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Arctic Monitoring and Assessment Programme
Russian Association of the Indigenous Peoples
of the North, Siberia and Far East

Persistent Toxic Substances, Food Security and Indigenous Peoples of the Russian North

Final Report

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Preface

The project "Persistent Toxic Substances, Food Security and Indigenous Peoples of the Russian North" has been initiated by the Indigenous Peoples Organizations – Permanent Participants of the Arctic Council and the Secretariat of the Arctic Monitoring and Assessment Programme (AMAP) as a follow-up of the conclusion of the 1st AMAP Assessment Report that some Arctic indigenous communities are among the most exposed groups of population in the World to persistent toxic substances. This initiative has been supported by the Global Environment Facility (GEF), in particular its UNEP Coordination Unit, practically all countries-members and observers of the Arctic Council, as well as by a number international organizations. Without their political, substantial financial and technical support, implementation of this exclusive work would not be feasible.

The project has been fulfilled mostly by Russian institutions and experts, with the organizational support from the relevant Russian federal governmental executive bodies and the local administrations of the regions of the Russian Federation. At the same time, active participation of a number of international experts in all stages of the project, from drafting the project proposal to the compilation of its conclusions and recommendations and development of the dissemination strategy, was important for its success. Close collaboration of the project team with the AMAP Human Health Expert Group was a necessary step for making its outcomes consistent with the circumpolar assessment work being made in all Arctic states under the auspices of AMAP.

Wide participation of the Russian Association of the Indigenous Peoples of the North, Siberia and Far East (RAIPON) and its regional branches in the project should be specifically highlighted. For the first time, the indigenous experts acted in this project not as assistants, but as equal partners of the research teams. Efficient work of the indigenous peoples coordinators, both at the central level and in the regions, and their collaboration with the local administrations and human health authorities, was one of valuable lessons learned during the project implementation. Work among the indigenous communities, particularly at the stages of the dietary and lifestyle surveys and human sampling, would not be feasible without their everyday involvement.

On behalf on the project Steering Committee, we would like to thank all experts involved in the field work, assessment of the results and drafting the final documents of the project, and people who took a hard technical work on issuing this report. Special thanks should be addressed to a large number of indigenous persons, particularly to the mothers of newborn children for their understanding of the project importance and active participation in the survey. We highly appreciate all donor countries and organizations for their generous support. The project Steering Committee expresses sincere hope that the project results will make its contribution to the improvement of the health status of the indigenous peoples of the Russian North, and will serve as an information tool for the Russian Government, local authorities, indigenous organizations and the international community.

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August 2004

Chapter 1

Background and introduction

1.1. Background

In 1997, the Arctic Monitoring and Assessment Programme (AMAP) presented the report *'Arctic Pollution Issues: A State of the Arctic Environment Report'* (AMAP, 1997) to the Fourth Ministerial Meeting of the Arctic countries (Alta, Norway). This first AMAP assessment was supported by a substantial scientific background document, the *'AMAP Assessment Report: Arctic Pollution Issues'* (AMAP, 1998), which was submitted to the First Ministerial Conference of the Arctic Council (Iqaluit, Canada) in 1998. Both of these reports clearly documented the fact that persistent toxic substances (PTS) are transported to, and accumulate in, the Arctic region.

The explanation for this lies in the physical and chemical properties of PTS, which promote their long-range transport by atmospheric, oceanic, and riverine pathways to the Arctic. Due to their low solubility in water and high solubility in fat, they tend to accumulate in lipid-rich Arctic biota species, and to biomagnify in food webs, particularly in long marine food chains. As a result, the upper trophic levels of Arctic food webs are highly exposed to PTS, and certain Arctic indigenous populations, whose lifestyle is based on the consumption of traditional country foods, are subject to some of the highest exposure levels to PTS of any population groups on Earth.

The AMAP assessment provided evidence that, for example, blood levels of some PTS, such as polychlorinated biphenyls (PCBs) and mercury, can be several times higher in residents of Arctic Canada and Greenland than levels measured in residents of industrialized areas of North America. In some cases, PTS intake exceeded World Health Organization (WHO) guidelines, and attained levels comparable to those associated with the potential to cause negative impacts on human health in areas such as neurological development, reproductive health, immuno-suppression, and cancer, etc. Due to the ability of some PTS to cross the placenta, and also to accumulate in breast milk, this raises concerns regarding the potential of PTS to affect the growing foetus and young children, during the most critical periods of human development.

At the same time, it is important to note the benefits that traditional diets provide. For many indigenous peoples, the traditional diet is not only a vital source of nourishment, but also an integral part of their cultural and spiritual identity. Any threat to continued consumption of these foods, including chemical contamination, is not only a potential threat to the health of the individual concerned, but also to the social structures and entire cultural identity of these indigenous peoples.

Preliminary studies in the Russian Arctic have shown that, as in Arctic Canada and Greenland, levels of PTS in biota may be significantly elevated as a result of long-range transport of contaminants, and that in some areas this is compounded by local pollution occurring as a result of the heavy industrialisation of the Russian North. Recently, as a result of economic and social changes in Russia following the break-up of the U.S.S.R., after years of declining consumption, use of traditional foods by indigenous peoples appears to be increasing again. In Chukotka, the harvesting of walrus in greater numbers, as well as the recent resumption in native hunting of bowhead whales for subsistence purposes, are examples of this trend. However, at the time of the first AMAP assessment, the situation of the Russian Arctic indigenous peoples had not been studied sufficiently to allow a clear understanding of the impact of contaminants on the overall health status of indigenous populations. This lack of information precluded a reliable assessment of the Russian situation with respect to PTS exposure within the circumpolar context. It also prevented the development of adequate measures to reduce the risks to Russian northern populations associated with exposure to PTS.

Representatives of the Arctic Indigenous Peoples Organizations (IPOs), which, at the time of the first AMAP assessment, included the Russian Association of Indigenous Peoples of the North (RAIPON), the Inuit Circumpolar Conference (ICC), the Saami Council (SC), and the Aleut International Association (AIA) are permanent participants in the Arctic Council. Deeply concerned by the findings of the AMAP assessment regarding possible impacts of PTS on the health of their peoples, particularly through contamination of traditional foods, the IPO representatives, in collaboration with the AMAP Secretariat and supported by the Arctic Council, took the initiative to launch a special project to address the deficiencies in information identified by the AMAP reports. The aims of this project were not only to assess the situation with respect to PTS impacts on the health of indigenous peoples, but also to develop recommendations to federal and local authorities, to the indigenous peoples themselves, and also to the international community on (a) measures to reduce the exposure of indigenous peoples of the Russian North to PTS, and (b) means to empower indigenous peoples to participate actively and fully in the process of PTS elimination.

It is important to note that the IPOs consider the elimination of risks to human health from PTS as a key component of their activities, and are active participants in all relevant international negotiations that are concerned with reducing use and environmental releases of these chemicals. Their role in the development and adoption of the Persistent Organic Pollutants (POPs) and Heavy Metal Protocols to the United Nations Economic Commission for Europe (UN ECE) Convention on Long-range Transboundary Air Pollution (LRTAP), and particularly in promoting the development of the United Nations Environment Programme (UNEP) global Stockholm Convention on POPs, cannot be overestimated. Due to the current economic situation in Russia, the Russian Federation has yet to become a signatory to the above-mentioned UN ECE LRTAP Protocols, and also has still to ratifiy the Stockholm Convention. The proactive work of the IPOs, and of RAIPON in particular, in such processes, is vital if the major goals of these Conventions are to be realised.

The IPOs initiative, to develop and implement the project *'Persistent Toxic Substances, Food Security and Indigenous Peoples of the Russian North'*, received full support from the UNEP Global Environment Facility (GEF), the Arctic Council, and all the Arctic Countries and International Organizations. Additionally, and of vital importance for the project, it received support from all relevant Federal executive bodies of the Russian Government, the Russian Parliament (the State Duma), and the local authorities in all the pilot regions selected for project implementation. The project formally started in February 2001, although some preliminary studies had already been undertaken in the summer and autumn of 2000.

There are, today, some 30 indigenous minority peoples in Siberia, the North, and the Far East of the Russian Federation, in total numbering approximately 200000 persons. Eleven of these minorities live in the Arctic region, the combined land area of which is approximately 3.1 million km^2. Together with five other northern indigenous minority peoples who live close to, or partly within, the Arctic region, the indigenous minority population within Arctic Russia numbers some 67000. Approximately 75% of the minority population within the Arctic Russia live in rural areas. In addition, the two most numerous groups of indigenous peoples (the Komi and Yakuts), which represent the majority within their territories, have lifestyles that are similar to the indigenous minorities, and hence are exposed to similar environmental risks.

Conditions for indigenous peoples in the Russian Arctic have been steadily worsening over recent years. The effects of economic changes occurring throughout Russia have been felt acutely in the Arctic, with indigenous minorities being particularly affected. According to a report by RAIPON and UNEP/GRID-Arendal, the indigenous peoples in northern Russia are on the brink of 'physical extinction' (GRID-Arendal, 1998). Health issues, particularly those related to environmental contamination, are a matter of urgent concern, with life expectancy of the indigenous peoples twenty years shorter than that of the average Russian (as low as 41-42 years for men in some regions). Infant mortality is increasing, as is the incidence of disease.

During recent years, Russian Federal authorities have taken a number of steps to address the critical economic, social and health problems affecting the indigenous peoples. In 1992, the President of the Russian Federation issued a special Decree: *'Urgent Actions on Protection of Habitats and Subsistence Activities of Indigenous Minorities Of The North'*. Following from this, the Federal Law, *'Fundamentals of the State Regulation of Social and Economic Development of The Russian Federation North'*, with an Article dedicated to environmental protection and the use of natural resources, was adopted in 1996. The Federal programme *'Children Of The North 1998-2000'*, which was adopted by the Russian government in 1997, also proposed practical steps for improving the situation in the region. Unfortunately however, the critical economic situation affecting the country has meant that these measures have not received the necessary financial support, and, consequently, that they have failed to achieve the desired results. Although the adopted Federal Law *'On Guarantees of the Rights of Indigenous Minorities in The Russian Federation'* created a legislative framework for improving the existing situation, it is not able to solve problems associated with the lack of the financial resources required to implement necessary remedial actions.

The Russian Federation actively participates in circumpolar monitoring and assessment activities conducted within the framework of AMAP. In this, they provide significant contributions of data and information needed to complete the Russian component of the AMAP circumpolar assessment. Due to financial constraints, however, studies during the first phase of AMAP (1992-1997) concerning the impacts of environmental contamination on human health were restricted to a limited area of the Russian North, and were essentially lacking for the eastern part of the region. Activities under the *'Persistent Toxic Substances, Food Security and Indigenous Peoples of the Russian North'* project have contributed significantly to the assessments conducted during the second phase of AMAP (1998-2002) (AMAP, 2002, 2003a, 2004) and have assisted in the elimination of gaps previously identified with respect to geographical scope and knowledge.

1.2. Scope of the project

1.2.1. Project overall goal and objectives

The project *'Persistent Toxic Substances (PTS), Food Security and Indigenous Peoples of the Russian North'* is designed to help reduce contamination of the Arctic environment by PTS. To further this aim, the following objectives were established:

1. To assist indigenous peoples to reduce the health risks resulting from contamination of their environment and traditional food sources through the development of appropriate remedial actions.
2. To enhance the position of the Russian Federation in international negotiations concerning reduction of PTS use; and to empower indigenous peoples to participate actively and fully in these negotiations.
3. To enable the Russian Federation and the Russian Association of Indigenous Peoples of the North (RAIPON) to increase their involvement in the work of the eight-nation Arctic Council aimed at reducing emissions of PTS.

