	NOS (↓) Reflex cluster score (↓) No effect on tone score No effect on hypokinesia More hyperkinesia (↑) More opisthotonus (↑)
PCB-118	NOS ↓↓ Reflex cluster score ↓ Postural tone cluster score ↓ More hypokinesia (↑) No effect on hyperkinesia Less opisthotonus (↓)	NOS (↓) Reflex cluster score (↓) Postural tone cluster score (↑) Much more hypokinesia (↑↑) No effect on hyperkinesia Much less opisthotonus ↓↓
PCB-153	NOS ↓ Reflex cluster score ↓ Postural tone cluster score (↓) More hypokinesia (↑) No effect on hyperkinesia Less opisthotonus (↓)	NOS (↓) Reflex cluster score (↓) Postural tone cluster score (↑) Much more hypokinesia ↑↑ No effect on hyperkinesia Much less opisthotonus ↓↓
PCB-105	NOS ↓↓ Reflex cluster score (↓) Postural tone cluster score (↓) More hypokinesia (↑) Less hyperkinesia (↓) Less opisthotonus (↓)	NOS (↓) Reflex cluster score (↓) Postural tone cluster score (↑) Much more hypokinesia ↑ No effect on hyperkinesia Less opisthotonus (↓)
PCB-138	NOS ↓ Reflex cluster score ↓ Postural tone cluster score (↓) More hypokinesia (↑) More hyperkinesia (↑) Less opisthotonus (↓)	No effect on NOS Reflex cluster score (↓) Postural tone cluster score (↑) Much more hypokinesia ↑↑ No effect on hyperkinesia Much less opisthotonus ↓↓

PCB-156	NOS ↓ Reflex cluster score (↓) Postural tone cluster score (↓) More hypokinesia (↑) No effect on hyperkinesia Less opisthotonus (↓)	No effect on NOS Reflex cluster score (↓) Postural tone cluster score (↑) Much more hypokinesia ↑ No effect on hyperkinesia Much less opisthotonus ↓↓
PCB-180	NOS ↓ Reflex cluster score ↓ Postural tone cluster score ↓ More hypokinesia (↑) No effect on hyperkinesia Less opisthotonus ↓	NOS (↓) Reflex cluster score (↑) Postural tone cluster score (↑) Much more hypokinesia ↑↑ No effect on hyperkinesia Much less opisthotonus ↓↓
DDE	NOS ↓↓ Reflex cluster score (↓) Postural tone cluster score (↓) More hypokinesia (↑) No effect on hyperkinesia Less opisthotonus (↓)	NOS (↓) Reflex cluster score (↓) Postural tone cluster score (↑) Much more hypokinesia ↑ No effect on hyperkinesia Much less opisthotonus ↓↓
DDT	NOS ↓↓ Reflex cluster score (↓) Postural tone cluster score (↓) More hypokinesia (↑) More hyperkinesia (↑) No effect on opisthotonus	NOS (↓) Reflex cluster score: no effect Postural tone cluster score (↑) Much more hypokinesia ↑ No effect on hyperkinesia Much less opisthotonus ↓↓
Tans-nonachlor	NOS ↓ Reflex cluster score (↓) Postural tone cluster score (↓) More hypokinesia ↑ More hyperkinesia (↑) Less opisthotonus (↓)	No effect on NOS Reflex cluster score (↓) Postural tone cluster score (↑) Much more hypokinesia ↑↑ More hyperkinesia (↑) Much less opisthotonus ↓↓

↑↑/•• : Significance of t- resp. p-value <0.050
↑/• : Significance of t- resp. p-value 0.050 – 0.250
(↑)/(•) : Significance of t- resp. p-value 0.251 – 0.750
— : Significance of t- resp. p-value > 0.750
o : No effect

6.2.7.3 Figures

Figure 6.2.4 Distribution of corrected age of infants in days (age after expected date of delivery, which was calculated after last menstrual period) at neurological examination.



6.3 Dietary Survey of Faroese Women in Third Trimester of Pregnancy

6.3.1 Material and Methods:

In August 1998 Faroese health authorities recommended women to reduce their intake of pilot whale meat and blubber in order to protect the foetus against adverse effects from food contaminants. This study describes the effects of this recommendation. To cover the daily variations we used 24 hour recall (24 h recall), as well as a food diary (FD), where all food consumed during one day at a time was reported. To adjust for seasonal variations the women answered a food frequency questionnaire (FFQ) where what is considered Faroese food was listed and we asked about consumption during the past 12 months. General information about height, weigh and smoking and drinking habits, previous deliveries and educational level were recorded. Blood samples were taken in the 37th week of pregnancy and analysed for heavy metals and organochlorines. The registration sheets were in accordance with a previously performed dietary survey in the Faroes and in accordance with datasheets approved upon in the human health group of AMAP.

In the Faroe Islands there are three delivering units, one main unit at the main hospital in Tórshavn and the other two at hospitals in Tvøroyri and Klaksvik. When a woman becomes pregnant, the GP reports this to the delivering unit where she is expected to give birth. We used these lists with names, ID numbers, addresses and term dates to enter the participants in a data base designed for this purpose, and each subject was assigned her own file number. A standard letter, where the purpose of this study was explained and how we were obtaining the information, was sent to the women when they were 24-26 weeks pregnant. They could respond themselves by returning the signed form but often we contacted them by telephone approximately one week after the letters were sent, to provide further information and ask if they wanted to participate. We sent letters for one month at a time.

The data collection was done for 51 weeks, from Oct. 2000 until Sep. 2001. Two individuals served as interviewers, one clinical dietician and one trained midwife. During this period there were a total of 486 pregnant women and 298 = 65,6% were invited to participate. 100 women did not want to participate, but did not give any specific reason, 3 women had had a miscarriage, in 2 women the term date did not equal the list we had and they were too close to term date and 4 women were abroad. A total of 189 (66,4%) agread to participate. During the investigation period 8 subjects (2,7%) did not want to continue, 14 subjects (4,7%) did not take the blood sample and dropped out, 10 subjects (3,4%) did accept to participate but an appointments was not made and 9 subjects (3%) did accept to participate but we could not accommodate the interviews because of lack of time. We ended up with 148 (49.7%), who participated in the entire project.

Data Collection: We interviewed the women at home when they were about 28, 33 and 38 weeks pregnant. They received a telephone call the evening before to make an appointment, at 8:30–10:00 p.m. The usual time for supper in the Faroe Islands is around 6:30 p.m. and by calling them at this time we assumed that most of the meals that day already had been consumed. In some cases we called the morning of the interview.

To estimate the amount consumed we used (food) models and pictures completed with instructions where the weight of the food was defined in proportion to the models/pictures. These models and matching instructions were borrowed from The National Food Agency in Denmark. We made models for Faroese food items as needed.

First visit: 24 h recall, starting with first item consumed the previous day and during the next 24 hours in the order of time of consumption, what was consumed and how much according to the food models. Then the Food Frequency Questionaire (FFQ) was answered and the questionnaire on general questions. Sheets for Food Diary (FD) for 3 days were handed out with a detailed explanation about recording everything consumed during the days agreed upon. We included always one weekend in the FD.

Second visit: 24 h recall questionnaire performed as at the first visit. The FD recording was checked with the subjects using the models to quantify the consumption. FD-recording sheets for three more days were handed out.

Third visit: 24 h recall questionaire performed and the Food Diary checked with the subjects.

All together there were obtained 409 24h recall interviews from the 148 women (116 did all three interviews, 29 two interviews and 3 women only one interview). The main reason for not doing all three interviews was delivery and scheduling difficulties.

In total 732 FD recordings were collected (in average five FD´s per woman. The reasons for not doing all six were mainly delivery and lack of motivation. Altogether this totals 1,141 recordings.

Before the data collection started we completed 17 interviews as pilot tests covering all parts of our concept, equally divided between the interviewers and mutually observed. During the collection period we tried to keep the participants separate so that the interviewer who started also finished each participant, but for different reasons this was not possible for all women. A total of 97 women only had one interwiever as intended and 51 saw both interviewers during the data collection phase. 26 times the interviewers supervised each other, and weekly meetings ensured continuity of data quality.

After each home visit all food items were estimated according to the models and recorded with name of item and matching weight on a sheet designed for this purpose. When all data collection was done the clinical dietician reviewed all 1,141 recordings to confirm all data and ensured consistency.

Data entering: After confirming of all the data two assistants were reading while the interviewers keyed in all the data. For data entering we used the dietary evaluation soft-ware Dankost 3000. The calculation is based on Atwater. This program calculates the macro- and micronutrients. Food items, which did not exist in Dankost 3000 beforehand, were entered form Faroese- and Icelandic food records. For some food items we used the declaration on the package. For many of the items entered the only available information was the macronutrients and a few micronutrients. In some cases, mostly sweets with no declaration on the package, the clinical dietician decided which food item with known values came the closest. For statistical purposes data were exported to ACCESS and SPSS.