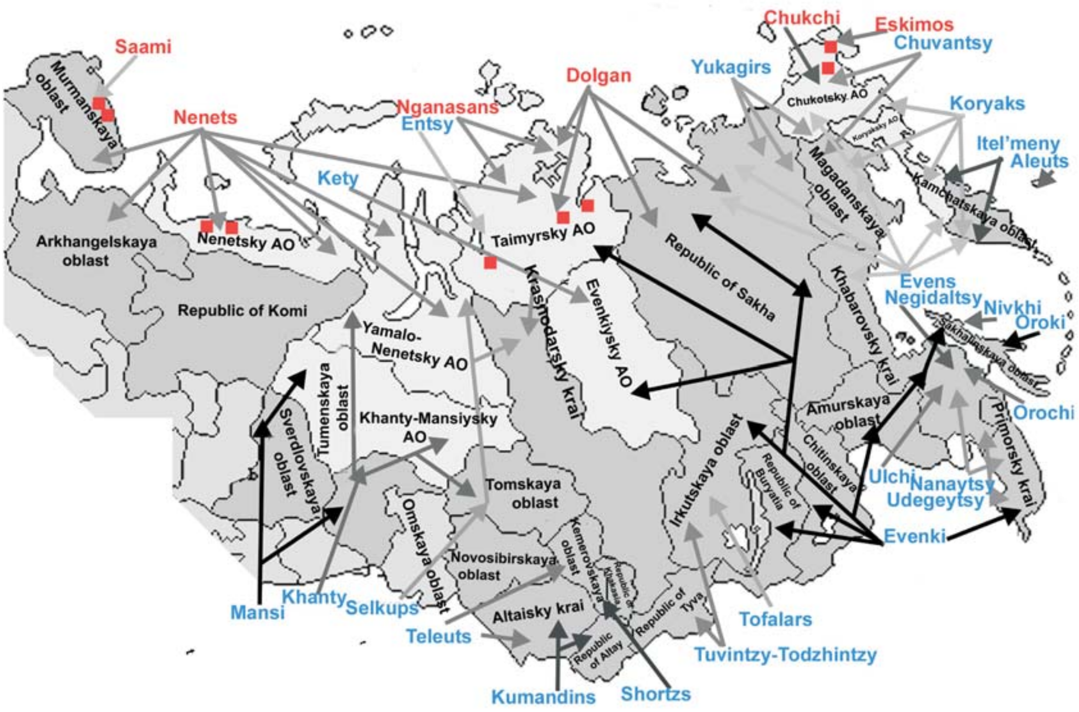


Figure 1.1.
Indigenous peoples and administrative territories of the Russian Federation. The indigenous peoples groups and the locations of the pilot study areas covered by the PTS project work are indicated by red labels and markers, respectively.

The project has been designed as an integral component of a wider strategy that addresses identified information needs regarding the extent of environmental contamination in Arctic Russia; its effects on indigenous peoples; and identification of measures to improve the situation in the region. A number of international projects and programmes, including those of the Arctic Monitoring and Assessment Programme (AMAP), provide data and information that both complement and support this project. In many respects, the project itself is envisaged as the key component in this overall strategy, providing information that would not otherwise be available.

The project has been designed to obtain the following three key outcomes:

1. Recommendations to federal and local authorities, indigenous peoples and the international community on measures to reduce exposure of indigenous peoples to PTS, including identification of priority areas where actions are needed.
2. Assessment of the significance of aquatic food chains as a pathway of exposure of indigenous peoples to PTS.
3. Assessment of the relative importance of local and distant sources, and the role of atmospheric and riverine transport of PTS.

Table 1.1.
Populations of the Russian Arctic, by the administrative territories and ethnicity (1989 census).

Indigenous peoples	Administrative territories						Russian Arctic	Russia
	Murmansk Oblast	Nenets AO	Yamalo-Nenets AO	Taymir AO	Republic of Sakha (Yakutia) Arctic area	Chukchi AO		
Saami	1615	0	0	2	0	0	1617	1835
Enets	4	0	2	103	0	0	109	198
Nenets	176	6423	20917	2446	0	10	29972	34190
Khanty	10	5	7247	3	0	4	7269	34190
Nganasan	5	0	3	849	0	0	857	1262
Dolgan	18	0	14	4939	0	4	4975	5363
Even	10	1	46	34	1793	1336	3220	17055
Evenk	20	27	78	311	1285	54	1775	29901
Chukchi	2	0	11	1	428	11914	12356	15107
Eskimo (Yupik)	3	6	7	0	0	1452	1468	1704
Yukagir	3	0	3	0	476	160	642	1112
Selkup	1	1	1530	8	0	0	1540	3564
Chuvan	9	0	0	4	0	944	957	1384
Koryak	5	1	31	16	0	95	148	8942
Ket	0	3	6	11	0	0	20	1084
Mansi	18	1	216	1	0	3	239	8279
Total indigenous	1899	6468	30111	8728	3982	15976	67164	
Total population	1164586	53912	494844	55803	66632	163934	1999711	
% indigenous	0.16	12.0	6.08	15.64	5.98	9.75	3.36	

1.2.2. Geographic and ethnographic scope

The Russian North is populated by a variety of indigenous peoples with different cultures and traditional lifestyles (Figure 1.1, Table 1.1). Careful consideration was therefore given to selecting a study strategy capable of providing results with optimal regional and demographic significance. In order to ensure that recommendations based on surveys of the relatively limited study groups were applicable to indigenous populations throughout the Russian Arctic, the survey groups were selected to represent a range of traditional lifestyles involving use of different natural resources.

To optimise use of project resources, compatible information from other projects has been used to provide a more comprehensive information base than would otherwise be the case. The following regions, which coincide with AMAP key monitoring areas, were therefore selected as the pilot areas for implementation of the project.

i) The Kola Peninsula (Murmansk Oblast): populated by the Saami people who rely heavily on reindeer and freshwater fish as components of their traditional diet. Pollutants affecting the area are derived from local mining activities, metallurgical industries (non-ferrous metal smelting), and long-range transport of European emissions. The area can be also affected by such a large population centre of Murmansk, with its harbour activities, including radioactive waste storage associated with Russian northern fleet operations. The pilot study area was centred on Lovozero and its surroundings, which is the main settlement for the Saami population in the region, as well as the village of Krasnoshchelye.
ii) The lower basin of the Pechora River: the area is populated by the Nenets, whose traditional diet includes reindeer and freshwater fish. The area is subject to long-range transported pollution, and multiple local pollution sources, including sources associated with oil activities in the region.
iii) The Taymir Peninsula, including the lower reaches of the Yenisey River: populated by the Dolgans and the Nenets whose traditional diet includes reindeer, freshwater fish and game. This area is affected by multiple pollution stresses, including the mining and metallurgical industries at Norilsk, and river-borne pollution, including radioactive contamination, from the catchment of the Yenisey River. Two areas within the region were selected for study, Dudinka (Nenets) and Khatanga (Dolgans).
iv) The Chukotka Peninsula: populated by the Chukchi and Eskimo (Yupik) peoples, whose traditional diet includes marine mammals, fish and reindeer. The area is affected by long-range transported pollutants, particularly from sources in south-east Asia. As the traditional diet of coastal and inland indigenous people of Chukotka differs significantly, two areas within the region were selected for study: Kanchalan (inland) and Lavrentiya – Uelen (coastal).

In 1998 there were some 117 native communities recorded in the selected study areas (Table 1.2.). By national legislation, these settlements are under the administrative jurisdiction of four separate administrative territories of the Russian Federation: Murmansk Oblast; the Nenets Autonomous Okrug; the Taymir Autonomous Okrug; and the Chukotka Autonomous Okrug. It is worth noting that the number of indigenous people permanently residing in the selected areas represent approximately two-thirds of the total indigenous population of the Russian Arctic.

The present day population of most of the communities in the region is a mixture of both indigenous and non-indigenous people. The latter generally dominate in the ethnic composition (see Table 1.2), although there are a number of settlements, particularly in the eastern part of the Russian Arctic, where indigenous people still constitute the majority.

Geographical pilot area	Title of the administrative territory	Number of native communities*	Total population*	Indigenous population*
Kola Peninsula	Murmansk Oblast	9	12455	1386
Basin of Pechora River	Nenets Autonomous Okrug	36	43768	7395
Taymir Peninsula	Taymir Autonomous Okrug	28	44094	9255
Chukotka Peninsula	Chukchi Autonomous Okrug	44	32650	15533
Total		117	132967	33569

Table 1.2. Populations of the selected pilot areas.
* data provided by the local authorities (as recorded at 01.01.1998)

Ethnic group	Number surveyed	% of survey population
Chukchi	84	35.4
Nenets	57	24.1
Dolgan	51	21.5
Komi	15	6.3
Saami	6	2.5
Eskimo (Yupik)	3	1.3
Chuvan	9	3.8
Yukaghir	3	1.3
Nganasan	4	1.7
Evenk	4	1.7
Koryak	1	0.4
Total	237	100.0

Table 1.3. Breakdown of the mother-child survey participants by ethnicity.

Under the project, both mother-child pairs and general indigenous population surveys were undertaken. Thirteen ethnic groups are represented in these surveys. (Table 1.3. and 1.4.). This represents a large proportion of the eighteen officially recognized indigenous ethnic peoples of the North (Governmental Decree No 255 dated 24.03.2000), although the main groups represented in the study were the Chukchi, Nenets, Dolgans, Komi, Saami, and Yupik (Eskimo), who together constituted about 97% of total number of survey participants.

Table 1.4.
Breakdown of the general indigenous population survey participants by ethnicity.

Ethnic group	Number surveyed	% of survey population
Chukchi	554	35.2
Nenets	357	22.7
Dolgan	339	21.5
Komi	134	8.5
Saami	120	7.6
Eskimo (Yupik)	24	1.5
Chuvan	10	0.6
Yukaghir	11	0.7
Even	7	0.4
Nganasan	6	0.4
Evenk	1	0.1
Itelmen	2	0.1
Koryak	1	0.1
Other	10	0.6
Total	1576	100.0

Thus, the study areas and ethnic groups selected for the surveys are believed to adequately represent the general variety of dietary habits and other key characteristic of the traditional lifestyles of the indigenous populations in the Russian Arctic. This representative coverage has allowed the inclusion in the project of both exposed and non-exposed groups of people from different indigenous populations, demonstrating distinct dietary characteristics, as well as groups living in geographically diverse locations which are exposed to different primary sources of contaminants.

1.2.3. Project activities

In addition to activities targeted towards reaching specific project objectives and undertaken within a geographically defined area, the project implementation plan included a range of core activities, concerned with support of the overall project. These core activities included project coordination; administration and management activities, including organization of Steering and Coordination Group meetings; translation, provision of ongoing information on the project; progress reporting, and part of the work associated with dissemination of key results and the preparation of project reports. Additional activities included the provision of supporting information and data, such as emission inventories, meteorological input data for modelling work and associated data handling activities, required for assessing the long-range transport of pollutants (i.e. from sources not linked to any specific geographical area within the study region).

The following activities were included into the project work program:

Activity 1: Co-ordination, management, and support to the project.

General project management and coordination was conducted by the project Steering Committee (SC). The SC comprised one representative from the Implementing Agency (UNEP); one from each of the Executing Agencies (RAIPON and the AMAP Secretariat); and one from each of the international organizations, countries, NGOs, financial institutions and foundations who contributed to the project financing. Russian ministries and other federal executive authorities were also represented in the SC. Countries and institutions providing other types of contribution, and whose involvement was considered useful for the project implementation, could obtain SC observer status.

The AMAP Secretariat was designated as the international project coordinator and, with assistance from RAIPON, was responsible for the execution, coordination and administration of the project. In addition, RAIPON participated in project activities concerning assessments of local pollution sources; food consumption and traditional diets; assessment of the levels and effects of pollution in the indigenous population; impacts of socio-economic and demographic conditions on the lifestyle and health of the indigenous population; and information dissemination.

Activity 2: Assessment of local pollution sources in the vicinity of selected indigenous communities

The objective of this activity was to produce an inventory of PTS sources in areas populated by indigenous peoples. This work was implemented by the Centre for International Projects (CIP), Moscow, on the authorisation of the Ministry of Natural Resources, and with the active participation of the local environmental protection authorities responsible for pollution control in the regions/areas concerned. The work relied to a large extent on baseline activities carried out by the Ministry of Natural Resources. Also, local indigenous organizations played an active role in obtaining the data and information needed for this part of the assessment.

Activities within the framework of the Arctic Council Plan to Eliminate Pollution of the Arctic (ACAP) also provided an important contribution to this activity. This included results from projects such as the Phase 1 of *'Multilateral Cooperative Project on the Phase-out of PCB Use and Management of PCB-contaminated Wastes in the Russian Federation'* (AMAP, 2000) and the project on *'Environmentally Sound Management of Stocks of Obsolete Pesticides in the Russian Federation'*. Another work being implemented in part of the project area that contributed significant data and information to the project was the NEFCO/AMAP activity *'Updating of Environmental 'Hot Spots' List in the Russian Part of the Barents Region: Proposal for Environmentally Sound Investment Projects'* (AMAP, 2003b).

Activity 3: Assessment of distant sources

The objective of this activity was to assess PTS transport from distant sources to areas of northern Russia inhabited by indigenous peoples. The activity consisted of two independent components:

i) Assessment of long-range atmospheric transport of PTS to the Russian North

Information on PTS concentrations, from measurements at background air monitoring stations operated under the AMAP monitoring network and through bilateral and national monitoring activities, was provided by AMAP and the organizations concerned.

Modelling work required to assess the atmospheric transport of PTS from long-range sources was undertaken by the Meteorological Synthesising Centre-East (MSC-E), Moscow, the centre responsible for modelling heavy metals and persistent organic pollutants under the Co-operative Programme for Monitoring and Evaluation of the Long-range Transboundary Air Pollution in Europe (EMEP). In addition to work directly associated with the project, other EMEP activities undertaken within the European part of the Russian North constituted contributions to the project by the UN ECE. Meteorological data needed for the modelling of long-range atmospheric transport was provided by the Russian Federal Service for Hydrometeorology and Environmental Monitoring as part of its in-kind contribution.

The modelling work was based on preparatory activities such as the AMAP *'Workshop on Long-range Transport Modelling and Source-Related Activities'* (Bergen, June 1999) where a number of relevant issues were addressed, in particular the need for global inventories of PTS and the development of global/hemispheric transport models.

ii) Preliminary assessment of riverine fluxes as a source of PTS to Arctic Russia

Riverine fluxes of PTS have been assessed for the Pechora and Yenisey Rivers. Assessments were made using data collected at the most downstream sampling sites of the Russian Federation's national freshwater monitoring network, and additional cross-sections further downstream located in areas inhabited by indigenous peoples. Sampling, together with simultaneous hydrological observations, was conducted during four typical hydrological phases of the year. This work was carried out by the Regional Centre 'Monitoring of the Arctic' (RCMA, St. Petersburg). Long-term hydrological data for the rivers concerned was provided by the Russian Federal Service for Hydrometeorology and Environmental Monitoring as part of its in-kind contribution.

Activity 4: Study of biomagnification in Arctic food chains

This activity considered marine, freshwater and terrestrial food webs, the upper trophic levels of which are used as traditional food sources by the local indigenous population. Samples were taken of key species (and, where relevant, abiotic media) from the food chains leading to the main food sources identified. The selection of primary food items was made according to the geographical location and consumption patterns of the indigenous peoples concerned, and therefore depends to a large extent on the results of the dietary survey (Activity 5). However, in order not to miss the field season in the Arctic and to get timely data, it was decided to use expert and traditional knowledge to design the field missions under this activity, without awaiting the outcome of the dietary surveys. In general, this approach has subsequently proved to be valid, with some limited exceptions for which adjustments were been made during the later stages of project implementation.

Field sampling, pre-treatment and conservation of samples was conducted by qualified personnel from the Regional Center 'Monitoring of the Arctic'. Field work was strongly supported by the local indigenous communities. It should be noted that a number of specific biota samples could not have been collected without active involvement of local hunters; particularly since only indigenous communities are licensed to hunt certain species. Standardized and prescribed sampling, pre-treatment, storage and transportation procedures were used to ensure that contamination was avoided, necessary measurements at the time of sampling (e.g., location, age and sex of organism, etc.) were correctly carried out; and samples were appropriately packaged and transported to the laboratory.

Samples were analysed for PTS in the analytical laboratory of the Regional Center 'Monitoring of the Arctic' which was selected by the Steering Committee following a tender for the work. All work was performed according to internationally acknowledged methodology and strict Quality Assurance/Quality Control (QA/QC) procedures. Since the RCMA laboratory is not certified for analytical determination of dioxins/furans, this work was undertaken by the Bashkortostan Analytical Center (Ufa). As an additional quality assurance measure, fifty of the environmental samples were split for duplicate analysis; these were conducted by Unilab Analyse (Tromsø, Norway).

Activity 5: Dietary surveys of selected indigenous communities

The work under this activity was performed by the North-Western Public Health Research Centre, St. Petersburg, with active participation of medical personnel from local hospitals and regional branches of RAIPON.

Prior to surveys being undertaken, guidelines for dietary surveys were developed and a detailed questionnaire, compatible with that used in the AMAP Human Health Circumpolar Programme, was compiled. Practical survey activities were anticipated by special workshops arranged under Activity 8 (Capacity building) of the project, at which local medical personnel and RAIPON coordinators were given instruction on ethical and professional aspects of dietary surveys, filling in questionnaires, and for medical personnel, procedures for blood sampling and sample conservation.

A detailed questionnaire was used for individuals that participated in the study of PTS levels in humans. The purpose of the questionnaire was to establish the nutritional adequacy of their diet; to evaluate the dietary importance of the various food items; and also to reveal any dietary differences among the ethnic groups. Lifestyle factors, e.g. alcohol consumption, smoking habits, socio-economic conditions, etc., were also included. In addition to pregnant women, who were the main target of the study, the survey was extended to represent other groups within the indigenous population (males, different age groups, etc.) to ensure coverage of the overall indigenous population in the selected communities.

Information obtained from the dietary surveys and data on PTS levels in humans (see Activity 6) were compiled in a data base specifically designed for the project needs.

Activity 6: Monitoring of PTS levels in humans
The fetal period is regarded as the most vulnerable time for exposure to toxic substances, so pregnant women and their newborn children constituted the primary study group for the project. Key information for this activity is therefore provided by sampling maternal and cord blood of delivering women for analysis for PTS. The sampling strategy needed to take into account the fact that the study covered small population groups living in small communities. A minimum sample size of 30 mother/child pairs at each location was established, representing sample numbers that provided a compromise between achieving a desirable level of statistical validity for the study, and a realistic work programme. In addition, during the dietary surveys, a considerable number of blood samples were collected from various other groups within the general indigenous population to provide additional background data.

The activities were based on the sampling of indigenous people attending hospitals located in regional centres, with possible visits to more isolated communities where necessary or feasible. To increase capacity of these hospitals to arrange sampling and sample storage, the work plan included installation of necessary equipment for sample storage (freezers, liquid nitrogen supplies, etc.) and for registration at these centres. Special storage of samples of maternal and cord blood (at −70°C) for later analysis of additional selected parameters was also arranged.

Analytical work was carried out at the Centre for Environmental Chemistry 'SPA Typhoon' (Obninsk). The Centre was selected by the Steering Committee following a tender for the work and taking account of the results of the circumpolar ring-test on analyses of human blood samples organized by AMAP. Analytical work was conducted using internationally acknowledged methodology and QA/QC procedures. A number of the human blood samples were also analyzed in the laboratory of the Norwegian Institute for Air Research (NILU, Norway), and at the Institut National de Santé Publique du Québec (INSPQ, Québec, Canada) to ensure data quality and comparability with other circumpolar blood analyses.

Provisional results of the dietary surveys and blood sample analysis indicated that PTS levels in the blood of some indigenous families could not be explained by consumption of contaminated traditional food alone. To substantiate conclusions and recommendations of the project, the Steering Committee requested the North-Western Public Health Research Centre to arrange an additional targeted survey of selected indigenous families with the highest and lowest PTS levels in blood. This survey covered the sampling and analysis of not only human blood from the given family members and foodstuff consumed by them, but also their indoor and occupational environments. Due to the short time frame available for conducting this additional activity, it was decided to divide the resulting samples between the Regional Centre 'Monitoring of the Arctic' and 'SPA Typhoon' laboratories.

After completion of the analytical work, the AMAP Secretariat convened a special international expert meeting to evaluate the validity of the data, with participation by all of the analytical laboratories involved in the project. This meeting made a significant contribution to ensuring the reliability of data and information used in the assessment process and in the development of conclusions and recommendations.

Activity 7: Assessment of the role of pollution on health, and development of recommendations
This activity is considered as a keystone of the whole project. It's objectives are to assess the exposure of indigenous peoples to PTS including the means by which PTS are acquired, the effects on health, and the risks associated with PTS; and to develop recommendations for federal and local authorities, indigenous peoples, and the international community concerning measures to reduce exposure of indigenous peoples to PTS.

The assessment process and development of recommendations was directed by an Assessment Group, established by the project Steering Committee. The group consisted of the lead Russian experts involved in the project implementation, as well as a number of international experts selected from relevant AMAP Expert Groups. The Russian members of the Assessment Group were responsible for the preparation of the first draft of the assessment report.

Activity 8: Capacity building
The major component of this activity during project implementation was the training of local personnel (representatives of the indigenous peoples and medical staff) in how to conduct dietary surveys and health related interviews. Additionally, local medical staff were trained to take human blood and breast milk samples according to internationally recognized guidelines. Equipment necessary for the sampling and storage of samples, and other expendables were also supplied to the local hospitals involved.

Local indigenous hunters and other personnel involved in environmental sampling were trained in procedures for the sampling of biota species, with assistance from project scientific field personnel. This was particularly important where hunting of species is restricted by licence to the indigenous communities.

All pregnant indigenous women, who participated in the study, received a newborn child care kit on departure from hospital, together with detailed instructions for taking care of newborn children.

It is envisaged that, following publication of the project results in Russian, special workshops will be arranged in each of the pilot regions. Besides the role of these workshops in information dissemination, they will also have a strong capacity building component, since future training of the local human health authorities and indigenous representatives will be based on activities that follow from the project recommendations.

Activity 9: Dissemination
RAIPON, the AMAP Secretariat, and the agencies of the Government of the Russian Federation are fully committed to making all research results public. All project participants in the human health survey will receive information on their individual contaminant levels, with any conclusions made regarding the risk to their health, likely sources of contamination, and recommendations on risk reduction. This commitment will be carried out in close collaboration with, and through the active participation of local health authorities, medical personnel and regional branches of RAIPON.

Although the project Steering Committee, and RAIPON in particular, has so far directed and monitored the ongoing dissemination of information and results from the project, the major phase of dissemination work will follow publication of the project final report, with its conclusions and recommendations. To improve awareness of the project and increase the effectiveness of communication, four levels of written information will be prepared

- the project Final Report (this report), in English, for wide international distribution;
- the project Executive Summary, in Russian and English;
- booklets for distribution in each of the pilot regions, containing specific conclusions and recommendations;
- recommendations to the relevant federal executive bodies and the Government of the Russian Federation.

Written material will be supported by a video film, produced by professional media bodies in consultation with project consultants representing health professionals and indigenous peoples.

However, it is the regional workshops, to be held following publication of the project results and involving the participation of local administrations, human health and environmental protection authorities, and the regional branches of RAIPON, which are considered to be the main mechanism for communication and information dissemination.

After completion of the regional workshops, a meeting in Moscow is planned as the final stage of the project, with participation by the Government of the Russian Federation, the State Duma (the lower chamber of the Russian parliament), relevant federal executive authorities, and RAIPON.

1.2.4. Persistent Toxic Substances included in the project

The project covers the following Persistent Toxic Substances:

Persistent Organic Pollutants (POPs):

Selected congeners from both parent compounds and metabolites of the following classes of industrial products:

- Polychlorinated biphenyls (PCBs): (major congeners found in blood: PCB 28, 52, 99, 101, 105(132), 118, 128, 138(163), 153, 156, 170, 180, 183 and 187)
- Hexachlorobenzene
- Brominated flame-retardants (PBD, PBDEs)

Selected chlorinated pesticides and their metabolites:

- Hexachlorocyclohexanes (α-HCH, β-HCH, γ-HCH)
- DDT-group (e.g. *o,p'*-DDT, *p,p'*-DDT, *o,p'*-DDE and *p,p'*-DDE)
- Toxaphenes
- Cyclodienes (e.g. *cis/trans*-chlordane, dieldrin)
- Mirex (this pesticide has not been used in Russia/former USSR but can be a good indicator of long-range transport)

Combustion by-products:

- Selected polycyclic aromatic hydrocarbons (PAHs), dioxins/furans

Heavy metals:

- Mercury, cadmium and lead

In some cases different types of samples have been analysed for different groups of contaminants, as appropriate to the geographic location and the objectives of the specific activity for which samples were collected. Selection of sampled media and contaminant combinations for which analysis was undertaken was based on AMAP guidelines, in combination with available baseline information such as likely pollution sources.

Chapter 2

Lifestyle, social and economic status of indigenous peoples

2.1. Background

Russian legislation defines indigenous populations of the Russian Federation as follows:

"The numerically small indigenous populations of the Russian Federation (hereafter referred to as Indigenous Peoples) are those residing in the areas of the traditional settlements of their forefathers, preserving their traditional lifestyle, economy and trades, who perceive themselves as an independent ethnic entity, and whose population in the Russian Federation does not exceed 50000. The Common Register of the Indigenous Peoples of the Russian Federation is approved by the Government of the Russian Federation based on information provided by the authorities of the administrative territories of the Russian Federation where the indigenous populations reside."

The law further clarifies that:

"... the traditional lifestyle of Indigenous Peoples is the strategy of survival which has been developed throughout their history, based on the experience of their forefathers in nature management, original social structure, accommodation, original culture, and the preservation of customs and beliefs." (Federal Law, 1999).

Currently these charcteristics provide the main criteria for the identification of the indigenous peoples in Russia. To date, this definition has applied to 40 indigenous minorities, who are listed in the Common Register, mentioned in the Law[1]. Individuals belonging to these indigenous minorities are eligible for special targeted programs and a number of privileges to ensure their security.

The indigenous peoples included in the Register share many common characteristics and problems. At the same time they also differ significantly from each other, which makes the framing of a single concept of sustainable development a difficult task.

Based on their original settlement patterns, the indigenous peoples of Russia can be classified into several groups. One of these groups comprises the indigenous peoples of Northern Russia, Siberia and the Far East, a group that are are distinguished by extreme living conditions, prolonged isolation from other cultures, their distinctive material and spiritual culture and migratory habits, in addition to other traits. One important feature shared by this group of indigenous peoples is a more deep overall social and economic crisis than that encountered in other minority population groups in Russia.