6.3.2 Results

6.3.2.1 Lifestyle factors among 165 pregnant women according to the food frequency questionnaire (AMAP questionnaire), administered by the interviewers:

Sample caracteristics:

Number	Age median (min-max)	Height in cm mean (min-max)	Weight in kg median (min-max)
	29 (17-40)	165.8 (150-183)	65.2 (47-115)

Smoking:

Number of valid questionnaires: 165	Never smoked	Former smoker	Present smoker	Occasional smoking
Number (%)	84 (51%)	38 (23%)	30 (18%)	13 (8%)
Cigarettes per day, mean (min-max)	-	6.6 (1-20)	7.7 (2-15)	2 (1-3)
Years smoking, mean (min-max)	-	3.6 (1-5)	4.2 (2-6)	3.9 (2-5)

Alcohol Consumption in Pregnancy:

Trimester of Pregnancy	Bottles of beer per month mean (max); Std. Dev.	Glasses of wine per month mean (max); Std. Dev.	Shots of liquor per month mean (max); Std. Dev.
First	1.05 (24); 2.7	0.98 (18); 2.10	0.75 (19) ; 2.47
Second	0.30 (6); 0.83	0.72 (8); 1.23	0.25 (20); 1.66

38,3 % Reported to be total abstainers in first trimester of pregnancy
49,7 % Reported to be total abstainers in second trimester of pregnancy

Pilot whale for dinner in average during the last 12 months:

N= 157	
Once a month or less	2-3 times per month
154 (92.2%)	3 (1.8%)

Ocean fish for dinner in average during the last 12 months:

N=155			
Once per month or less	2-3 times per month	1-3 times per week	4 times or more per week
5 (3.0 %)	26 (15.6%)	93 (55.7%)	31 (18.6%)

Birds for dinner in average during the last 12 months:

N=154			
Once per month or less	2-3 times per month	1-3 times per week	4 times or more per week
39 (23.4 %)	80 (47.9 %)	34 (20.4 %)	1 (0.6 %)

6.3.2.2 Characteristics of the diet based on calculations of the 409 24-h recall interviews and the 732 food diary recordings:

	Mean	Minimum	Maximum
Energy per day	10,231 kJ	2,878 kJ	37,766 kJ
Protein, % of total energy	14.7%	5.7%	47.3%
Lipid, % of total energy	33.3%	9.6%	67.5%
Carbohydrates, % of total energy	51.9%	23.4%	75.0%
Dietary fibres in grams pr. 1000 kJ	1.7 g		
Saturated fatty acids per day	28.8g	0.78g	122.5g
Monounsaturated fatty acids per day	21.26g	0.32g	139.8g
Polyunsaturated fatty acids per day	9.97g	0.036g	73.5g
Oceanic fish in average per day	40.2g		
Pilot whale meat in average pr. day	1.45g		
Pilot whale blubber in average pr. day	0.60g		
Sea birds in average pr. day	3.00g		

The dietary intake of pilot whale meat and blubber is remarkably low compared with the last dietary survey in 1981-82, where the average consumption of pilot whale meat among adult men and women was 12 grams per day and of blubber 7 grams. This reduction is most likely to be a result of the recommendations to pregnant women to avoid contaminated seafood, such as pilot whale meat and blubber.

6.3.2.3 *Contaminants in the blood of the mothers in 38th week.*

MEAN CONCENTRATIONS OF ORGANOCHLORINES IN MATERNAL BLOOD SERUM - WET WEIGHT BASIS (MEANS, UG/L)

	N	Minimum	Maximum	Mean	Std. Deviation
A-HCH	148	N.d.	N.d.	-	-
B-HCH	148	N.d.	0.597	0.114	0.099
G-HCH	148	N.d.	N.d.	-	-
Hexachlorbenzol	148	.050	1.934	0.36363	0.319
Oxychlordan	148	N.d.	1.427	0.159	0.196
Cis Chlordan	148	N.d.	N.d.	0.001	0.000
Trans-Chlordan	148	N.d.	N.d.	0.001	0.000
Nonachlor	148	N.d.	4.221	0.671	0.826
Toxaphene Parlar 26	148	N.d.	1.496	0.152	0.212
Toxaphene Parlar 32	148	N.d.	0.059	0.002	0.008
Toxaphene Parlar 44	148	N.d.	0.326	0.030	0.052
Toxaphene Parlar 50	148	N.d.	1.609	0.194	0.251
P,p-DDE	148	0.351	39.438	5.534	6.051
P,p-DDT	148	N.d.	1.461	0.175	0.251
PCB-28	148	N.d.	0.151	0.004	0.017
PCB-52	148	N.d.	N.d.	-	-
PCB-101	148	N.d.	0.225	0.012	0.032
PCB-99	148	N.d.	1.275	0.292	0.268
PCB-138	148	,110	10.341	1.834	1.690
PCB-187	148	,030	3.500	0.682	0.664
PCB-183	148	N.d.	0.811	0.166	0.148
PCB-128	148	,052	4.031	0.756	0.686
PCB-118	148	,031	2.852	0.470	0.481
PCB-153	148	N.d.	14.529	2.189	2.051
PCB-105	148	N.d.	0.583	0.091	0.105
PCB-156	148	N.d.	1.486	0.167	0.180
PCB-180	148	0.057	7.355	1.432	1.272
PCB-170	148	N.d.	4.304	0.666	0.660
Lipid (mg/dl)	148	394.12	1438.43	827.01	166.97

Non-detecable (n.d.) concentrations were assumed to be 0.001 ug/l

MEAN CONCENTRATIONS OF METALS IN MATERNAL BLOOD, WHOLE WEIGHT BASIS (MEANS UG/L)

Metal	N	Minimum	Maximum	Mean	Std. Deviation
Lead	124	13.3	99.8	22.46	10.0
Cadmium	124	0.020	2.90	0.42	0.46
Mercury (total)	124	0.001	7.50	1.86	1.4
Selenium	121	54	169	102.1	23.9

6.3.3 Discussion:

The PCB concentrations are elevated, as seen in other studies among pregnant women in the Faroes. In 1994 the sum of PCBs (geometric mean of (PCB 138+153+180) * 2 was 1.12 µg/g lipid. The corresponding value from this study is 0.94 µg/g lipid. The reduction of PCB´s in pregnant women is moderate compared to reduction of mercury, which is dramatic. Cord blood mercury concentrations in 1,023 births in 1986/87 was 24,2 µg/l (median). In this study the median is only 1,4 µg/l.

The results from the dietary survey showed a very significant reduction in whale meat and blubber intake, and blood analysis shows a corresponding reduction in the mercury exposure. However, the PCB levels are still high and must be considered to be a potential health problem in the Faroese community. According to the dietary survey the daily intake of both whale meat and whale blubber has been reduced up to one order of magnitude. However, the concentration of organochlorines has not declined to the same extent as the mercury, indicating that organochlorines can have other significant sources, e.g. seabirds. The longer half-life of most of some organochlorines compared to methylmercury may be too be an explanation of this observation.

6.4 Exposure to Seafood Contaminants and Immune Response in Faroese Children

From the fall of 2000 the youngest subset of Cohort 3 (N = 130) was invited for a check-up before and after the scheduled childhood vaccination at age 12 months. All infants had followed the normal vaccination program for Danish and Faroese children and were vaccinated with tetanus toxoid (TT), diphtheria toxoid (DT), pertussis toxin (acellular pertussis antigen), polio (inactivated polio virus I, II and III) mixed in one syringe, and *Haemophilus influenzae* type b polysaccharide (HibCP) conjugated to TT (ActHib®) in another. Vaccinations were given approximately at the ages of 3 months, 5 months and 12 months. Serum antibody concentrations against TT, DT and HibCP were determined at the State Serum Institute in Copenhagen, which also produced the vaccines and delivered ActHib (from Avantis Pasteur). TT and DT are classical protein antigens depending on a T-cell help for both primary and recall antibody responses (T-cell dependent antigens). In contrast, as a polysaccharide antigen coupled to a protein carrier (TT), HibCP relies on T-cell function for the primary activation of naive B-cells in infants, while boosting of the response in connection with subsequent vaccination can be elicited by the capsular polysaccharide alone (T-independent activation). The results of this study will be available in the near future.

6.5 Exposure to mercury and organochlorines 1985-2001.

6.5.1 Introduction

Several large studies have taken place in the Faroe Islands (table 6.5.1) to examine the effects of contaminated seafood on pregnancy outcome and neurodevelopment. A total of five cohorts with 2,400 persons were generated. Exposure data obtained in these studies are collected in this section in a way to provide the best possible basis for comparison of exposure levels of the different groups during the 15-year period. A summary of the most important characteristics of the study cohorts can be found in table 19 in this section (Description of study populations). The exposure variables are listed in the following paragraphs.

Table 6.5.1 List of studies

1	Pilot study in 1985
2	Study on the effects of antenatal exposure to methylmercury (cohort 1: 1986/1987)
3	Study on the effects of pre- and postnatal exposure to methylmercury and PCB (cohort 2: 1994/5)
4	Study about the effects of prenatal exposure to methylmercury and organochlorines (cohort 3: 1998/2000)
5	Intervention study with questionnaires and hair samples about diet in 1999 and 2000
6	Dietary Survey of Faroese Women in 3rd Trimester of Pregnancy, 2000/2001

6.5.2 Mercury in maternal blood

Analyses of total and inorganic mercury in whole blood and serum in the 53 women living in Leirvík of the pilot study in 1985 resulted in the following values (Grandjean et al., 1992):

Table 6.5.2

	N	Median in nmol/L (µg/L)	Range In nmol/L (µg µ/L)
Whole blood: total mercury	53	60 (12.1)	13 – 250 (2.6 – 50.1)
Whole blood: inorganic mercury	47	10.5	<0.5 – 25
Serum: total mercury	50	10.5	<0.5 – 41
Serum: inorganic mercury	52	8.5	<0.5 – 1.5

Inorganic mercury represented an average of 11.0 ± 1.85% of the total mercury concentration (Grandjean et al., 1992).

In the following cohort, mercury in maternal hair and in umbilical cord blood were used as biomarker for the exposure during pregnancy.