The group of indigenous peoples of Northern Russia, Siberia and the Far East is a sub-group, comprising 11 indigenous peoples whose residence in the Arctic region (i.e. in the coastal and northern areas of the Arctic Ocean catchment) is a determining characteristic. It is generally believed that the forefathers of these contemporary Arctic indigenous peoples came to the Arctic region 10-12000 years ago, during the final stage of the last glaciation. This was the beginning of a period of migration by ancient tribes across the Arctic zones of Eurasia, and by northward migration of tribes from the south. This mixing between the new immigrants and the ancient indigenous tribes started a new page in the ethnic history of the North.

In fact, northern ethnic groups were continuing to develop up until the 19th century and it was only when the original inhabitants of 'Siberia' came in contact with 'European civilization', that they were considered to be 'indigenous peoples', as this term is understood today. Prior to this they were considered 'disintegrated ethno-linguistic communities, characterized by unstable population density, dispersion, ethno-cultural heterogeneity and weak intra-ethnic communication' (National Report, 2000).

The features which characterise the northern indigenous peoples are determined by their environment. Their small population size also results from external factors and does not indicate either under-development or inherent population decline. On the contrary, for their specific geographic environment and economy type, a small population size represents an optimal solution (Gumilev and Kurkchi, 1989). However the same factors which ensured the high degree of adaptability of northern populations to their extreme living conditions, also made it difficult for them to integrate with other cultures, especially those which were more 'developed'. The resulting conflicts have affected all aspects of their life, including social, cultural and spiritual integrity.

Before conversion to Christianity, the indigenous populations of northern Russia were animists, believing all creatures and objects of the world to possess souls. This allowed them to explain the world around them, including many natural phenomena, and also created a need for communicating with spirits. Such beliefs led to the emergence and development of shamanism. Shamanism and shamanistic practices provided faith in one's own abilities in the face of fears aroused by the incomprehensibility of nature and mans inability to influence it. This was the shaman's role and explains his influence on his fellow-tribesmen (Kasavin, 1990).

The arrival of Europeans in the northern regions brought significant changes to the world of the indigenous populations – especially in connection with the discovery and development of mineral deposits. It was during this period that the various indigenous ethnic groups were defined and assigned their modern names (generally different from those used by the indigenous people themselves). This occurred as a result of various political and legal decisions, reforms and government activities, including the introduction of the census and passports, administrative and territorial division, and deliberate elimination of dialects and even some ethnicities.

[1] There also exist other definitions of the term 'indigenous minorities' which are not considered here.

The expanding 'Register of Indigenous Peoples of Northern Russia', established by law, currently identifies 30 indigenous peoples who reside within the five Republics, four Krais, ten Oblasts, and eight Autonomous Okrugs which comprise almost the whole area of the Russian North, Siberia (including Southern Siberia) and the Russian Far East. The total population of northern indigenous peoples is less than 200000 people, and constitutes less than 2% of the total population of the northern regions of Russia.

It is clear that the northern indigenous peoples have undergone significant changes, which have distanced them from their forefathers in economic, social, cultural, and even anthropometrical respects. However, certain groups of the contemporary indigenous population still preserve both the cultural identity and the economic activities which are considered to determine a traditional lifestyle and pattern of settlement (nomadic or semi-nomadic lifestyle, etc.).

Table 2.1.
Indigenous peoples of Northern Russia, Siberia and the Far East. Indigenous groups and administrative territories studied within the project are highlighted in grey.

Ethnonym: modern / previous (own) language	Main area of habitation (see also Figure 1.1)	Population in the 1989 Census	Main traditional trades
Aleut / Aleut (aleuts, unangany, unangan, unanghan) In fact two indigenous peoples	Kamchatka Oblast	278	Sea-hunting Fishing Gathering
Chukchi / Chukchee (Luoravettan), Language: Chukotko-Kamchatkan family. Several dialects. The oldest nation of North-Eastern Russia, which spread towards Kolyma and coastal areas of the Chukchi peninsula putting pressure on other indigenous populations.	Chukchi Autonomous Okrug, Republic of Sakha (Yakutia), Magadan Oblast, Kamchatka Oblast, Koryak Autonomous Okrug.	12995	Two original types of economies: deer-breeding with large herds (continental nomadic groups) and sea-animal hunting (coastal settled groups). Secondary activities: hunting, fishing, gathering. The deer-breeders travel across tundra with deer teams, coastal sea-hunters travel with dog teams. Ski - snow-shoes. When travelling by water they used dugouts, leather kayaks. Dwelling: Nomads: yarangas (dome-shaped) formed of a frame covered with deer skins. Settled: yarangas or mud-huts built on a frame made of sea animal bones. Heating and lighting: fat-based lamps Clothing: two layers, fur, no fastenings.
Chuvantsy (Chuvan) / -- Etel	Chukchi Autonomous Okrug, Magadan Oblast	487	Fishing, hunting, dog-breeding, picking
Dolgan / Dolgans (Dolgan), the language: Turkic, Altaic family. Nomadic life in forest-tundra.	Krasnoyarsk Krai, Taymir (Dolgan-Nenets) Autonomous Okrug, Republic of Sakha (Yakutia)	5754	Deer-breeding of mixed type, Hunting for wild deer at river crossings and with deer-decoy, fowling etc. Fishing Dwelling: a conical choom, a hut on sleigh, driven by 5-7 deer. Clothing: furs and textiles, a type of caftan.
Enets / Yenisey Samoyeds, (Enneche, Madu) several subgroups	Krasnoyarsk Krai	116	Hunting, fishing
Eskimo / Eskimoes (Yupik, Yuit). Three groups	Chukchi Autonomous Okrug	1514	Hunting for whale, walrus and other marine mammals. Wild deer hunting, fowling, fishing, berry picking, seaweeds. Dwelling: dugouts. The walls are built of stones and whale bones. The frame is covered with skins. Yarangas similar to Chukchi. Clothing: fastened, made of deer or seal skins, or birds' skins.
Evenk (Evenki) / Tungus (Evenki, Orochon)	Amur, Irkutsk, Sakhalin, Chita Oblasts, Krasnoyarsk, Primorsky, Khabarovsk Krais. Republic of Buryatia, Republic of Sakha (Yakutia)	25548	Hunting, fishing, deer-breeding, gathering
Even / Lamuts (Even, Orochel) several subgroups	Magadan, Kamchatka Oblasts, Khabarovsk Krai, Chukchi Autonomous Okrug, Republic of Sakha (Yakutia)	12017	Deer-breeding, hunting, fishing, gethering
Itelmen / Kamchadals (itelymem)	Kamchatka Okrug	1449	Fishing, hunting
Ket / Yenisey Ostiaks (Kets)	Krasnoyarsk Krai	939	Fishing, hunting
Khanty / Ostyak (Khanti) – three subgroups, two independent groups	Tomsk, Tyumen' Oblasts	17289	Fishing, hunting, deer-breeding
Korya k / Koryaks (Nymylans, Chavchuvens) Several subgroups, include Kereks and Alutors.	Kamchatka, Magadan Oblasts, Chukchi Autonomous Okrug	6254	Sea-hunting, fishing. Gathering, deer-breeding, Hunting
Kuman / -- (Cuman) - one of subgroups of Altaic indigenous populations	Altay Republic, Altay Krai	662	Cattle-breeding, deer-breeding, hunting, fishing, gethering, blacksmithing.
Mansi / Voguls (mansi, mansiy)	Tyumen', Sverdlovsk Oblasts.	4873	Hunting, fishing, deer-breeding
Nanai / Goldi (Nanaj, Nanai) – Several sub-groups	Khabarovsk, Primorsky Krais	8280	Hunting, fishing, gathering
Negidal / ogilyaks (elkan-baianin)	Khabarovsk Krai	384	Fishing, hunting, gathering
Nenets / Yurak Samoyeds (Nenetsy, Nentse, Nenec) Several subgroups Language: Samoyedic groups, Uralic family.	Krasnoyarsk Krai, Taymir (Dolgan-Nenets) Autonomous Okrug, Archangelsk, Tyumen', Murmansk Oblasts, Nenets, Yamal-Nenets, Khanty-Mansi Autonomous Okrugs.	33045	Deer-breeding for production and transportation, travelling with sled driven by a team of 3-5 deer. Dwelling: dismantleable conic wigwam. Hunting for wild deer, furry animals, and birds, fishing. Clothing – double fur.
Nganasan / Tavgi Samoyeds (Nganasans) – include two subgroups Language: Samoyedic group, Uralic family. The most northern nation of Russia.	Krasnoyarsk Krai, Taimyr (Dolgan-Nenets) Autonomous Okrug	829	Wild deer hunting at river crossings and with deer-decoy, geese hunting and hunting for other animals and birds; Net fishing, fishing with gaffs, deer-breeding mainly for transportation. Dwelling: conic choom, clothing double fur.

Ethnonym: modern / previous (own) language	Main area of habitation (see also Figure 1.1)	Population in the 1989 Census	Main traditional trades
Nivkh / Gilyaks (Nivkhs, Nivkhi) several sub-groups	Sakhalin Oblast	2711	Fishing, hunting, dog-breeding, gathering.
Orochi / Oroches (Orochen, Nani)	Khabarovsk Krai	601	Fishing, hunting
Orok / -- (Ulta, Ujlta) , two subgroups	Sakhalin Oblast	5	Hunting, fishing, gathering
Saami / Lapp (Saami) The most Western small Northern nation. Saami also live in Finland, Sweden and Norway. Language: Finno-ugric group, Uralic family. The language has several groups and dialects.	Murmansk Oblast	1105	Wild deer hunting, including herding and traps, coastal and sea fishing, deer- breeding for transportation and partially for production. Semi-nomadic life. Travel with one-runner sled, ski. Hunting for fur animals. Skin, wood, horn processing. Spinning. Different types of dwelling - conical frame-type and rectangular, stationary and dismantleable. Clothing: double fur. Their culture shows many elements from traditional cultures of other Northern indigenous peoples.
Selkup / Ostyak Samoyeds (Selkups) Several subgroups Language – Samoyedic groups, Uralic family. Three dialects.	Krasnoyarsk Krai, Taymir (Dolgan-Nenets) Autonomous Okrug, Tomsk, Tyumen'Oblasts, Yamal-Nenets Autonomous Okrug	2980	Hunting with guns and traps for different animals, birds; fishing with nets, rods; deer-breeding for transportation (Northern Selkups). Various crafts: blacksmithing, spinning. They also acquired cattle-breeding and gardening. Travel: sled driven by deer, ski, dugouts, horses. Dwelling: mud-huts, frame-type buildings Clothing: fur, fish skin Cultural influence of adjacent indigenous populations. Currently traditional activities are destroyed by industry (oil etc.) – they are deprived of their grounds and pastures.
Shor / Kusnets Tatars, Kondom Tatars, Aba (shor) – two sub-groups	Kemerovo Krai	3485	Blacksmithing, hunting, gathering, apiculture
Teleut/ -- (Telengetters) – several subgroups	Kemerovo Oblast, Altay Krai	2161	Hunting, horse-breeding, gathering
Tofalar / Karagas (Tofa)	Irkutsk Oblast	636	Hunting, deer-breeding
Tuvin-Todzhin / Soyot, Soyon, Soyod, Uriankhai (Tyva) – a small Eastern part of Tuvins.	Irkutsk Oblast, Republic of Tuva	5144	Hunting, deer-breeding, gathering
Udege / Udihe (Udekhe)	Primorsky, Khabarovsk Krais	1116	Hunting, fishing, gathering, antler deer-breeding
Ulchi / Manguns (nanai)	Khabarovsk Krai	2439	Fishing, hunting, gathering
Yukaghir / Yukaghir (Odul)	Chukchi Autonomous Okrug, Republic of Sakha (Yakutia)	672	Main activities: hunting, fishing, gathering.
Total population of the northern indigenous peoples: 156038 people			

Table 2.1 provides general information on the indigenous peoples of Northern Russia, Siberia and the Far East, their main areas of habitation, and occupations followed.

2.2. Traditional lifestyle

By definition, the indigenous peoples of northern Russia (including the indigenous peoples of the Arctic area) occupy remote regions of Eurasia, including the northern polar areas and islands in the Arctic Ocean. The proximity of the Pole and the Arctic Ocean determine the climate and nature of these areas, and also their landscape, which mostly consists of tundra and forest-tundra. Vast areas are covered by mountains and bogs, and there are many lakes and rivers. Fog, strong winds, long winters (lasting from September/October until June), permafrost, and scanty vegetation are only a few of geographic features that illustrate the challenges faced by any creatures living in these areas. Thus, the lifestyle as well as type and seasonal character of the economy of the northern indigenous peoples has been mainly determined by the extreme conditions and the associated severe constraints imposed on human communities.

The severe climate and limited natural resource base makes it impossible to use the agricultural and subsistence practices commonly found in more southern areas. As a result, northern indigenous peoples took longer to develop their primary economies than other indigenous populations. Up until the 20th century, most of the indigenous peoples predominantly practiced primitive forms of hunting (including sea-hunting), fishing, and gathering. Whilst some of the indigenous peoples also mastered, to varying degrees, the practice of nomadic reindeer-breeding, for many this also took a rudimentary form.