6.5.3 Mercury in maternal hair samples

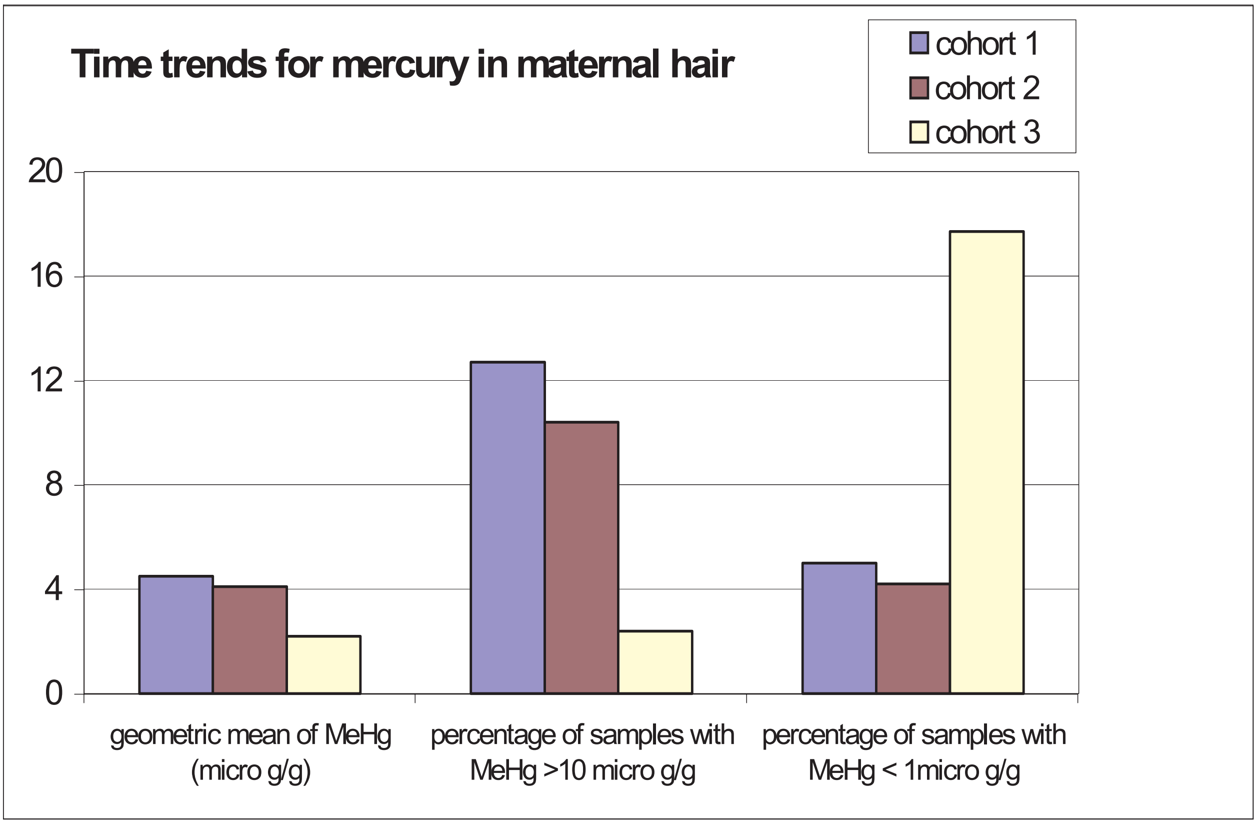
The geometric average hair-mercury concentration in 1,020 Faroese women from Cohort 1 (children born in 1986/1987) was 4.5 µg/g, with 130 samples (12.7%) above 10 µg/g (50 nmol/g). Five samples (0.5%) exceeded 25 µg/g (125 nmol/g). The maximum was 39.1 µg/g (195 nmol/g). Only 5% of the Faroese women from Cohort 1 had hair-mercury concentrations below 1 µg/g. Compared to Cohort I, a slightly lower mercury concentration was found in Cohort 2, with a geometric mean of 4.1 µg/g. Fifteen hair samples (10.4%) exceeded a mercury concentration of 10 µg/g (Steuerwald et al., 2000).

The most recently established cohort (cohort 3) showed a geometric mean for mercury in maternal hair of 2.2 µg/g. In this cohort, which was created in the years 1998 to 2000, only 2.4% (15 of 617) had a mercury concentration above 10 µg/g while in 17.7% (109/617) the concentration was below 1 µg/g (See section 6.2.).

Table 6.5.3 Mercury in maternal hair (μg/g)

	N	Mean	Median	Geometric mean	P25	P75	Mini-mum	Maxi-mum
Cohort 1 (Grandjean et al., 1992)	1,020	5.6	4.6	4.5	2.5	7.7	0.17	39.1
Cohort 2 (Steuerwald et al., 2000)	144	5.3	4.5	4.1	2.5	7.4	0.36	16.3
Cohort 3 (See section 6.2.)	617	3.1 (SD 3.2)	2.2	2.2 (SD 2.5)	1.2	4.0	0.02	32.7

Figure 6.5.1: Time trends for mercury in maternal hair



6.5.4 Mercury in umbilical cord blood

In cohort 1, the geometric mean for the mercury concentration in umbilical cord blood was 24.2 μg /L. 250 of the 1,023 samples (25.1%) had a blood-mercury concentration that exceeded 40 μg /L (200 nmol/L). Twenty samples (2.0%) exeeded 100 μg /L (500 nmol/L) (Grandjean et al., 1992). The highest level that was measured for this cohort was 351 μg /L (1,755 nmol/L) (Weihe et al., 1996). Again, the concentrations measured in cohort 2, which was established eight years after cohort 1, were slightly lower: the geometric mean for mercury in cord blood reached 20.4 μg /L (Steuerwald et al., 2000).

Table 6.5.4 Mercury in umbilical cord blood (μg/L)

	N	Geometric mean	Median	P25	P75
Cohort 1 (Grandjean et al., 1992)	894	22.9	24.2	13.0	40.2
Cohort 2 (Steuerwald et al., 2000)	163	20.4	21.0	11.8	40.0

Cord blood mercury concentrations from cohort 3 are being analyzed and are not yet available for reporting. For comparison the total mercury concentration in 124 pregnant women in 38th week was only 1,26 microgram/l in Cohort 4 (see section 6.3. in this report). For comparison, mercury concentrations in cord blood are usually about 25-50% higher than in maternal blood.

6.5.5 Mercury in breast milk

During a one-month period (Grandjean et al., 1992) 88 samples of transition milk were collected from mothers from Cohort 1. Total mercury concentration was between 1 and 4 μg /L for most of the samples with a median of 2.45 μg/L and a maximum of 8.7 μg /L (Grandjean et al., 1995). No further results of mercury in breast milk are available, but the results suggest that human milk may contribute an important exposure source.

6.5.6 MeHg in hair in children

Of about half of the cohort 1-children (583 children or 57.0%) a hair sample of at least 100 mg could be obtained at the age of about 12 months (Grandjean et al., 1994). A second sample of the children was collected when they were 7 years old. At that age the geometric mean for methylmercury was nearly threefold the concentration found at the age of one year (Grandjean et al., 1999).

Table 6.5.5 Methylmercury in children's hair at different ages (in μg/g)

(MeHg in μg/g)	Cohort 1 at 12 months (Grandjean et al., 1994)	Cohort 1 at 7 years (Grandjean et al., 1999)
number of samples	583	903
geometric mean	1.10	2.99
P25	0.66	1.70
P75	1.88	6.10
Maximum	8.82	37.61

6.5.7 Mercury in children at age 7 years

In 672 children out of the 1,024 children of cohort 1, a blood sample was analyzed at 7 years. The geometric mean for mercury was 8.82 μg /L with an interquartile range of 4.8 to 18.2 μg /L (Grandjean et al., 1999). Children from cohort 2 have just reached 7 years, and blood samples are being collected. However, no comparable data for this age group are available at the moment.

6.5.8 PCB in maternal serum

Maternal serum was collected at week 32 of pregnancy for cohort 2 and at week 34 – 36 for cohort 3. In cohort 2, the geometric mean of ΣPCB (sum of 28 PCB congeners, namely IUPAC nos. 28, 52, 56, 66, 74, 99, 101, 105, 110, 118, 138, 146, 153, 156, 170, 172, 177, 178, 180, 183, 189, 193, 194, 195, 201, 203, and 206) was 0.86 μg/g lipid (Grandjean et al., 2001). Results of the analysis of the samples collected for cohort 3 are not available yet.

Table 6.5.6 Sum of PCB in maternal serum

	ΣPCB (in μg/g lipid)							
	N	Mean	Median	Geometric mean	P25	P75	Minimum	Maximum
Cohort 2-1994 (Steuerwald et al., 2000)	173	1.58	1.15	1.12	0.62	1.87	0.04	18.4
Cohort 4-2001 (see section 6.3)	148	1.33	0.92	0.94	0.54	1.55	0.06	8.0

[1]: Sum of PCB was calculated as 2.0 times the sum of the most prevalent congeners 138, 153, and 180. While analyzing the PCB concentration in transitional milk of cohort 1, it was found that the three congeners (138, 153, and 180) constituted 50% of the total PCB concentration.

6.5.9 PCB in cord blood

For cohort 2 cord blood values of ΣPCB are available, but not for the other cohorts. Results are not published. But the relation between lipid-based PCB values in maternal and cord serum samples is about 1:1 (Steuerwald et al., 2000). Thus the magnitude of the values in cord blood can be estimated when using the numbers given in table 5. In Cohort 1, instead of cord blood, 435 umbilical cords were examined for their PCB content. The mean of the measured sum of PCB (calculated as twice the sum of congeners 138, 153, and 180) was 1.12 ng/g wet weight with an interquartile range of 0.57 to 1.55 ng/g. The lipid content of the tissue showed an average of 2.2 mg/g (Grandjean et al., 1997).

6.5.10 PCB in breast milk

Four pooled samples collected while establishing cohort 1 in 1987 showed a total PCB concentrations of 1.9 to 3.5 μg/g lipid (Grandjean et al., 1995). PCB in breast milk from day 4-5 in cohort 2 reached a geometric mean of 1.52 μg/g (total range 0.07-18.5 μg/g) (Steuerwald et al., 2000). The lipid-based concentrations of PCB in maternal serum were closely associated with those of the corresponding milk sample (r=0.92). The concentrations in transitional milk were generally higher than in maternal serum with the milk/serum ratio being 1.44 (Winnecke, 1999). However, note must be taken that milk analysis results were recovery-adjusted, but serum results were not (average recovering of PCB confiners was about 65%).

Table 6.5.7 PCB in breast milk

		ΣPCB (in µg/g lipid)						
	N	Mean	Median	Geometric mean	P25	P75	Minimum	Maximum
Cohort 2 (Steuerwald et al., 2000)	168	2.17	1.53	1.52	0.87	2.52	0.07	18.5
Cohort 3 (See section 6.2)	587	1.72 (SD ± 1.54)	1.31	1.32	0.82	2.11	0.08	17.59

[1]: Sum of PCB was calculated as 2.0 times the sum of the most prevalent congeners 138, 153, and 180 (International Union of Pure and Applied Chemistry numbers)

Table 6.5.8 Specific PCB-congeners in breast milk of Faroese mothers (µg/g lipid)

	Cohort 2 (n=144)[1]		Cohort 3 (n=569)[2]	
	Arithmetic mean (SD)	Geometric mean	Arithmetic mean (SD)	Geometric mean
PCB-105	0.035 (0.043)	0.022	0.018 (0.017)	0.012
PCB-118	0.103 (0.138)	0.067	0.082 (0.075)	0.058
PCB-138	0.398 (0.386)	0.293	0.280 (0.261)	0.213
PCB-153	0.445 (0.447)	0.319	0.372 (0.313)	0.285
PCB-156	0.027 (0.026)	0.013	0.027 (0.021)	0.021
PCB-180	0.237 (0.246)	0.167	0.208 (0.183)	0.159

Source: 1: Winnecke, 1999; 2: See section 6.2. in this report
n.a. : not available

6.5.11 Lead in cord blood

Lead in cord blood was measured in cohort 1; the median of 1015 samples was 82 nmol/L with P25 at 58 nmol/L and P75 at 106 nmol/L. In the 52 women of the pilot study, whole blood lead was measured with a median of 96 nmol/L (range 39 – 174 nmol/L (Grandjean et al., 1992).

6.5.12 Selenium

Blood selenium was analyzed in 1020 cord blood samples of cohort 1. The median was 1.4 µmol/L (110 µg /L) with P25 of 1.27 µmol/L and P75 of 1.55 µmol/L (Grandjean et al., 1992).

84 transition milk samples were analyzed for their selenium content. The concentrations ranged between 6.7 and 38 µg /L with a mean of 19.1 µg /L (Grandjean et al., 1995).

In cohort 2, the mean of cord blood selenium was 1.31 µmol/L (103.4 µg /L) with a standard deviation of 0.18 µmol/L (14.2 µg /L) (Grandjean et al., 2001).

6.5.13 Other contaminants in maternal serum

TABLE 6.5.9 OTHER CONTAMINANTS IN MATERNAL SERUM OF FAROESE MOTHERS (μG/G LIPID)

	Cohort 2 (Steuerwald et al., 2000)
p,p'-DDE (μg/g lipid)	(N=173) geometric average 0.72 P25: 0.40 P75: 1.21 range 0.18 – 8.0

6.5.14 Other contaminants in breast milk

TABLE 6.5.10 MEAN CONCENTRATIONS OF OTHER ORGANOCHLORINES AND PERSISTENT PESTICIDES IN BREAST MILK OF FAROESE MOTHERS (μG/KG LIPID)

	Cohort 2 (N=168)[1]		Cohort 3 (N=587)[2]	
	Arithmetic mean (SD)	Geometric mean	Arithmetic mean (SD)	Geometric mean
Trans-nonachlor	157.8 (197.0)	78.1	151.4 (176.3)	96.3
p, p'-DDT	61.1 (70.4)	38.3	35.3 (42.3)	22.2
p, p'-DDE	1,310.1 (1,446.7)	856.1	848.9 (953.6)	591.9
DDE/ DDT*			31.07 (24.15)	
HCB	70.2 (51.1)	58.4	44.8 (28.4)	38.6
β-HCH	38.5 (19.1)	27.5	23.6 (16.8)	20.7
Musk-xylene	41.4 (26.2)	33.3	16.7 (22.1)	12.8

Source: 1: Steuerwald et al., 2000; 2:See section 6.2 in this report)
* : normal distribution, therefore geometric mean was not calculated

In cohort 2, the range of p,p'-DDT was 0.05 – 13.7 μg/g lipid, P25 and P75 reached 0.49 respective 1.55 μg/g lipid (Steuerwald et al., 2000).

6.5.15 Contamination levels in two consecutive pregnancies

It was possible to compare exposure data in two following pregnancies for few mothers in cohort 2: 10 women provided two children from two different pregnancies to the cohort. Birth weight, length at birth and head circumference, length of gestation and maternal pre-pregnancy BMI and weight gain during pregnancy did not differ significantly between the group of earlier and later born infants. Four boys and six girls resulted from the earlier pregnancy, the distribution of gender for the next parity was converted: six boys and four girls.

For nine of the mothers two samples of hair were collected and analyzed for methylmercury. The interval between the first and the second samples ranged from 13 to 23 months (average of 18.8 months). The mean of mercury concentration in the second samples was lower but the difference was not significant. If the values measured in the individual mothers in connection with the earlier and the later pregnancy were compared, in three of them a slightly higher value was found in the second samples. The differences between the first and the second sample were 27.3%, 9.6%, and 1.7%. The decrease in the remaining six sample pairs were 30.3%, 48,5%, 70.1%, 70.7%, 71.0%, and 73.8%.

For analysis of organochlorines one earlier sample of breast milk was missing, thus giving the possibility to compare two milk samples of 9 mothers. The means for the different organochlorines as well as for all the PCB-congeners were lower in the following pregnancy. But none of the differences was significant. When looking at the individual mothers, musk xylene increased in four mothers, PCB 138 in three mothers, β-HCH, PCB 180, and trans-nonachlor in two, HCB and ΣPCB in one. All other contaminants were lower or at the same concentration in the following pregnancy. This observation finds to the observations of other authors who reported lower values of contamination in the following pregnancy.

6.5.16 Influence of dietary recommendation

After the results of the earlier studies became available, new recommendations for consumption of whale products were published by the health authorities (Heilsufrøðiliða Starvsstovan, 1998). To examine the effects of the new recommendations, a questionnaire was sent out to all women residing in the Faroe Islands, aged 26 to 30 years. They were asked about their dietary habits. Those who wanted to could send a sample of hair to be analyzed for mercury. One year later all women were contacted again with the offer to send a new hair sample for analyses. 45.7% of questionnaires could be used for statistical analyses. 370 single hair samples were available taken either after the first or after the second letter. 146 women provided two hair samples. The geometric mean methylmercury in the first samples was 2.57 μg/g (arithmetical mean 3.54 μg/g with a standard deviation of 2.90 μg/g). In the second sample the results were 1.83 μg/g (2.56 μg/g ± 2.22 μg/g). The difference between the two concentrations is highly significant (Man-Withney U-test: $p<0.001$; CI_{95} 0.52 – 1.44) (see section 6.3 in this report).

6.5.17 Diet during pregnancy

Data or dietary habits during pregnancy were obtained from the cohorts (table 6.5.10).

In Cohort 2, about 60% og the women had whale meat for dinner, and slightly more than one-half had whale blubber, for dinner at least once per month; Most women (147 or 82.6%) had not changed their dietary habits in this regard during the pregnancy (Grandjean et al., 2001).

Table 6.5.11 Dietary habits during pregnancy

	Cohort 1 (Grandjean et al., 1992)	Cohort 2 (Grandjean et al., 2001)	Cohort 3 (See section 6.2)	Intervention study
Number of whale meat dinners / month	0 = 208 (20.5%) 1 = 285 (28.1%) 2 = 251 (24.7%) 3 = 88 (8.7%) ≥4 = 183 (18.0%)	0 = 48 (12.9%) <1 = 48 (27.0%) 1 = 45 (25.3%) 2 = 30 (16.9%) 3 = 14 (7.9%) ≥4 = 18 (10.0%)	0 = 122 (38.4%) <1 = 168 (52.8%) 1 = 17 (5.4%) 2 = 9 (2.8%) 3 = 0 (0.0%) ≥4 = 2 (0.6%)	0 = 126 (24.3%) <1 = 214 (41.3%) 1 = 94 (18.2%) 2 = 59 (11.4%) 3 = 9 (1.7%) ≥4 = 16 (3.1%)
Number of blubber dinners / month	N.a.	0 = 53 (29.8%) <1 = 32 (18.0%) 1 = 32 (18.0%) 2 = 30 (16.9%) ≥3 = 31 (17.3%)	0 = 198 (63.3%) <1 = 97 (31.1%) 1 = 15 (4.7%) 2 = 2 (0.6%) ≥3 = 1 (0.3%)	0 = 201 (39.7%) <1 = 161 (31.8%) 1 = 74 (14.6%) 2 = 44 (8.7%) ≥3 = 26 (5.2%)
Number of fish dinners / week	0 = 27 (2.7%) 1 = 140 (13.7%) 2 = 365 (35.8%) ≥3 = 488 (47.8%)	0 = 2 (1.1%) 1 = 34 (19.1%) 2 = 52 (29.2%) ≥3 = 90 (50.6%)	0 = 0 (0.0%) <1 = 22 (7.0%) 1 = 65 (20.8%) 2 = 112 (35.8%) ≥3 = 114 (36.4%)	0 = 2 (0.4%) <1 = 11 (2.1%) 1 = 117 (22.3%) 2 = 179 (34.2%) ≥3 = 215 (41.0%)

*: Some of these women might have been pregnant, but pregnancy was not an inclusion criterion

Unfortunately the questionnaire about the dietary habits during pregnancy differed slightly. Therefore, it is not clear how far the number really represent the same consumption.

In the second cohort, the majority of the participating women resided outside of the capital Tórshavn and it suburbs. The availability of whale meat and blubber was higher in the small villages. Thus lower percentages of mothers who reported no or only few dinners with whale products might not only be caused by the awareness of the women of the potential endangerment related to food and the new recommendation from the national health authorities. The reduced access to whale products might also be have caused lower numbers.

6.5.18 Comparison of contamination in Faroese and non-Faroese mothers

When comparing exposure data of Faroese (N=562) and non-Faroese (N=21) women participating in cohort 3 it was found that the level of all contaminants are higher in Faroese mothers except for β-HCH. The difference is highly significant for all measured PCB-congeners and trans-nonachlor. Arithmetic means in Faroese mothers are 1.3-fold to 4.2-fold the means of non-Faroese mothers. β-HCH was twice the value in non-Faroese mothers than in Faroese mothers, the level of significance for the difference was 0.069 (see section 6.2 in this report).