In general, by the time the Russians arrived in Arctic Eurasia, the indigenous peoples of the area were still evolving their economic and cultural systems. Their survival strategies, especially those relating to everyday life, have been classified as a 'traditional lifestyle'. Later, however, during the Soviet and post-Soviet periods, the lifestyle of the northern indigenous peoples underwent radical changes. When speaking of 'preservation of the traditional lifestyle' under modern conditions, therefore, it is necessary to take account of these differences.

Research has shown that in some areas of northern Russia the 'traditional lifestyle' and 'traditional trades' have survived and are still developing. However, in most regions, the traditional economy and associated way of life have either been eliminated or are in crisis.

Nevertheless, even in those areas where the traditional lifestyle and economy are considered to be in crisis, there are still some traditional communities trying to overcome their difficulties and seeking to adapt their households to modern life, whilst at the same time retaining or reviving the knowledge of previous generations.

2.3. Traditional economic activities

The main traditional activities undertaken by the northern indigenous peoples include reindeer-breeding, hunting, fishing, sea-hunting, and gathering.

2.3.1. Reindeer-breeding

The reindeer is a unique animal that can find food where other domestic animals are unable to survive. The European (or Lapponian), Novaya Zemlya, Siberian, Tundra, Siberian Woodland, Okhotian, Barguzin, and Spitsbergen reindeer are all sub-species of reindeer found in Russia.

Reindeer-breeding is still the main economic activity for most indigenous peoples of the Russian Arctic. It is primarily practiced by Nenets, inland Chukchi, Koryaks, Nganasans, Dolgans, northern Khanty, Saami, Mansi, and some Evens, Evenki and Enets. Domestic reindeer breeding began mainly in the 18th century, through the domestication of wild reindeer, and represents a form of nomadic stock-breeding.

During the Soviet period, reindeer-breeding underwent significant change and was developed as an agricultural industry, with the family communities being transformed into production teams. At that time, Russia had up to 2.3 million domestic reindeer, which constituted three-quarters of the world's stock. Reindeer breeding as an industry was very profitable.

For deer breeding, a herd is normally maintained by one extended family or a group of relatives. In the Arctic zone, herds are usually large, migration routes are long and reindeer breeding is oriented towards production. One of the main functions of reindeer is to provide people with food and clothing. Meat, blood, marrow, intestines and other tissues are consumed, both fresh and processed. The skin is used for clothing and shoes, and for the construction of lodgings and other accessories.

In winter, reindeer eat mainly lichen, fallen leaves and grass, which they find under the snow. The summer diet consists of grass, leaves, mushrooms, berries and even birds' eggs and nestlings. Reindeer herds constantly migrate in search of new pastures and to escape blood-sucking insects.

The life of reindeer-herders is largely determined by the biological cycle of the reindeer. Reindeer herders have to move constantly, following the reindeer migration. In summer they migrate towards the ocean or mountainous areas, whilst in autumn, they return inland to river valleys, forest-tundra and taiga. To travel across tundra, nomadic herders use sleds pulled by teams of one to four, and occasionally even up to seven reindeer. The types of sleds and teams differ. The Saami use one-runner sleds without stanchions; Nenets use high-stanchion sleds, and Chuckchi use low sleds with seven or eight stanchions. There are a range of different sleds for women, men, children and transportation of goods, as well as covered sleds.

The nomads traditionally live in yarangas or chooms, wooden frame tents covered by reindeer skins that have been sewn together (in winter, in two layers are used), which can be easily dismantled and put up at a new location. Curtains made of skins are often put inside to give added protection from cold. The nomads' clothing normally has no fastenings and is made of deer skins. Winter clothing has two layers, with fur both inside and outside.

To the south, within the subArctic forest-tundra and taiga (where hunting is better developed), reindeer breeding differs. Reindeer are larger but the herds are less numerous and the animals are mainly used for transportation. In woodlands, as the use of sleds is difficult, the reindeer are usually used with pack-saddles or ridden astraddle. Also, migration routes in woodlands are shorter and depend upon the season. Therefore, reindeer-breeding in forest-tundra is usually combined with hunting.

In modern life the traditional dwellings and clothes of reindeer-breeders begin to be replaced by tarpaulin and synthetic tents, rubber boots, warm textile clothing and other artificial materials. Whilst being convenient and easy to handle, these materials are not altogether suitable for people following a traditional lifestyle. Reindeer-breeders, fishermen and hunters are always working outside. Thin tarpaulin does not protect from the cold as well as reindeer skins, and synthetic clothes can prevent normal exchange of heat and moisture which can increase likelihood of illness.

2.3.2. Sea-hunting

Sea-hunting is a traditional activity of the indigenous peoples of coastal areas of the Arctic and Pacific Oceans. These are primarily Eskimos, Aleuts, coastal Chukchi and Koryaks, and to a lesser extent Nenets, Evens, and some other indigenous groups. The object of this type of hunt are whales, walruses and seals (including Ringed seals), which provided indigenous communities with meat, fat and skins. Meat and fat from marine mammals, both fresh and processed, as well as preserved in traditional ways, were the main food sources for some coastal communities.

Whaling had special importance for the indigenous population of Chukotka. A team of 8-10 people took part in the hunt, and one bowhead (Greenland right whale) or grey whale could provide enough food for a whole village.

Sea-hunters built their settlements on higher parts of the coast, where they had a good view of the sea to assist in searching for whales. When a whale appeared, the hunters would rush to the sea in several kayaks. They would first throw harpoons with floats to keep the whale from diving, and then kill it with spears. Later on, guns were also used in whale hunting. Koryaks used belt nets to catch and kill whales.

During the Soviet period, independent indigenous hunting was prohibited and whales were hunted by a special state-owned whaling fleet. Whaling ships would bring their catch to the villages where the role of the indigenous community was to transport carcasses from the ships to the coast and to process them. All villagers were involoved in this work. The first whale was always a feast and all meat and fat was shared among the families. The whaling ships were in use until the early-1990s. It was during the Soviet period that the most important traditional skills were lost and the lifestyle of sea-hunters threatened. In the post-Soviet period, economic problems prevented the lease of whaling ships and a slow revival of traditional skills took place.

Walrus were traditionally hunted in open sea in spring and autumn, either while in the water or on ice-floes. In summer, walrus were caught on the coast at their rookeries. At sea, hunters used boats, made from a frame covered with walrus and seal skins. Previously, animals at sea were hunted using a rotary harpoon with special detachable tip. Hunting of Ringed seal and other seals species took place throughout the year, usually by individual hunters in kayaks in the open sea and using both weapons and traps on the ice.

Sea-hunters were settled. They travelled with dog teams from permanent dwellings built from a frame of whale bones, covered with turf and skins to form a spacious hut. Stone lamps filled with sea mammal fat provided heating and lighting. Their clothing was made from sea mammals skins and intestines of and had no fastenings.

The hunting practices were reflected in the culture and spiritual beliefs of indigenous populations, which developed over millennia. Some traditions were lost during the Soviet period, but in recent years some noticeable efforts have been made to restore them.

2.3.3. Hunting and trapping

Historicaly, hunting was very important for indigenous peoples, especially for the Khanty, Mansi, Kets, Yukaghir, Udeghes, some Orochis, Nanais, Negidals, Itelmens and some other groups. The purpose of the hunt was determined by the prevailing environmental, ethnical and historical situation. Originally the primary aim of the hunt was to provide meat, later, hunting animals for the fur trade also became important.

The main quarry were wild deer, moose, brown and polar bears, snow sheep, hare, and various birds, including geese, ducks and partridges among others. The main fur animals were sable, squirrel, marten, wolverine and otter.

In some areas, for example the Taymir, wild reindeer hunting was a traditional activity, performed during the short period of time when reindeer herds were crossing rivers. On these occasions, hunters killed the animals from boats. This short hunt provided sufficient food to support the neighbouring villages for a long time. Later this activity was commercialized, using new technology and fire-arms and was mainly undertaken by non-indigenous workers for commercial enterprises. The carcasses were also processed along the river banks, causing environmental damage. This form of commercial 'hunt' differs in form and meaning from the traditional one. Furthermore, the indigenous population was forced away from the reindeer crossings and deprived of the means of sustaining itself. Other forms of reindeer hunting involve the use of domestic reindeer to entice wild reindeer.

The main hunting tools used originally were various traps, but later on guns came into widespread use. Indigenous hunters traditionally lived a semi-nomadic or semi-settled life, moving to several different locations throughout the year. They lived in different kinds of dwellings: the simplest being log houses, mud huts, or chooms, covered with bark and tree branches. Hunters travelled on reindeer or on foot, and also at times used special skis and small sleds. Their clothing was made mainly from deer fur and fastened down the back.

2.3.4. Fishing

Fishing has always been one of the most important traditional activities of the northern indigenous peoples. Until the present day, fish has been the most important food product for both people and dogs. The most active fishing takes place in spring and autumn during the seasonal migration of anadromous fish. Fishing has traditionally been the main activity of the Ob Khanty, Mansi, southern Selkups, some Kets, Nivkhs, Ulchis, Nanais, Negidals, Orochis, Oroks, Itelmens, some Koryaks and Chukchi. Fishing also provides materials for clothing and shoes.

2.3.5. Gathering wild plants

Gathering wild plants and berries has been widely practiced since the earliest times and contributes to the provision of food and other needs of the indigenous peoples, for example, products to assist in tanning and dyeing of skins for clothing.

2.4. Social impact of recent political and economic reforms

The State policy towards northern indigenous peoples has changed at various times. From the very beginning of colonization, the Tsarist government faced the problem of the formalization of citizenship of the colonized indigenous peoples and their lands. The problem arose because at the when the Russians came to Siberia, the indigenous peoples had not yet formed integral ethnic communities with an administrative structure. Social networks and administration were restricted to families, and tribal or clan communities. This was due to a certain extent to their geographical isolation and also to the nature of a subsistence family economy.

The archaic economic and social relations of the northern indigenous peoples also influenced their spiritual life, culture, behavioural standards and law. This introduced certain complications during the integration of the northern indigenous peoples and their lands into Russia, as the indigenous communities had no recognized leaders to sign the contracts and documents, confirming their consent to join the Empire and to ensure the legal formality of colonization.

The key strategy used to solve this problem was the introduction of 'yasak' – a tribute paid by the indigenous peoples as a symbol of their obedience to Russia and of their Russian citizenship. The main goods paid as yasak were sable skins and other furs, as well as tusks from mammoth remains and walrus, and other luxury items. The yasak commitments and the introduction of new commodity-money relations and trade led to the development of fur trading, which had not been very widespread amongst northern indigenous peoples until then. This change in activities led to an alteration in the traditional lifestyle.

Colonization was not, of course, easy and bloodless, however it is generally accepted that the main intention of the Russian state towards newly colonized indigenous populations was not to cause their displacement or extermination, but rather their naturalization. The peaceful nature of colonization is reflected in the legal documents of the time, for example the first legal document – the 'Code of Law of 1649', which recognized the right of the indigenous populations to preserve their customs and beliefs and traditional law system. Later on, during the period 1819-1822, the 'Statute on the Administration of Foreigners' was approved, which until the Revolution remained the most important document relating to the northern indigenous peoples. The Statute introduced a different approach to different indigenous peoples and established a structure that best suited the characteristics of various indigenous communities.

After the Revolution, in December 1917, the Declaration of the Peoples of Russia was adopted. This proclaimed the right of all national minorities and ethnic groups living in Russia to independent development. This was confirmed by the Constitution of 1918. Thus, the indigenous peoples of the Russian North acquired equal rights with other ethnic groups of Russia. Also worth noting is the 'Decree of the Government On the Preliminary Protection of Indigenous Tribes' of 1923, which banned the import of alcohol to areas of permanent migrations of northern indigenous peoples, and also introduced a state monopoly on the fur trade, and other measures.

During this period, scholars and politicians proposed two alternative concepts for the further development of the northern indigenous peoples:

- The 'Traditionalist' or 'Native' concept implied the preservation of the culture of the northern indigenous peoples. This concept proposed that contacts with the newly arrived population be minimized and the creation of 'reserved' areas similar to those existing in Western countries (Bogoraz-Tan, 1923).

- The 'Innovative' or 'Integrative' concept was based on the need for the rapid and radical integration of the northern indigenous peoples into the culture of other peoples of Russia and their adoption of socialist values.

Originally the 'traditionalist' policy was followed, characterized by a partnership approach and very slow, limited reforms to the indigenous lifestyle. Later, the policy of radical change prevailed. New administrative and territorial divisions were introduced, whereby some indigenous peoples were assigned their 'own' national (later renamed 'autonomous') administrative territories, known as Autonomous Oblasts or Autonomous Okrugs. Such 'autonomy' did not in fact imply any form of self-administration. On the contrary, the indigenous communities were increasingly subjected to total and radical transformation. Reforms and standardization were imposed on nearly all aspects of life. New production associations emerged rapidly, such as artels, cooperative societies, collective farms (Kolkhozes), etc. Later on, kolkhozes in the northern areas were replaced by Soviet farms (Sovkhozes) and almost all the property of indigenous population was nationalized[2].