6.5.19 Description of study populations

	Pilot study	Cohort 1	Cohort 2	Intervention study	Cohort 3	Cohort 4
Main references	Grandjean et al., 1992	Grandjean et al., 1992	Steuerwald et al., 2000; Grandjean et al., 2001	Weihe 2001 (unpublished data)	See section 6.2	See section 6.3
Period of establish-ing the cohort	December 1985	1.3.1986 – 31.12.1987	3/1994 – 4/1995	2/1999 (first hair samples and questionnair e) 3/2000 (second hair sample)	12/1997 - 2/2000	10/2000-10/2001
Mode of selection	All women in the fertile age group (20 to 50 years old), residing in the small fishing village of Leirvík in the Faroe Islands	Consecutive births at all three hospitals in the Faroe Islands	Consecutiv e singleton births of mothers residing outside of the Tórshavn area at the hospital in Tórshavn	Questionnair e about diet and twice a request for a hair samples were sent to all women residing in the Faroe Islands, aged 26 to 30	Consec utive births at the Nationa l Hospita l in Tórshav n, all mothers include d	Consecuti ve births at all 3 hospitals
Number of participants	53	1,022	182	370 (one hair sample) 146 (two hair samples) 539 (questionnair e)	656	148
Portion of all eligible children born in the period	(84% out of the 63 women of this age group)	75%	64%	31.4% (one hair sample) 12.0% (two hair samples) 45.7% (questionnair e)	55.3%	49.7%
Maternal age: mean (SD)	N.a.	26.9 years (range 15– 45)	28.0 years (± 5.8)	N.a.	29.2 years (± 5.2) (range 16– 43)	29 17-40)
BMI (kg/m²) mean (range)	N.a.	22.3 (16.0 – 42.4)	23.1 (17.0 – 38.6)	N.a.	23.9 (16.6 – 44.1)	23.7
Number of teetotaller mothers	N.a.	771 (75.4%)	159 (87.4%)	N.a.	375 (58.6%)	49.7% (in 2. trim.)
Number of non-smokers	N.a.	614 (60.0%)	125 (68.7%)	N.a.	448 (70.0%)	122 (74%)

N.a. = Not available

6.6 Acknowledgement

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7 The Human Health Effects Biomarker Program

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7.1 Introduction

Human exposure to environmental contaminants is ubiquitous and is not restricted to individuals who live next to industries or waste disposal sites. Everyone carries a burden of POPs and heavy metals in their body. Persistent organochlorine compounds, such as dioxins/furans, polychlorinated biphenyls (PCBs) and certain pesticides, e.g., toxaphene and DDT/DDE, accumulate in body fat; meHg accumulates in organs, Pb in bones, etc. Environmental contamination is a global issue and POPs are transported to the Arctic by atmospheric and oceanic currents. Because of the lipophilic and persistent nature of POPs, bioaccumulation and biomagnification's occur in the marine food web and in some freshwater predatory fish and piscivorous birds. Although far distant from the major pollution sources, some populations living in regions north of the Arctic Circle display a greater body burden of POPs than people living in industrialized regions, largely due to their reliance on a traditional diet that includes species high up in the marine food chain (see section 2 - 4 in this rapport) [Asplund et al., 1994; Dewailly et al., 1999; Dewailly et al., 1992; Dewailly et al., 1994; Jensen and Clausen, 1979]. Use of several organochlorine compounds, such as DDT and PCBs, was restricted or banned in most countries in the 1970s. Even though their concentrations in the environment have been slowly declining over the past 30 years, these compounds are still the most abundant persistent organochlorine contaminants found in wildlife and in human tissue and milk samples in the Arctic region. While concentrations of several organochlorine contaminants are decreasing, the continual introduction of 'new compounds', such as brominated flame-retardants, into the environment has generated new concerns [Rahman et al., 2001]. In addition, attention has recently shifted from chronic diseases and reproductive endpoints to effects that are induced following exposure during the sensitive period of *in utero* development. Of particular concern are effects on development resulting from prenatal exposure to endocrine disrupting compounds.

The burden of POPs in Arctic peoples has been monitored for some years. In 1997, the Alta Declaration extended AMAP's mandate to cover assessment of the combined effects of environmental stressors. The AMAP Phase I assessment report (AMAP, 1998) gave an overview of the classical toxicology of contaminants. Only recently a programme for measuring the potential biological effects of these contaminants has been established: *The AMAP Human Health Effects Monitoring Programme* (Table 1). Body burden data alone are not enough to allow the health risks associated with exposure to environmental contaminants in Arctic peoples to be assessed. Furthermore, laboratory studies of the effects of single chemicals or chemical mixtures in laboratory animals and cell cultures cannot fully elucidate the human health risks. Integration of epidemiological and effect-biomarker studies on humans from exposed populations in the Arctic is needed in order to obtain information about the real health risks resulting from exposure to the accumulated mixtures of contaminants in the Arctic.

The broad category of human health effects that are suspected to result from exposure to environmental contaminants include cancer, birth defects, effects on the reproductive and the neuro-endocrine-immune systems, altered metabolism, and specific organ dysfunction. Table 1 presents possible effect biomarkers that may be useful to include in epidemiological studies. By integration of epidemiological and biomarker effect studies it will be possible to establish a connection between traditional toxicological studies and new methods designed to study the potential of chemicals to interfere with the normal homeostasis by exerting endocrine-disrupting effects.

As mentioned, most efforts have over the past decade been focused on the characterization of exposure of Arctic peoples to contaminants. Epidemiological studies have been conducted in which clinical endpoints, such as psychometrics, neuropsychological parameters, infection incidence, bone density, and sexual maturation among others, were the main focus (see chapter 5 -6 in this rapport). However, in order to detect the early biological changes preceding disease, knowledge about the mechanism of action of toxicants is required. Thus, biomarkers of effect need to be validated and used as concluded at the International Conference on Artic Development, Pollution and Biomarkers of Human Health in Anchorage, Alaska, May 2000. Effect biomarkers are early biological responses of the organism to an external toxic stress. Since the overall weight of evidence at the epidemiological level for adverse endocrine-related human health effects is not strong, further studies including validated biomarkers in epidemiological studies may help in identifying the possible relevant associations between exposure to contaminants and detrimental health effects in Arctic populations.

7.1.1 Endocrine disruption

In order to establish consensus on the scope of endocrine disruption, to facilitate the identification of active chemicals, and to underpin future regulatory control it is essential to agree on a precise definition of an endocrine disrupting compound, *The International Programme on Chemical Safety and the US EPA's Endocrine Disrupter Screening and Testing Advisory Committee* (EDSTAC) in 1998 proposed the following working definition.

> *"An endocrine disrupter is an exogenous chemical substance or mixture that alters the structure or function(s) of the endocrine system and causes adverse effects at the level of the organism, its progeny, populations, or subpopulations of organisms, based on scientific principles, data, weight-of-evidence, and the precautionary principle".*

Thus, the term 'endocrine disrupters' covers all kinds of exogenous interfering chemicals; including synthetic chemicals and synthetic and naturally occurring hormones. Exposure can occur via food intake (especially high fat products) drinking water, pharmaceuticals, etc. The ability of a chemical to affect humans or wildlife depends on factors such as structure, concentration, bioavailability, degradation/metabolism, uptake, etc. The observed potency of a chemical is, therefore, very dependent on concentration and the system applied for testing. This can result in several classifications for any one single chemical, for example as carcinogenic, teratogenic, toxic, and endocrine disrupter, depending on which characteristic of the chemical is studied.

Many of the compounds suspected of endocrine disrupting activity are known to be toxic (in some cases acutely toxic) at higher concentrations. They were therefore banned or controlled in some countries, either on this basis or because of their persistence and capacity to bioaccumulate in biota. Chronic low dose exposure and the subsequent bioaccumulation of lipophilic POPs with long biological half-lives are of special concern. These POPs may over time bioaccumulate to a critical level capable of eliciting an effect. Moreover the 'life-long' duration of exposure, together with increasing environmental levels, may maximize the likelihood of induction of effects. Such factors must be taken into account in sub-chronic, chronic and/or multi-generation tests. Because of the complexity of the endocrine system, and the complex nature of human epidemiological studies, animal studies and *in vitro* screening methods are widely used for toxicity evaluation and risk assessment.

To date, no clear-cut evidence for adverse endocrine-related human health effects has been obtained at the individual or population level. However, data from studies on wildlife species, studies on laboratory animals, and biomarker studies *in vitro* have strengthened the need for further research to address the uncertainty and alleviate concerns. Taking a precautionary approach, the weight of evidence would suggest that exposure levels seen in the Arctic have some potential for adverse effects on human health.

Studies on wildlife populations have documented adverse effects that correlate with exposure to one or more putative endocrine modulating chemicals [Safe, 2000]. Adverse developmental and reproductive effects have been primarily linked to POPs and alkylphenols derived from alkylphenol ethoxylate surfactants used in industrial detergents. In many instances, it has been difficult to assign causality because of the complexity of environmental contaminant mixtures and the level of exposure during critical developmental windows. However, lower concentrations of POPs in the Great Lakes region were correlated with dramatic improvements in reproductive success and significant increases in an array of predatory birds in the Great Lakes basin [Tremblay and Gilman, 1995].

The range of toxicological effects that estrogenic chemicals can produce is illustrated by work on the synthetic estrogen diethylstilbestrol (DES). DES was used pharmaceutically from the late 1940s to the early 1970s to prevent abortions and pregnancy complications in women. However, studies found DES exposure to correlate with increases in abortions, neonatal death and premature birth, and an increase in the incidence of vaginal adenocarcinoma in young women who were exposed *in utero* [Herbst et al., 1971], and *in utero* exposed men had 4 times higher abnormalities of the reproductive tract compared with controls [Gill et al., 1979]. The abnormalities included cryptorchidism and hypospadias, and reduced sperm concentration and quality, although reduced fertility was not observed in these men [Wilcox et al., 1995]. Not all the effects of DES are ascribed to its binding to the estrogen receptor and recent studies have shown that several endocrine disrupting compounds induce their effects via different receptors and signaling pathways [Andersen et al., 1999; Andersen et al., 2002; Bonefeld-Jorgensen et al., 2001; Bonefeld-Jorgensen et al., 1997; Vinggaard et al., 1999a; Vinggaard et al., 2000; Vinggaard et al., 1999b].

The convergence of several lines of inquiry was crucial for the rapid growth of interest in the issue of endocrine disruption in the 1990s. A number of worrying trends related to human male reproductive health had been reported globally, including decline in semen quality parameters and increases in the incidence of testicular cancer, hypospadias and cryptorchidism. At the same time, adverse trends in the reproductive health of wildlife in some regions outside the Arctic had also been noted and correlated with exposure to environmental contaminants, and in some cases specific chemicals were implicated. Evidence was also emerging from a variety of experimental studies that many widely used chemicals, distributed extensively in the environment, had the ability to bind and activate estrogen receptors. Although their affinity for the receptor was weak compared with the natural ligand their activity was regarded as sufficient to support a working hypothesis that environmental chemicals might be damaging the reproductive health of human and wildlife populations by interfering with sex hormone activities. Behind this concern was the suspicion that chemicals acting through hormone receptors might mimic the natural hormones and have profound effects at very low concentrations. The conjunction of threat both to human and wildlife populations led to responses from international organizations (including AMAP), governments, and the chemical industry. The following general needs were identified.

Further research to confirm the existence of effects from environmental exposure on reproductive health of humans and wildlife.
In cases where an adverse effect was confirmed, establishment of the causative link of exposure to an environmental chemical.
Development of reliable methods, and possibly new methods, for detection of chemicals with potential to cause adverse effects (monitoring).
Ranking of known and suspected endocrine disrupting compounds for possible regulatory action (prioritization).
Possible action to limit release of certain chemicals to the environment.