There were continuous efforts to eliminate nomadic habits and to introduce a settled lifestyle. To achieve this aim, the state established centralised estates in kolkhozes and sovkhozes. Originally these were tiny settled bases, which later developed into large villages, accommodating administration and service personnel.

The main strategy used to eliminate the nomadic lifestyle was to transform reindeer-herding and other traditional activities into production activities, and to remove aspects of the traditional lifestyle from the everyday routine life of the indigenous peoples. For this purpose, children, women and the elderly population were moved from reindeer herding camps, and fishing and hunting sites, to the newly-built villages.

The transition to a settled way of life was a complicated and painful process, because it involved crucial changes of the whole lifestyle and the wholesale destruction of traditional values. The result was the following: men nomaded in the tundra, women were moved to villages, and children sent to boarding schools.

[2] Statistical data: By 1934, 37% of all households of northern indigenous populations and 10% of the deer population were collectivized. By 1943, 97% of all households of northern indigenous populations and 89% of the deer population were collectivized (of which 18% were given to Sovkhozs) and only 11% remained privately owned.

It was the total collectivization and the mass forced separation of children from their parents that led to the most destructive changes in the traditional lifestyle. The traditional lifestyle, which had developed over the long course of history, was rapidly transformed into a modern form of society, with changes occurring in all spheres of material and spiritual life. Villages acquired health centres and schools, secondary education became obligatory, literacy and proficiency in Russian language increased, and indigenous peoples got professional education. Ideology was a very important component of life and representatives of the indigenous peoples, in common with the rest of the USSR population were actively recruited to the Communist Party and the Youth Communist League.

At the same time, however, traditional skills, customs and native language were gradually being lost. Detary habits also underwent radical changes and the diet came to consist mainly of imported food products, preserves, sugar, dairy products and other non-traditional food.

Despite the negative impacts of the socialist state, problems relating to unemployment, the health service, education, provision of acceptable living conditions and food provision for the indigenous populations, were however alleviated.

During and after the second World War, massive industrial development of northern areas commenced. This included intensive geological research and the development of mineral deposits, which resulted in the reduction of areas available for use as pasture, and hunting and fishing grounds.

During the post-Soviet period, there was a further radical change in State policy. After the dissolution of the USSR, Russia entered a period of political, economic and social change, affecting both state and society. At the beginning of the 1990s, some Autonomous Okrugs populated by northern indigenous peoples attempted to follow the general trend of the Russian ‘struggle for independence’ and to change their status. Such movements were, however, initiated mainly by the (usually non-indigenous) leaders of the relevant administrative territories rather than the indigenous peoples themselves. At the same time, the leaders of the administrative territories were opposed to the creation of national districts, national village councils, communities and other forms of aboriginal self-administration, even at a basic level.
The turning point of this period occurred when the State rejected the policy of ‘paternalism’, which had allegedly existed before, and granted the northern indigenous peoples the ‘freedom’ of self-sufficiency within a declared policy of ‘partnership’.

Economic reforms and transition to a market economy were followed by the reorganization of sovkhozes in areas populated by the indigenous peoples, which represented one of the most important changes. This campaign led to a change of ownership of property whereby former state farms were converted into various private, family-owned, joint-stock and commercial agricultural, hunting and processing enterprises.

Theoreticians of the market economy forecasted the revival and the development of private farms and enterprises, but in practice the changes actually resulted in the destruction of the remaining economic, social and cultural foundations of many northern communities. However, practical reorganization of agricultural enterprises in fields traditional northern indigenous activities, which operated in the Soviet times, often led to their destruction. Some of the reasons for this are briefly outlined below.

Although both hunting and fishing were traditional activities of the indigenous peoples, they had largely been forced away from rich hunting and fishing grounds to poorer and more remote locations by newcomers. These new hunters had the advantage of contacts with the town markets, allowing them to sell furs for higher prices. As the result, indigenous fur trade has significantly decreased since the introduction of a market economy due to a reduction in price of wild animal skins and the increasing price of ammunition. Skins of white fox have effectively lost their value and most of the hunting sites in the tundra have been abandoned. The price of squirrel skin currently approximates to the price of a cartridge. Only sable now remains profitable for hunters, but even in this domain, profits have fallen significantly (Klokov, 2002).

Fishing is also in crisis for economic reasons - lack of capital for investment and the high cost of transportation make commercial fishing impossible. At best it now serves to supply food to local trade network, but even here there are some problems. The interests of the indigenous peoples are contrary to those of large fishing enterprises and distribution of fishing licences and quotas results in conflicts, which are seldom resolved to the benefit of the indigenous population.

Similarily, gathering activities are unable to provide a reliable source of prosperity in the northern areas. The sale of berries brings only a small profit, as there is no established system of marketing in villages, no equipment for processing and preservation, and the market price is paltry.
In conclusion, these traditional activities are currently not capable to stimulate the economic prosperity of the indigenous population, and at best, can serve as a local food supply.

Marine mammal hunting and reindeer-breeding are more promising in all respects, being economic activities where the indigenous populaitons have encountered less competition from imported labour. These activities (and especially reindeer-breeding since it is more widespread) could, therefore, establish the economic foundations for sustainable development of. the indigenous peoples. In most regions, however, reindeer-breeding is currently in decline. Only the Yamal-Nenets and the Nenets Autonomous Okrugs show definite improvement, which can be explained by the fact that, in some areas, private herds, together with the appropriate traditions, were preserved during the Soviet period.

Local stability, however, will not save domestic reindeer production in Northern Russia as the whole. According to statistics, the total population of domestic reindeer in the Russian Federation halved between 1991 and 2001. Table 2.2 uses the example of Chukotka to illustrate the changes in the reindeer population.
Other social indicators in reindeer-breeding regions have also shown a deterioration. There is a massive migration of indigenous people from the areas associated with traditional activities, to villages and cities, where many of them are unemployed. Among some indigenous peoples, more than half the population number is now considered as an urban one.

Year	1988	1996	1997	1998	1999	2000	2001
Reindeer population	485959	189600	156794	121206	103466	92452	99984

Table 2.2 Changes in the reindeer population of Chukotka between 1988 and 2001.

The main negative consequence of the transition to a market economy and the subsequent financial and economic crises which have arisen is the reduction of social activity amongst the indigenous population. This, together with a lack of money, the collapse of the traditional economy and loss of familiar values has led to a mass expansion of alcohol consumption amongst the indigenous population.

2.5. Industrial pollution

A main feature of the northern regions of the Russian Federation is the co-existence of two diametrically opposed types of economy in a very vulnerable and fragile environment. One is the traditional indigenous lifestyle, attuned with the environment, and the other is the contemporary industrial economy which often leads to the destruction of the environment. Frequently, mineral deposits coincide with reindeer pastures, hunting and fishing grounds and other areas of traditional nature management.

Another feature is that, historically, the Far North has been the supplier of raw materials to the central part of the country. Originally these materials were furs, but now the products are silver, gold, diamonds, wood, coal, oil, gas, and other goods. Raw material exploitation effectively provides prosperity for other parts of the country, but to the detriment of the environment in the northern regions, and with little benefit to norhtern indigenous peoples.

A third characteristic of the northern regions is the absence of any real self-administration, and a lack of the means to influence or control the industrial development of natural resources, or, to at least obtain realistic compensation for the areas affected.

During the Soviet period, when military and industrial development of the North began and numerous work camps occupied by prisoners were established, a policy of secrecy and restricted access was instituted and has been followed since. The Arctic, in particular, was classified as a restricted region and remained a closed area with an enforced frontier. Development of the Arctic has, therefore, been regulated by confidential resolutions and directives of the party authorities and the government. For this reason, it has always been difficult and sometimes impossible to obtain information relating to the environment.

Currently the Ministry of Natural Resources relies on the mass media to keep the northern indigenous peoples informed. However, problems arise because the mass media have little or no access to areas of traditional nature management, and furthermore, the Ministry and other authorities themselves lack the necessary information about the land and sites which are of concern to the indigenous population. Ecological maps available at the present time only provide coverage of small areas within some regions.

Some quotes from local indigenous people:

"Since 1995, there is gold extraction in the upper reaches of the Peledon river. Although we have been informed that the environmental impact assessment has been made and approved, people do not believe this. Unhealthy water flows downstream of the mines, and dead fish can be often seen. Peledon river enters Anadyr river, which is the largest spawning river in Chukotka, and which feed a lot of people. And these people are strongly concerned."

Fedor Ugyansky, Lamutskoe village, Chukchi Autonomous Okrug

"The situation arose that the Oblast has no environmentally pristine areas. The nature of Murmansk Oblast was used for dozens of years without considering negative consequences. Neither large, nor small industrial enterprises or the Northern Fleet make any attempts to improve the situation. These is no independent control, or penalties to violators of environmental legislation."

Lyubov Vatonena, Settlement Lovozero, Murmansk Oblast

The development of the natural resources of the Far North led to a radical reduction in the areas used by the northern indigenous peoples for traditional nature management, both through direct requisitioning and destruction of these areas, and also through their pollution. Vast areas of industrial devastation exist across the whole territory of Far North, including some areas of environmental destruction due to anthropogenic activities. As a result, in many regions, large areas of reindeer pasture, rivers and lakes are no longer in use. Industrial sites represent dangerous sources of chemical pollution, affecting large areas well beyond the actual boundaries of industrial acivites or of the deposits under development.

This has resulted in irreversible transformations and far-reaching changes in the activities of the indigenous population. Of particular concern is that fact that pollution of the environment leads to pollution of the natural food resources used by the indigenous population. These food resources constitute an important element not only of physical survival, but also the preservation of the traditional culture. It is not surprising that pollution and environmental degradation, together with the extreme northern climate, has led to an increase in both the morbidity and mortality of indigenous peoples (See Chapter 8).

2.6. Biological and anthropological features of Arctic indigenous peoples

Regardless of their ethnicity, the indigenous peoples of the Arctic share many common features, both in the social and cultural domain, and also in anthropological-biological characteristics. The shared features show themselves both in the constitution of the people and also in a number of psycho-physiological parameters. This suggests that these features represent 'standard characteristics' evolved under the influence of the geographic and climatic conditions of the Far North. These 'standard characteristics' seem to have become a permanent feature for northern indigenous peoples, as opposed to some area adaptation features observed among more recent immigrants (Alekseeva, 1998).

Some characteristic features are briefly summarized as follows:

- constitution is solid, with well developed musculoskeletal systems and a mainly cylindrical chest shape;
- [bone] marrow occupies a relatively large area;
- lungs demonstrate a high ventilation capacity;
- blood serum contains an increased gamma-globulin fraction;
- blood haemoglobin content is increased;
- blood serum contains a high content of proteins and lipids;
- fat oxidation capacity is increased;
- energetic and heat regulatory processes are enhanced;
- metabolism levels are very stable.

It is noticeable that, for certain parameters, the variability range between individuals in the general population is smaller compared to populations who live under moderate climatic conditions with a more optimal geochemical balance. This loss of upper and lower extremes in such characteristics contributes to the stability of the complex of morphological and functional characteristics found in the extreme conditions of northern regions. It appears that these features are particularly significant in the adaptive responses demonstrated by the northern indigenous populations to the evolving natural and social environment. Research described below supports this hypothesis.

The extreme climate, hard living and working conditions, overcrowding and poor hygiene within dwellings, high level of infection among the older population, late disease detection and lack of medical supplies all contribute to the high incidence of tuberculosis amongst the northern indigenous peoples. Other factors, such as the change to non-traditional foodstuffs, with associated immune system impacts, are also very important. Reduced disease resistance is related to specific metabolic characteristics of northern indigenous peoples. About 90% of subjects belong to a group of 'fast acetylators' who cannot fully assimilate nutrients from important food products. Furthermore it has been shown that the degradation of pulmonary tissues occurs faster in the 'fast acetylators', leading to a greater variety of destructive forms of tuberculosis even at early detection (Sulejmanov, 1996).

Respiratory diseases also play an important role in the morbidity structure of northern indigenous peoples. One specific feature, which promotes the emergence of such diseases, is the functional characteristics of the respiratory system of indigenous population. As a result of long exposure to the severe northern climate, the indigenous peoples have developed a special respiratory 'defence mechanism' in which the inhalation phase is shortened, whilst the exhalation phase is prolonged. This reduces contact between cold air and the respiratory tracts. Air that is retained in the lungs ensures the dilution and warming of new portions of air as they enter the lungs. Under modern conditions, this adaptive reaction becomes harmful as it contributes to oxygen deficiency and accumulation of the toxic substances inhaled from the atmosphere. This promotes pulmonary diseases, including cancer (Sedov, 1998).

The change in traditional dietary habits has had a greater impact on the health of indigenous population than it is generally believed. A distinctive feature of nutrition in the Arctic is the amount of protein consumed. According to calculations, an adult Eskimo in the early 20th century normally consumed, on a daily basis, 1.8-2.2 kg of meat from sea mammals (Krupnik, 1987). Meat and fat are essential components in the diet of the northern indigenous peoples because, together with plants, they are main source of energy, vitamins and micro-elements.

This diet led to genetic adaptations and the development of adaptive mechanisms, including a reduced level of hormones in the thyroid glands and pancreas, specific biochemical processes, whereby the breakdown of fat takes precedence over its synthesis, and the utilisation of protein as the main source of energy rather than carbohydrates. Figure 2.1 compares the recommended and actual nutritional pattern of northern populations in some Russian regions.

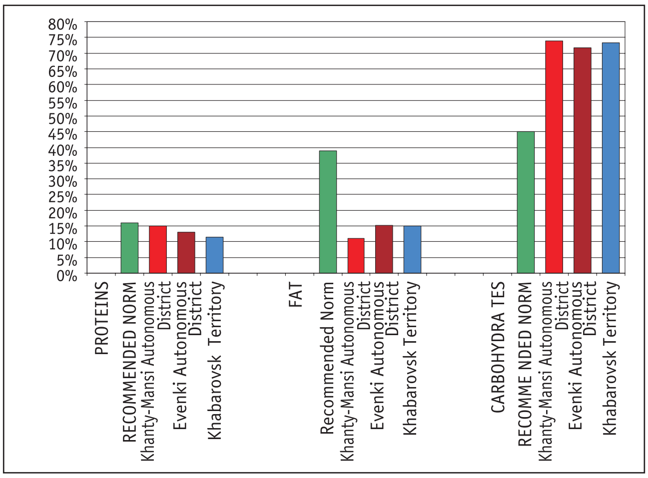


Figure 2.1. Recommended and actual nutritional pattern of northern indigenous peoples in some Russian regions, according to data of the State Statistics of the Russian Federation (compiled from Pika and Prokhorov, 1994).

Over past decades, the fat metabolism of northern indigenous peoples has been subjected to a radical 'modernization' due to the aggressive promotion of 'soviet', and more recently 'western' lifestyles and food habits. This has affected the balance of lipids and sugars in blood, which, together with an overall decrease in physical activity, has led to the development of various diseases, in particular atherosclerosis and insular diabetes.

The major change in dietary habits began during the Soviet period, when the reindeer-breeders nomadic herding routes were changed, followed by the virtual cessation of traditional activities. Fishermen and hunters, both on land and sea, were affected by various restrictions introduced by the government, and by the falling populations of fish and animals. This was accompanied by the spreading influence of imported food products and a greater orientation towards 'ready-made' or 'European' food.

The overall result was a reduction in the amount of meat, fat and local plants in the diet of northern indigenous people, as they adopted an unfamiliar diet. According to data provided by the State Committee for Statistics for the Republic of Sakha (Yakutia), consumption of wheat bread is 146% of the recommended norm and sugar and candies 492%, while the consumption of meat is only 82% of the recommended physiological norm, fish is 39%, and vegetables less than 50%. It is no accident that obesity, and endocrine diseases have increased, and that there is high level of anaemia among pregnant women and children.

Increased content of carbohydrates in the diet has made mechanisms of food assimilation less effective. This particularly affected children in nurseries and schools, where carbohydrates and dairy products formed a significant part of their diet. Menus in these institutions were compiled to match those in central and southern regions, without taking the peculiarities of the metabolism of indigenous children into account. Until recently, staff in educational institutions were unaware that dairy products and sugar could not be properly metabolised by some children. It should also be noted that, until recently, prolonged breast-feeding, (sometimes until the child is 6-7 years old), has been important in the development of immunity to diseases.

Disruption of lipid metabolism in people, affects the oxygen balance in tissues, which is aggravated by a lack of iron. The failure in supply of essential micro-elements is a result of both changes in dietary habits (for example, deer previously acted as a kind of 'repository and carrier' of biologically integrated micronutrients), and also from changes to lifestyle, in particular the reduction and discontinuance of migrations, which had previously ensured the enrichment of food with micro-elements derived from different geological environments (Kozlov and Vershubskaya, 1999).

It is clear that various adaptive changes were previously useful and helped ensure the survival of indigenous peoples in an extreme climate. However under modern conditions, many of these adaptations have become useless or even harmful. Mechanisms that evolved to protect health may now contribute to its decline, encourage a range of diseases and impede general development, including that of higher mental functions. For the Arctic and subArctic populations, a well-known saying could be re-phrased as follows: 'negative factors occurred in the wrong place in the wrong time' (Kozlov and Vershubskaya, 1999).

Furthermore, negative dietary and lifestyle changes affect different aspects of the physiological system. Carbohydrate and lipid metabolism, which are closely connected to each other, are both affected, making adaptation processes more complicated.

Examination of the range of traditional food products consumed, and traditional cooking methods of northern indigenous populations can provide further insight.

2.7. Traditional food and dietary habits

The indigenous peoples of the Arctic have traditionally shared the same nutritional base (which is one of the criteria used to classify northern indigenous people). This similarity and peculiarity in diet derives from both food products used and cooking methods. The diet has developed through a combination of geographical location and the traditional activities pursued (i.e. hunting, fishing, reindeer-breeding and gathering) and consists mainly of animal products, sometimes combined with local wild plants.

Historically, the Arctic indigenous peoples consumed only what they were able to obtain themselves locally. Although imported products, such as flour, pasta, cereals, butter, sugar, salt, tea and preserves became increasingly available in historically recent time, people living in areas, where traditional activities were followed, continued to use traditional foodstuffs. In recent years, however, this has changed.

The traditional diet of the northern indigenous peoples is also characterized by the consumption of raw products and the restricted use of forms of heat processing, as introduced via the European culture. Popular means of cooking food included baking using stones, sand and open fires. Boiling was used only occasionally, pickling not at all, and oil-frying only became popular due to the influence of other cultures.

Traditional cooking methods were a practical response to a lack of metalware, ovens, salt, and other factors.

As described above, through prolonged use of animal products as a source of food, the northern indigenous peoples have developed a genetically fixed pattern of metabolism to utilise the protein-fat rich nutrition, which helps protect their health.

In the recent past, when the traditional diet was still widespread, many indigenous peoples from the various Arctic regions actively consumed raw meat; fat and fresh blood (from reindeer, walrus, seal, and whale). These products were consumed immediately following slaughter while they still maintained their excellent taste properties and proteins.

Blood was consumed not only fresh but virtually 'live', from a cut made in a reindeer's artery while the animal was still alive. Blood was often mixed with other products (pieces of liver, kidney, marrow, or reindeer milk, and also fresh fish). Reindeer or sea mammal meat, was used to make a broth, which provided a quick restorative of physical strength and also acted as medicinal agent.

The excellent taste properties of meat from reindeer and other hoofed animals was partially due to the unstressed state of the animal when killed, quick slaughter, and special ways of exsanguination.

Until recently, raw animal products were generally frozen while still fresh, and then served sliced, chipped or broken into small pieces. Raw meat or fish was usually served with berries (bilberries, cowberries, cloudberries, crowberries), wild leek, and other pickled or frozen plants. Other popular dishes were meat and fish dried in the open or smoked over open fires in the traditional lodge. These traditional foodstuffs were complemented by poultry, including partridges (all year long), geese, ducks (in summer) and also eggs. Apart from berries, various parts of plants, wild roots, mushrooms and moss were also eaten.

The main natural food products used include:

- Terrestrial mammals: reindeer, hare, elk.
- Marine mammals: whale, walrus, seals
- Birds: geese, ducks, partridges
- Fish: freshwater and anadromous – whitefish, loach, smelt, trout, grayling, salmon (Siberian salmon, hunchback salmon, and other kinds), pike, burbot, perch; marine - herring, navaga, pollock.
- Plants: leaves or fresh shoots from polar willow, wild leek, several kinds of sorrel, laminaria (seaweed), mushrooms, berries (cloudberries, crowberries, bilberries, cowberries, blueberries, cranberries and currants).

2.8. Environmental challenges

Changes in the environment (both ecological systems and social relations, including those between ethnic groups) always require an adequate feedback response. Stress symptoms are frequently caused by exposure to extreme experiences, and in such circumstances an individual can lose control of social aspects of their life. Rapid changes in the environment, which overwhelm previously developed adaptive responses can aggravate the stress. The most destructive 'environmental changes' experienced by the northern indigenous peoples were forced separation of children and parents, prevention of family nomadic lifestyles, and the decline of traditional economic activities and self-administration in communities. Natural disasters and anthropogenic upheavals can both have a seriously deleterious effect on human health.

It is health (in the broadest sense of the word) that is the most important factor in survival, both for an individual and for the whole community. This is a critical issue for the indigenous peoples of Arctic Russia, who, under the pressure of increasing social and health problems, now collectively feel a deep sense of crisis.

Environmental problems, including both destruction and pollution of the natural environment are of special concern. Sources of pollution can be both in the immediate vicinity of indigenous communities, and also far distant from the Arctic. Chemical substances accumulate in traditional foods, such as plants and animals, and thus enter the bodies of northern indigenous people.

The northern indigenous peoples are effectively caught in a dilemma: on one hand, rejection of traditional food and lifestyle threatens both their community and individual well-being and cultural identity, and on the other hand, the same traditional foods have become suspect as a result of chemical pollution.

Chapter 3

PTS limits and levels of concern in the environment, food and human tissues

3.1. Environment and food

A basic approach used to assess the potential risk posed to ecosystems and human health by toxic and other harmful effects of pollutants involves comparison observed concentrations of pollutants in the environment with established 'Maximum Permissible Levels' and 'Levels of Concern' (values that trigger action) in corresponding media. There are a number of guidelines and other normative documents that provide values for such levels, for various substances in different media. Among these, the following documents are of relevance to the project:

1. List of Fishery Standards: Maximum Permissible Concentrations and Approximately Permissible Levels of Harmful Substances Effects in Water of Water Bodies of Fishery Value (State Committee of the Russian Federation for Fishery, 1999).

2. List of Maximum Permissible Concentrations and Approximately Permissible Concentrations of Chemical Compounds in Soil (Ministry of Health of the USSR, 1993).

3. Neue Niederlandische Liste. Altlasten Spektrum 3/95. Rules for Building SP 11-102-97, Annex B (State Committee of the Russian Federation for Building, 1997).

4. Maximum Permissible Concentrations of Pesticides in Foods and Methods of their Analysis (Ministry of Health of the USSR, 1989).

5. Drinking Water. Hygienic Guidelines for Water Quality in Centralized Water Supply Systems. Quality Control (State Committee of the Russian Federation for Sanitary Epidemioilogical Control, 1996).

6. Provisional Method of Isomer-specific Estimation of Polychlorinated Dibenzo-n-dioxins in Water (Ministry of Health of the USSR, 1991).

7. Hygienic Limits of Pesticide Contamination of Environmental Objects (Ministry of Health, 2003).

8. Hygienic Requirements for Safety and Nutrition Value of Foodstuffs (Ministry of Health, 2001).

9. Toxic Substances and Disease Registry Update (U.S. Department of Human Health and Services, 2003).

Guideline values from these documents relevant to substances and media considered under the project are presented in Tables 3.1–3.7.

Contaminant	MPC, mg/L
Cadmium	0.005
Mercury	0.00001
Lead	0.006
Naphtalene	0.004
HCH	0.00001
DDT	0.00001
PCB	0.00001

Table 3.1. Maximum Permissible Concentrations (MPC) of selected contaminants in water, for water bodies of value to fisheries.

Contaminant	Guideline value, mg/kg dry weight
Lead	32.00
Mercury	2.10
Benzo(a)pyrene	0.02
γ-HCH	0.10
ΣHCH	0.10
Heptachlor	0.05
ΣDDT/DDE/DDD	0.10
HCB	0.03

Table 3.2. Maximum Permissible Concentrations (MPC) and Approximately Permissible Concentrations (APC) for selected contaminants in soil.

Contaminant	MPC, mg/kg dw	LOC, mg/kg dw
Lead	85.0	530
Cadmium	0.8	12
Mercury	0.3	10
ΣPAHs	1.0	40
ΣDDT/DDE/DDD	0.0025	4

Table 3.3. The Netherlands Maximum Permissible Concentrations (MPC) and Levels of Concern (LOC) for selected contaminants in soil and bottom sediments (as employed in the Russian Federation).

Pesticide	Guideline for soil, mg/kg dw	Guideline for water, mg/L
DDT	0.10	0.100
HCB	0.03	0.001
ΣHCH	0.10	0.020
Heptachlor	0.05	0.001

Table 3.4. Guideline values for pesticide concentrations in soil and water of freshwater bodies.