The Endocrine Disrupter Screening and Testing Advisory Committee (EDSTAC, 1998) has developed a strategy for testing chemicals for endocrine modulating activity including an initial sorting of chemicals (based on existing data), priority setting (based on knowledge of exposure), and tier 1 screening and tier 2 testing, comprising:

Tier 1 screening
In vitro assays
Estrogen receptor binding and reporter gene assays.
Androgen receptor binding and reporter gene assays.
Steroidogenesis assay with minced testis.

In vivo assays
Rodent 3-day uterotrophic assay: increase in uterine weight in ovariectomized rat.
Rodent 20-day pubertal female with thyroid: age of rats at time of vaginal opening.
Rodent 5–7 day Hershberger assay: change in weight of prostate and seminal vesicles in castrated rats.
Frog metamorphosis assay: rate of tail resorption in Xenopus laevis.
Fish gonadal recrudescence assay: effects on light and temperature sensitive sexual maturation.

Tier 2 testing
(Intended to determine and characterize the effects of the chemical on the endocrine system.)
Two-generation mammalian reproductive toxicity study or a less comprehensive test.
Avian reproduction test.
Fish life cycle test.
Mysid (shrimp) life cycle test.
Amphibian development and reproduction test.

7.1.2 Exposure to chemical mixtures

There are a number of factors that complicate the toxicological evaluation of mixtures. First, it is important to remember that no test can evaluate all possible endpoints. However, existing methods in general include numerous endpoints that are sensitive to both strong and weak xenoestrogens such as the reproductive and developmental effects in humans and rodents of DES [Gill et al., 1979; Herbst et al., 1971; McLachlan, 1981; Wilcox et al., 1995] and DDT or chlordecone [Daston et al., 1997]. These endpoints, obtained by multi-generation studies in rodents, are sufficient to indicate a hazard. Subsequent decisions to further characterize the cellular and molecular steps in the hazard evaluation require mechanistic research for risk assessment, taking into account the possibility that the observed adverse effects may not be the most sensitive manifestation of toxicity. Second, two or more compounds may have additive effects as a result of acting via the same mechanism in concert. They may also elicit antagonistic, or synergistic (greater than additive) effects. Some studies have suggested synergistic responses of steroidal estrogens in vitro (yeast) and in vivo (turtle) [Arnold et al., 1997a; Arnold et al., 1997b]. However, estrogenic tests with mixtures of dieldrin and toxaphene in human breast cancer MCF-7 cells, yeast-based human estrogen receptor assays, and mouse uterus tests showed no apparent synergism [Ramamoorthy et al., 1997].
There are several other complications that must be taken into account when generalizing about what is known about the toxicity of single compounds and/or mixtures. A compound may have multiple sites of action and its toxicity may be mediated by different mechanisms. Many substances are biotransformed to metabolites (e.g., hydroxylated PCB metabolites) that may have a different biological activity than that of the parent compound. In addition, a single environmental contaminant may induce different effects depending on the organism's age and reproductive state at the time of exposure. Lead is an example of a contaminant having little effect on neurobehavioral function in adults but irreversible effects on intelligence quotient (IQ) and behavior when exposure occurs in utero during the development of the nervous system [Carpenter et al., 1998]. It is known that developmental toxicity is dependent on highly susceptible periods of organogenesis, as demonstrated by prenatal exposure to, e.g., DES and thalidomide, and postnatal exposure to Pb, pesticides, methylmercury (see chapter 6 this rapport) and radiation [Selevan et al., 2000].

Toxicity scales have been developed for compounds that share a common mechanism of action. This concept was applied to mixtures of dioxin-like compounds that bind the aryl hydrocarbon receptor (AhR). The AhR is an intracellular ligand-dependent transcription factor expressed in most tissues of mammals. Dioxins and furans (polychlorinated dibenzo-p-dioxins, PCDDs;

polychlorinated dibenzofurans, PCDFs) as well as non- or mono-ortho chloro-substituted PCBs are ligands to the AhR [Birnbaum, 1995; Brouwer et al., 1999; Carpenter et al., 1998]. The activated ligand-receptor complex triggers the expression of enzymes including P4501A1, P4501A2, P4501B1, glutathione S-transferase, glucuronyl transferase, δ-δ aminolevulinate synthethase, epidermal transglutaminase, NAD(P)H: quinone oxidoreductase and aldehyde-3-dehydrogenase, which are involved in metabolism and detoxification of many POPs [Hahn, 1998; Safe and Krishnan, 1995].
A common practice in risk assessment is to calculate the 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) toxic equivalents (TEQs) for mixtures comprising dioxin-like compounds. TEQs are calculated by multiplying the concentration of each dioxin-like compound by its Toxic Equivalency Factor (TEF), which corresponds to the relative potency of the specific compound in generating an AhR-mediated effect, in relation to that of TCDD, the most potent dioxin-like compound. Consequently, the classical TEQ/TEF risk assessment only accounts for potential dioxin-like properties of a mixture and not other relevant toxicological endpoints such as effects mediated via other receptors and biochemical pathways (e.g., interference with the sex hormones and thyroid hormone systems). For example, ortho-substituted PCBs are either weak ligands or do not bind at all to the AhR, therefore either very low or no TEF values are given for these compounds. Recently, however, it was reported that the three most highly bioaccumulated di-ortho substituted PCBs (CB138, CB153, and CB180) elicit the potential, *in vitro*, to interfere with cell proliferation as well as the function of the estrogen and androgen receptor [Bonefeld-Jorgensen et al., 2001]. These results emphasize that a full assessment of the toxicological potential of a chemical mixture is much more complex than can be deduced by the use of TEQ values alone.

7.1.3 POPs, gene polymorphism and hormone metabolism

Central to many of the influences on the biological system are effects that occur at the gene level. Genes regulate almost everything, including many aspects of hormonal production and the reproductive system, brain development and function, immune system balances, and organ physiology. A genetic disruption can, therefore, affect different organ systems, as a result of the extensive interaction among these systems; i.e., effects on one organ system may influence the function of other organs. During normal development, genes are activated and deactivated at different stages, often under the control of growth factors and hormones. Environmental factors interfere with these biologically balanced processes and may result in genetic dysfunction. Mutations in genes, inherited or induced by environmental factors, may thus result in reproductive effects, birth defects, and cancer.
Gene polymorphism is known to exist between different ethnic groups, which can result in differences in tolerance e.g., to food components such as lactose [Harvey et al., 1998; Nei and Saitou, 1986]. In addition, gene polymorphism in metabolizing enzyme, e.g. in the P450 enzyme system, is suspected to influence susceptibility to environmental carcinogens, affecting the risk of cancer [Autrup, 2000; Coughlin and Piper, 1999; Morabia et al., 2000].
Genetic polymorphism and breast cancer risk has been extensively analyzed, and significant differences in genotype frequencies between cases and controls were found, including the aromatase cytochrome P450 (CYP19) gene which catalyses the conversion of androgens to estrogens [Dunning et al., 1999].
Recently, a study suggested an association between PCB concentrations and CYP1A1 gene polymorphism in women breast cancer patients compared to control groups [Moysich et al., 1999].

Accumulation in fatty tissues and the potential of many persistent organochlorine contaminants to exert estrogenic/androgenic- or anti-estrogenic/anti-androgenic-like effects are hypothesized to promote the cancer process through the modulation of the estrogen receptor regulated responses [Wolff and Toniolo, 1995]. Therefore, to reject or verify the hypothesis future studies must include, in addition to the epidemiological investigation and burden of POPs, information on genetic polymorphisms and biomarkers related to the total impact of components with estrogenic (or anti-estrogenic), androgenic (or anti-androgenic), and dioxin-like activities. Currently, a pilot breast cancer study including these endpoints is being carried out in Greenland (E. Bonefeld-Jorgensen, personal comm., 2002).

PCBs and dioxin are well known for their ability to induce certain iso-enzymes of P450 in mammalian liver via the AhR. Some of these enzymes, P4501A1, P4501A2, and P4501B1, are involved in estradiol metabolism and might disrupt hormone levels [Spink et al., 1992a; Spink et al., 1994; Spink et al., 1992b; Spink et al., 1998]. In vitro, several persistent organochlorine contaminants have been shown to increase the 16α-OHE1:2-OHE1 estradiol metabolite ratio; 16α-OHE1 is regarded as highly estrogenic while 2-OHE1 is a weak anti-estrogen [Bradlow et al., 1995]. Some studies have reported higher levels of the 16α-OHE1 metabolite in urine of breast cancer patients [Bradlow et al., 1995; Safe, 2000], whereas other studies did not observe this association [McDougal and Safe, 1998; Ursin et al., 1997]. Thus, inconclusive results exist and await further research.

7.1.4 Effect on hormone receptor numbers

The responsiveness of a tissue to a hormone depends on the density of receptors within its component cells. The number of receptors is determined by their rate of synthesis and catabolism, which is in turn controlled by complex feedback mechanisms involving hormone action. Some chemicals are shown to interfere with this regulation. For example, TCDD can act to decrease or increase the expression of the ER [Romkes et al., 1987], and compounds which bind to the ER (e.g., ICI 182,780, toxaphene, CB138 and several pesticides) influence receptor functions as well as the cellular level of ER mRNA [Andersen et al., 2002; Bonefeld-Jorgensen et al., 2001; Jensen et al., 1999].

7.1.5 The AMAP Human Health Effects Monitoring Programme

As previously stated, there are broad categories of health effects that may be linked to exposure to environmental contaminants. These include cancer, birth defects, decreased fertility, altered sex hormone balance, immune system defects, neurological effects such as reduced IQ and behavioral abnormalities, altered metabolism, and specific organ dysfunctions [Carpenter et al., 1998]. At AMAP Human Health Expert Group meetings held in Rovaniemi, Finland, January 2000 and Tórshavn, Faroe Islands, October 2000, a Human Health Effects Monitoring Programme was recommended to the eight Arctic nations.

Table 7.1 Human Health Effect Monitoring Programme

Bio-Physical Indicators		Epidemiological Effect Markers		Molecular/Genetic Effect Markers
Health Statistic	E R	Morbidity/Mortality data Cancer incidence		
Genetic susceptibility Studies	R		R	Gene polymorfisms Gene ekspression (mRNA)
Fertility studies: Time to pregnancy (TTP) Semen quality and quantity Sex hormones (In blood from male partners providing semen samples and their spouses)	R R R R	 Time or number of menstrual cycles it takes a couple to conceive from discontinuation of contraception Sperm count/volume Sperm quality/mobility	R R	*Receptor/hormone toxicology; Measurements in steroid hormone cleared blood:* Estrogenic -, Androgenic- like activities Dioxin-like activities in serum *in vitro* hormone receptor bindings FSH, Inhibin-B, LH, Testosterone, Estradiol Sex hormone binding globulin Osteocalcin, pyridolins
Pregnancy outcome Developmental anomalies Developmental effects	E R R	Abortion (spontanous) Gestational age Birth weight/length Placenta weight Sex (single/multiple) Maldescent testis Hypospadias Epispadias Ano-genital distance and other indicies Breast milk (POPs, Fattyacids)	R	Estrogenic-, Androgenic- and Dioxin-like activities Cytochrome P450 modulations, DNA adducts
Immunological effects	R	Hospitalization Vaccination response	R R	Antibody (HIB), Vitamin A and Cytokines, Complement system Dioxin-like activities
Neurological effects	R R	Milestones + age Preschool tests: Neurophysiological Neuropsychological Audiogram and Visual tests	R R	Thyroid hormone Estrogenic- and Dioxin-like activities GSHRd, GSHPx, Ubiquinol 10/Ubiquinone 10, Ox-LDL, F2-Isoprostanes

R = recommended
E = essential

Effects on reproduction and development of dietary POP and heavy metal burden within the arctic.

Requirement of parallel indicators: dietary questionnaire and indicators, and POP measurements carried out by laboratories with documented AQ/AC
The AMAP Human Health Effects Monitoring Programme, (Table 7.1) includes several molecular biomarker endpoints for use in Arctic environmental health studies. Substances commonly found in the environment may have the potential to affect several organ systems. The diseases listed are identified on the basis of studies of both humans and animals, and in most cases these investigations were focused on a single contaminant. Several of these diseases, when found in a given individual, are difficult to ascribe to a particular exposure [Sharpe, 1993; Sharpe and Skakkebaek, 1993]. This is generally the case for cancer, reproductive effects (such as infertility, early birth, etc.), many of the endocrine modulators and nervous system actions. Others are clearly attributable to particular exposures, such as kidney disease following Cd exposure or the loss of particular neurons following MeHg exposure [Carpenter et al., 1998].

The main objective of the AMAP Human Health Effects Monitoring Programme is to characterize the impact of dietary exposure to POPs by monitoring biophysical indicators, and epidemiological and molecular/genetic effect markers (see Table 7.1). These effects studies are directed towards examining the hypothesis of xenobiotic interference with homeostasis of hormone functions, with a special focus on circumpolar populations. A number of persistent organochlorine contaminants exhibit estrogenic (and anti-estrogenic), androgenic (and anti-androgenic) and dioxin-like activities. Some bind to the estrogen receptor (e.g., DDT, toxaphene, CB126, CB153, CB180) [Bolger et al., 1998; Bonefeld-Jorgensen et al., 2001; Bonefeld-Jorgensen et al., 1997], and some bind to the androgen receptor (e.g., DDE, vinclozolin) [Bonefeld-Jorgensen et al., 2001; Crisp et al., 1998; Kelce et al., 1997; Kelce and Wilson, 1997] or bind to both receptors (e.g., metabolites of methoxychlor, CB138).

Dioxins have been characterized as anti-estrogenic due to their AhR mediated interference with estrogen receptor activities [Kharat and Saatcioglu, 1996; Safe, 1994]. Because of the wide variety of endocrine disrupting effects possibly induced by mixtures of persistent organochlorine contaminants, there is a need to develop markers that integrate the effects of several chemicals on specific hormonal pathways and combine them with epidemiological studies that are also part of the AMAP Human Health Effects Monitoring Programme.

The morbidity/mortality data and pregnancy outcomes are considered essential effect markers, whereas the other biomarkers listed in Table 1 are recommended measurements for inclusion within AMAP monitoring implementation plans. The biophysical indicators, and epidemiological and molecular/genetic effect markers included in Table 1 are, as far as possible, linked into the different studies. In addition, dietary questionnaires, relevant markers of a seafood based diet (e.g., n-3 fatty acid content in plasma phospholipids), should also be included in the studies, and laboratories performing these measurements must have documented quality assurance / quality control (QA/QC).

Some studies listed in the *Human Health Effects Monitoring Programme* (Table 7.1) have already been initiated in some parts of the Arctic, while others are still in the planning phase. In the Faeroe Island the epidemiological approach has been in focus concerning immunological and neurological effects (see chapter 5 – 6, this rapport). In Greenland the part of the programme including the recommended molecular/genetic effect marker analyses have been initiated and some blood samples have been analyzed for the concerted action of xenohormone activities, the sum of dioxin-like activities and the level interleukin-1 beta (IL-1ß) as well as the level of estrogen metabolites in urine. These data will be described in the *Results* part of this section.

7.2 Methods

7.2.1 Determination of xenohormone activities in serum.

Sonnenschein and colleagues have devised a method for estimating human exposure to a complex mixture of xenohormones (environmental compounds with hormone-like activities) [Sonnenschein et al., 1995]. First, endogenous steroids are separated from persistent organochlorine contaminants in human plasma samples by high-performance liquid chromatography (HPLC) and the resulting fractions are tested for estrogenic activity using a proliferation assay with MCF-7 cells. Other investigators (see below 7.3.1) have further developed and applied the HPLC fractionation of human serum for separating endogenous hormones from xenohormones to obtain integrative measurements of estrogenic, androgenic, and dioxin-like effects of compounds using reporter-gene cell assays. The estrogenic data referred to in this rapport was obtained by exposure of MVLN cells, which carries a stable integrated ER reporter gene (ERE-CALUX), to the hormone free serum extracts. Upon cell exposure the estrogen receptor (ER) activated reporter gene (luciferase) activity was determined.
Recently, a new assay for detection of xenoestrogens in serum upon eliminating the endogenous steroids by immuno-precipitation was reported [Natarajan et al., 2002].

7.2.2 Determination of the sum of serum dioxin-like activities

Using the stable transfected mouse hepatoma cell line Hepa1.1 [Garrison et al., 1996; Ziccardi et al., 2000] carrying a Ah-receptor directed reporter gene (luciferase), we measured the sum of dioxin-like activity by exposure of the cells directly to serum and after hexane:ethanol extraction of the POPs from the fatty fraction of the serum (performed in Jean-Philippe Webers lab in Quebec).

7.2.3 Determination of estrogen metabolites in urine

Urinary estrogen metabolite ratio, 2-hydroxyestrogen/16α-hydroxyestrone, were determined by the use of an enzyme immunoassay (ESTRAMET™ 2/16, Immuna Care Corporation, PA, USA)). Urine samples were collected and stored in tubes containing 1 mg/ml ascorbic acid. The samples was immediately placed on ice and then stored at -20^{0}C. The analyses were performed in accordance to the recommended protocol.

7.2.4 Determination of inflammatory cytokines in serum

Measurement of the cytokine interleukine-1 beta (IL-1ß) in serum was performed by the use of the chemiluminescence's ELISA analyses following the protocol recommended by the manufacturer (R&D, London, UK).

7.3 Results

In table7.2 is summarized the cellular effect biomarker analyses performed on Greenlandic samples from 1997 to 2002. As given in table 7.2, all of the planned effect biomarker analyses but genotypes are performed and under data processing and manuscripts are under preparation for publication in international journals.

Table7.2 Status of analyses of cellular effects biomarkers 2002

Location	Year	Target group	Cellular Biomarker	Analysed	Status
Geographical Greenland	1997	61 men 10 women	Dioxin activity	Yes	*Data processing
Uummanaq	1999	48 men, smokers/ non-smokers	Cotinine	Yes	Manuscript in press
Nuuk	1999-2000	30 pregnant women	E2-metabolites in urine Cytokines	Yes Yes	*Data processing *Data processing
Ilulissat	1999-2000	30 pregnant women	Cotinine Cytokines	Yes Yes	Data processing *data processing
Ittoqqortoormiit (Scoresbysund)	1999-2000	50 men 42 women and 8 pregnant women	Cotinine Cytokines Dioxin-activity	Yes Yes Yes	Data processing *Data processing Data processing
Tassiilaq (Ammassalik)	2001	40 men 42 women and 8 pregnant women	Cotinine Dioxin-activity Hormone-activity Genotypes Gene expression	Yes Yes Yes No No	Data processing Data processing *Data processing #In progress #In progress

(*)Manuscript under preparation, (#) Analyses design and set up performed

Concerning the effect biomarker analyses of samples from the geographical survey Greenland 1997 [Deutch and Hansen, 2000], measurements of the dioxin-like activities in serum were not originally planned since at that time we did not have the techniques available in the laboratory. However, because we think it is essential already now to start some kind of trend analyses, we decided to carry out the analyses.

7.3.1 Determination of xenohormon and dioxin-like activities in serum samples

Using a further developed (performed at Dept. of Environ. Med., South Danish University, Odense) serum extraction method of Sonnenschein and cooperators [Sonnenschein et al., 1995] 100 serum samples (Ammassalik (Tasiilaq), Greenland 2000-2001) free of endogenous hormones have been analyzed for effects on the estrogen receptor (ER) trans-activity. We used the MVLN cell line to obtain the concerted action of the actual mixture of accumulated persistent organochlorine contaminants in these human samples on the ER hormone receptor activity. The results indicated that this hormone free serum fraction, containing the mixture of accumulated POPs, exerts an inhibitory effect on the normal estrogen hormone function mediated through the ER activity in human cells (Bonefeld-Jorgensen, manuscript in prep.).

Another 71 serum samples from the Geographical Greenland (Geo) project (see chapter 4) and 100 serum samples from Ammassalik (Tasiilaq) have been analyzed for the sum of dioxin-like activities using the AH-receptor dependent AHR-CALUX, Hepa1.1 cell system. Approximately 30% of the samples from the Geo, analyzed by directly exposure of the responding reporter-gene cell line, elicited an increased dioxin-like activity compared to a reference control of pooled Danish serum samples (n = 10) with very low POP concentration (up to 100 times less) (see chapter 4.3.3, Table 4.3.16). The samples from Ammasalik await further analyses. Because it is known that various compounds in human serum can inhibit the activation of the AH-receptor and thus the AHR-CALUX system, we have analyzed the same samples for dioxin-like activities after extraction of the POPs from the fatty fraction of serum.) have been analyzed

The results are currently under advanced statistical (SAS, SPSS) evaluation and the preliminary data suggests that the cellular effect measurements may be associated to specific PCB congeners and/or pesticides. Unfortunately, because of promising new information concerning the cellular effect of the POPs on human health, the data cannot yet be released for publication in the *National Assessment Report* of *Greenland* since the conclusion of the data may have far-reaching influence on diet recommendations and health policy in Greenland. Moreover, the manuscript of these new data is meanwhile under preparation, for publication in an international journal.

7.3.2 Measurement of cytokine levels in serum

The IL-1ß cytokine level has been measured in 29 serum samples from Ilulissat (1999-2000), 100 serum samples from Ittoqqortoormiit, Scorebysund (1999-2000), 30 serum samples from Nuuk (1999-2000). The results are currently being statistically evaluated for eventual associations to accumulated POPs and a manuscript is under preparation.

7.3.3 Determination of the ratio of estrogen metabolites in urine

In total 70 urine samples (both sexes) from inhabitants in Ammassalik and 24 urine samples from pregnant women living in Nuuk have been analysed for the ratio of the estrogen metabolites 2-hydroxyestrogen/16α-hydroxyestrone. For references 10 urine samples from Danish women, selected for having a very low level of POPs in their blood, have been analyzed for the estrogen metabolites. The results are currently statistically evaluated for eventually association to accumulated POPs and a manuscript is under preparation.

7.3.4 Genotyping and gene expression

Blood samples (100) for DNA and RNA isolation and the following genotyping and gene expression have been colleted from inhabitants in Scoresbysund (2000) and Ammassalik (2001). These very advanced analyses are going to be performed on an on-line PCR apparatus (LightCycler, Roche). The analyses design and set up is performed for genes, which are relevant for metabolising POPs and the following analyses are under performance.

7.4 Discussion and Perspectives

The effects on human health of environmental contaminants like POPs are long-term effects, which means that to obtain a clearly evidential association between accumulations in human tissues, effects on cellular biomarkers and negative health effects, trend analyses in more than one generation may be necessary. However, there is increasing evidence of adverse trends in human reproductive health, most notably testicular cancer and female breast cancer, whereas the decrease in sperm counts apparent from some studies is still being discussed. Although, causal links between effects and exposure to environmental chemicals have still not been firmly established.

Environmental chemicals have been focused on because of their capacity to interfere with hormone activities and hence their possible relation to trends in hormone related health effects. In wildlife, there is more convincing evidence of links between environmental exposure and endocrine disruption. This strengthens the concerns about endocrine modulation by environmental chemicals in humans. Because the developing fetus is particularly susceptible to exposure to environmental chemicals, and because there are many different effect targets, evaluation in terms of both lifetime effects (generations) and effects on organs (time to dysfunction) is complicated. Much research and monitoring are still required, and there is a need to develop, refine, and validate test methods that can accurately predict the effect of chemicals on human health.

Importantly, it should be stressed that to elucidate the risk of these environmental contaminants, the future research must include an integration of the three disciplines 1) monitoring, 2) epidemiological analyses, and 3) cellular/genetic biomarker effect analyses.

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8 Conclusions and recommendations

8.1 General conclusions

Contaminants of anthropogenic origin are spread globally including the Arctic. The combination of environmental conditions and biomagnification in the marine and fresh water food webs result in accumulation of certain persistent contaminants in traditional food of Arctic peoples, as a consequence some Arctic population groups are much more highly exposed through the diet than most populations in the temperate zone. The social, cultural, spiritual and physical health of Arctic Indigenous Peoples depends on the collection and consumption of country food. It is unlikely that market foods currently available can provide the nutritional equivalent of traditional food. It is difficult in a scientific way to compare the benefits and risks of consuming traditional food. It is, however, important as dietary intakes are changing across the Arctic due to social pressures, perceived threats of contaminants, the availability of traditional food, and the availability and acceptability of store-bought foods.

Food is the major exposure route for contaminants in the Arctic, therefor uniform methodologies for dietary surveys applied across the circumpolar region would greatly assist risk assessment. In addition to dietary intake, recent studies have shown that uptake, metabolism, and excretion of xenobiotics are under genetic influence. Also life-style factors e.g. smoking and body mass index (BMI) influence the body burden.

The concentrations of some POPs in breast milk have raised concern among mothers in the Arctic. The substantial benefits of breast feeding justify the development of programmes to inform mothers how adjustments within their traditional diets can significantly reduce contaminant levels in their milk without compromising nutritional value.

Epidemiological evidence on the adverse effect of POPs and methyl mercury is emerging. The high exposure levels found in some Arctic communities are suspected to have negative influence on human health, based on the weight of all available evidence within and outside the Arctic, there is reason for concern and a need to continue to reduce human exposure

Progress in molecular biology has provided tools to identify biomarkers of contaminant effects in human samples. Implementation of the human effect programme combined with continued monitoring of exposure (including new contaminants of concern) would allow identification of early effects at the molecular level and serve as a warning system to signal increases in exposure to levels where overt signs of poisoning may appear. The new methodologies can integrate epidemiological and mechanistic biomarker effect studies to make it possible to estimate the effects of current exposure levels of the actual mixture of contaminants, possible interactions, and the modifying effects of nutrients and life-style factors, the combined effect.

8.2 General Recommendations.

The Human Health Expert Group recommends:
To continue the process of monitoring of contaminants.The Human Health Effect Programme should be more extensively applied. Uniform methods should be applied for the objective assessment of diets and estimation of exposure and studies on nutrient content of traditional food items should be included.

To continue support of studies of contaminant related effects on human reproduction and fetal and child development, immune and hormone status, and cancer.

To apply communication and consultation approaches that enhances the development of local information and advice to Indigenous Peoples concerning benefits of traditional food, contaminant exposures and effects.

To strengthen international efforts to control the production, use, and emissions to the environment of persistent organic pollutants and mercury.

To ratify and implement the Stockholm convention on Persistent Organic Pollutants and the protocols on POPs and heavy metals in the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP) and support the UNEP Global Mercury Assessment.
To support a global assessment of the linkages between health and the environment.

8.3 Specific conclusions

8.3.1 Conclusions from the AMAP, HH Programme in Greenland

The AMAP, Human Health, monitoring programme has been extended to cover all geographic regions of Greenland. The geographical survey has revealed that the highest human blood levels of POPs in particular of PCB to be found in East Greenland, with close to 100 % in excess of the Canadian blood-guidelines for PCB-aroclor1260 for both men, women of fertile age, and pregnant women.

Exposures to methyl mercury are more geographically uniform. In several areas close to 100% of the samples exceeds the blood concentration corresponding to the strict US- EPA guideline and a considerable part also exceeds the WHO guideline.

Selenium intake through the diet is high among Greenlanders, however, there is at the moment no information on a protective effect against POP´s. and methyl mercury.

It has so far not been possible to assess time trends in POPs exposure, due to a too short observation period. There are no indications of declined exposures to methyl mercury., whereas the blood levels of lead are continuing to decrease

New data on contaminant concentrations in animals used for food, in combination with improved dietary surveys have made exposure estimates possible with identification of species and organs with the highest contributions to human exposure. On a country wide basis seal blubber followed by whale blubber are the predominant sources of POPs whereas seal meat is the main source of methyl mercury. However in areas where polar bear is consumed that can be a major additional source of POPs.

To evaluate potential health effects of contaminants preliminary tests of effect-biomarkers carried out with blood serum from Greenlanders have indicated an association to the exposure level of POP´s measured as blood-lipid concentrations. Further investigation is needed to estimate the clinical relevance of these findings.

It is known that POP´s negatively influences the immune system. As the exposure to POP´s in some Greenlandic districts are among the highest ever measured it is reasonable to expect an influence on the immune status in these populations. As POP´s are only one of several influential factors causality is difficult to establish in these small populations

There is no epidemiological evidence from Greenland to correlate pregnancy outcomes, neonatal mortality, or prevalence of infectious diseases to POP exposure.

No overt health effects of endocrine disrupting POP´s have so far been confirmed. As the exposure level is very high in some communities, in excess of e.g. Canadian guidelines and that the possible effects should be viewed in a perspective of several generations the present situation warrants public health measures to be taken in order to reduce the exposure without jeopardising the nutritional values of the traditional diet

8.3.2 Recommendations for Greenland

It is therefor recommended that the Monitoring, Assessment and Human Effects Biomarker Programmes should be continued in Greenland to follow the temporal changes in the contaminant situation and to uncover any possible overt health effects at the clinical or subclinical levels.

It is furthermore recommended that dietary and other lifestyle advice should be established with the aim to reduce contaminant exposure among pregnant and fertile women taking the high nutritional value of certain traditional food items into consideration and at the same time assuring a sufficiently high nutritional value of the total diet.

8.3.3 Conclusions and Recommendations from The Faroe Islands.

Exposure to methylmercury and organochlorine compounds has been high in the Faroe Islands due to frequent ingestion of pilot whale meat and blubber.

Cognitive deficits and other adverse effects have been demonstrated in children with prenatal exposure to these compounds in the Faroes.

In August, 1998 the Faroese authorities issued an advisory that women, who plan to become pregnant within three months, pregnant women, and nursing women should abstain from eating pilot whale meat.

Furthermore, the best way to protect foetuses against the potential harmful effects of PCBs and other organochlorine compunds, is if girls and women do not eat blubber until they have given birth to their children.

The results from a dietary survey among pregnant women in 2000 – 2001 has revealed a dramatic reduction in whale meat and blubber intake.

Blood analyses showed a decrease corresponding to more than one order of magnitude in regard to mercury exposure. However, possibly because of their stability in the body, the PCB levels were still high and must be considered to be a continued potential health problem in the Faroese community. The reasons for the persistent high PCB concentrations are not fully understood, and further research is needed to elucidate this phenomenon.

Because of the advantages of conducting epidemiological studies in the Faroes and because of the continuing exposure to organochlorine compounds, research should be continued to explore the health consequences of the increased exposure levels.

8.4 Main Conclusion

The main conclusion of the Human Health Programme in AMAP phase 2 is that we are even more certain than before that the current human exposure at the prevailing levels and mixtures of contaminants influences the health of Arctic populations in a negative way. Subtle effects have been demonstrated to be present at a sub-clinical level. In consideration of the potential effects on future generations, efforts to reduce the entry of persistent substances into the ecosystems of the world should be accelerated. Furthermore, the process initiated through the AMAP under phase 1 and 2 should be continued and expanded to involve all relevant disciplines with the goal of pursuing a more holistic assessment of the health of the Arctic Peoples.