Food	MPC, mg/kg ww		
	Lead	Cadmium	Mercury
Meat and poultry raw	0.5	0.05	0.03
Internal organs of mammals and birds	0.6	0.3	0.1
Kidneys	1	1	0.2
Animal fat	0.1	0.03	0.03
Predatory freshwater fish raw	1	0.2	0.6
Non predatory freshwater fish raw	1	0.2	0.3
Marine fish raw	1	0.2	0.5
PTWI, μg/kg body weight	25	7	5 (total Hg)

Table 3.5. Maximum Permissible Concentrations (MPC) for heavy metals in food items, and internationally recommended Provisional Tolerable Weekly Intakes (PTWI).

3.2. Human blood and breast milk

In epidemiological studies, biological monitoring, or biomonitoring, is the assessment of exposure of a population to specific toxic substances by means of systematic or periodic measurements of these substances or their metabolites in human specimens, such as blood, urine, or breast milk, etc. Biomonitoring can be used to establish the body burden or internal dose of specific environmental contaminants through all possible routes of exposure. Population-based biomonitoring, in combination with environmental monitoring (e.g., of air, water, food, and soil), is considered to be one of the most valuable tools in providing information on spatial, temporal, ethnic and socio-economic trends in human exposure to contaminants. Biological monitoring is also becoming widely used in studies linking environmental exposure to pollution-related diseases, for general environmental health monitoring programs, and also to explore body burdens of contaminants in populations that may be at increased risk of exposure.

No	Contaminant	Raw food stuffs	Russian food safety limits: Concentration in food, mg/kg	Russian food safety limits: Maximum permissible levels of human exposure, mg/kg/day	MRL* Chronic oral exposure, mg/kg/day	TDI µg/kg body weight
1	Chlordane	-	Not established	Not established	0.0006	0.05
2	Hexachlorocyclohexane	Fish and sea products Meat and poultry	0.1 (sum of α-, β-, γ-isomers) 0.5	0.01; 0.005 for children;	α- 0.0080 β- 0.0006** γ- 0.00001**	0.30 (total)
3	Sum of DDT	Fish and sea products Meat and poultry	0.20 0.02	0.050; 0.025 for children	0.0005	20.00
4	Hexachlorobenzene	Cereals	0.01	0.0006	0.00005	0.27
5	Heptachlor	Not specified	Not allowed		Not established	Not established
6	Toxaphene		Not established		0.00100	0.20
7	PCBs	Fish and marine mammals	2.0		0.00002 (as Arochlor)	1.00 (as Arochlor) 0.30 (as Σ PCB14)
8	Dioxins (measured as 2,3,7,8-TCDD)	Fish and sea food Meat and poultry	11.0 ng/kg ww; 88.0 ng/kg lipids 0.9 ng/kg ww 3.3 ng/kg lipids	Not established	0.000001	0.00001
9	Mirex		Not established	Not established	0.0008	0.07

Table 3.6. Russian national food safety limits and internationally recommended Minimal Risk Levels (MRL) and Tolerable Daily Intake (TDI) values for persistent organic substances. * – (ATSDR, 2004). ** – established only for intermediate (> 14-364 days) exposure duration.

Food items	ΣHCH	ΣDDT/DDE/DDD
Terrestrial animal meat (muscle)	0.1	0.1
Terrestrial animal fat	0.2	1
Meat of marine mammals (walrus, seal)	0.01	0.02
Meat of marine mammals (larga seal, bearded seal)	0.01	0.2
Marine fish	0.2	0.2
Freshwater fish	0.03	0.3
Salted, smoked and marinated fish (as recalculated for wet weight of fish)	0.2	0.4
Fish liver	1	3
Salted herring	0.2	2

Table 3.7. Maximum Permissible Concentrations (MPC) for HCH and DDTs in various species, tissues, and processed foodstuffs.

Currently, levels of individual human exposure to the most important PTS that occur in the Arctic environment are assessed by measuring their concentrations (or those of their metabolites) in blood. The development of adequate analytical instrumentation and protocols, as well as the adoption of effective quality control procedures, makes possible reliable measurement of compounds and their metabolites at very low concentrations.

In spite of numerous advances in techniques, there are still some major challenges in the field of biological monitoring. A number of difficulties have been encountered in determination of specific health effects due to contaminant exposure in humans and their indicators, which are crucial components of the risk assessment process. Production of reliable risk assessments by means of biological monitoring alone is, for certain groups of persistent toxic substances, such as pesticides, still beyond current capabilities. This is due to a lack of detailed knowledge on how to interpret observed concentrations of the substances or their metabolites in various human body fluids and tissues, in particular in the typical situation of integrated exposure to a mixture of different chemicals in combination with other relevant (stress) factors that can influence health.

The best opportunity for the developing a reliable health risk assessment process is afforded by those biological criteria which are based on ‘limit values’ derived from well-designed epidemiological studies and supported by relevant laboratory experiments. Limit values such as those issued by the following organizations:

- *Deutsche Forschungsgemeinschaft (biological tolerance values for occupational exposure);*
- *Human Biomonitoring Commission in Germany (human biomonitoring values; HBM-1 and HBM-2);*
- *US American Conference of Governmental Industrial Hygienists (ACGIH) (biological exposure indices (BEI)); and*
- *Health Canada (Medical Service Branch – Biological Guidelines)*

help to interpret the analytical results of biological monitoring.

Limit values relating to human media, for contaminants under consideration in the project, are summarized in Table 3.8. At present, the number of such values for PTS in blood and breast milk is still very limited.

With respect to Table 3.8, it is important to note that the Health Canada Guidelines for PCBs are expressed in terms of ‘Arochlor 1254’ concentrations, and as such do not adequately reflect risks from contamination by the whole range of substances within the PCB group. Following discussion within the AMAP Human Health Assessment Group, it was therefore recommended that the Health Canada Guidelines should be employed only for the purpose of general comparisons of exposure levels and potential risks.

Contaminant	Matrix	Level of Concern (declarable)	Action Level	Ref
Lead	Whole blood	0.48 µmol/L; 100 µg/L for children ≤12 years and female <45	0.96 µmol/L 150 µg/L	[1] [4]
		150 µg/L (men and women >45)	250 µg/L	[4]
Cadmium	Whole blood	5.0 nmol/L	44.5 nmol/L 5 µg/L	[1] [3]
Mercury	Whole blood	75 nmol/L	100 nmol/L for children and women <40; 500 nmol/L for all men, and women >40	[1]
		5 µg/L	15 µg/L	[4]
Selenium	Plasma	Over 2.0 µmol/L	Over 3.0 µmol/L (children)	[1]
ΣDDT	Plasma	-	200 µg/L	[2]
PCBs (as Arochlor 1254)	Plasma	5 µg/L for children and women <40; 20 µg/L for all men, and women >40	100 µg/L	[1]
	Breast milk	-	50 µg/L (1.43 mg/kg lipids)	[1]

Table 3.8. Levels of Concern (LOC), and Action Levels and Limits for selected PTS in human blood and breast milk.
[1] Health Canada, 1997 – Guidelines adopted based on (CACAR, 1997)
[2] WHO, 1989c.
[3] ACGIH, 2004.
[4] German Human Biomonitoring Commission, 1996.

In cases where biological threshold values have not yet been established, judgments regarding guideline levels of a chemical or its metabolites in biological samples can, in many instances, be facilitated by comparison to suggested reference values (RVs). These describe an (acceptable) exposure situation for a given group of the general population to a contaminant. It should be explicitly pointed out that such reference values are strictly statistically-derived values, and are of no health relevance per se. However, RVs are often the only available means by which to assess integrated human exposure to environmental contaminants entering the body through several pathways, when relevant biological limits have not yet been established.

Table 3.9. Reference values for some persistent organic pollutants in whole blood (µg/L) of children aged 9 to 11 years living in Germany.

Contaminant	Reference Value (whole blood, µg/L)
PCB 138	0.3
PCB 153	0.4
PCB 180	0.3
ΣPCB 138, 153, 180	0.9
β -HCH	0.3
HCB	0.3
Total DDT	0.7

One of the most recently updated lists of reference values for environmental toxicants, based on a series of measurements of blood and breast milk concentrations of POPs in large populations, has been produced by the German Human Biomonitoring Commission (German Human Biomonitoring Commission, 2003); Tables 3.9-3.11.

Age (years)	PCB 138	PCB 135	PCB 180	PCB (138+ 153+180)	HCH	HCB	DDE West Germany	DDE East Germany
18-19	0.4	0.6	0.3	1.1	0.3	0.4	1.5	3
10-29	0.6	0.9	0.6	2.0		0.5	2	5
30-39	0.9	1.6	1.0	3.2		1.0	4	11
40-49	1.4	2.2	1.6	5.1		2.5	7	18
50-59	1.7	2.8	2.1	6.4	0.5	3.3	8	31
60-69	2.2	3.3	2.4	7.8	0.9	5.8	11	31

Table 3.10. Reference values for some persistent organic pollutants in whole blood (µg/L) of adults aged 18 to 69 years living in Germany.

Taking into account the need to ensure harmonized study protocols, another excellent opportunity for comparison of biomonitoring data is provided by the results of comprehensive national and international (e.g. circumpolar) human health monitoring programmes, such as those summarized and assessed by AMAP (AMAP 1998; 2002, 2003a).

It should be noted that there are no existing Russian biological exposure indices (BEI) of any type. BEI for lead and some other metals have recently been proposed and tentatively approved by the Sub-committee on Sanitary and Hygienic Regulations, of the Ministry of Health. However, they have not been formally endorsed, due to the adoption by the State Duma, in 2003, of new legislation on technical regulation. According to this legislation, the the Ministy of Health has no longer power to endorce any regulatory document. In general, reorganisation of Russian governmental structures have led to changes in the process of development, endorsement and enforcement of regulative documents.

As shown in the forthcoming chapters, a lack of formally adopted values of the levels of concern, threshold values, and other indicators of health effects of contaminants creates significant difficulties for human health authorities and practical medical personnel in assessment of PTS effects in general, and on indigenous population in particular. However, this lack should not block adoption of practical measures on reduction of human health risk due to PTS intake. In this case, application of the precautionary principle can be recommended.

Contaminant	Reference Value (breast milk, mg/kg lipid)
PCB 138	0.3
PCB 153	0.3
PCB 180	0.2
ΣPCB 138,153, 180	0.8
Total PCB	1.2
β-HCH	0.1
HCB	0.3
Total DDT	0.9

Table 3.11. Reference values for some polychlorinated biphenyls (PCBs) and organochlorine pesticides in breast milk, mg/kg lipid.

Chapter 4

Persistant toxic substances (PTS) sources and pathways

4.1. Introduction

In general, the human environment is a combination of the physical, chemical, biological, social and cultural factors that affect human health. It should be recognized that exposure of humans to PTS can, to certain extent, be dependant on each of these factors. The precise role differs depending on the contaminant concerned, however, with respect to human intake, the chain consisting of 'source – pathway – biological availability' applies to all contaminants. Leaving aside the biological aspect of the problem, this chapter focuses on PTS sources, and their physical transport pathways.

Contaminant sources can be provisionally separated into three categories:

- **Distant sources:** Located far from receptor sites in the Arctic. Contaminants can reach receptor areas via air currents, riverine flow, and ocean currents. During their transport, contaminants are affected by the combined effects of physical and chemical factors. Persistence in the environment is, therefore, one of the most important characteristic in determining the ability of contaminants to reach the Arctic. In this respect, PTS, due to their low degradation rates, are often considered to be 'global contaminants' subject to long-range transportation.

- **Local sources:** These are located in receptor region, often in the vicinity of indigenous communities. Although transport of contaminants from local sources to recipients is determined by the same physical and chemical processes as contaminants from distant sources, there are a wider range of pathways and mechanisms that may be involved in the case of local sources. For example, mechanisms of soil contamination from local sources can differ significantly, such that effects of local contamination can be much greater than those resulting from contamination from distant sources. In contrast to distant sources, local sources can also affect recipients through contamination by more readily degradable substances as well as the persistent contaminants. Although non-persistent contaminants are beyond the scope of this project, it is important to note that the effects of PTS, when combined with those of other types of contaminants originating from local sources, may be substantially increased. Similarly, humans exposed to and affected by PTS may be more sensitive to the acute toxic effects of other less persistent contaminants from local sources.

- **Contact sources:** These comprise the intentional or unintentional use of chemicals by recipients in everyday household and occupational uses. For example, the health of individuals using PTS-containing insecticides for pest control or for the treatment of reindeer may be directly affected by the products. A typical example of an unintentional contact contaminant source would be the use of paints and insulating materials containing PTS in the indoor environment.

4.2. Assessment of distant sources: Long-range atmospheric transport

Due to the nature of atmospheric circulation, emission sources located within the Northern Hemisphere, particularly those in Europe and Asia, play a dominant role in the contamination of the Arctic. Given the spatial distribution of PTS emission sources, and their potential for 'global' transport, evaluation of long-range atmospheric transport of PTS to the Arctic region necessarily involves modeling on the hemispheric/global scale using a multi-compartment approach. To meet these requirements, appropriate modeling tools have been developed.

Extensive efforts were made in the collection and preparation of input data for modeling. This included the required meteorological and geophysical information, and data on the physical and chemical properties of both the selected substances and of their emissions. It should be noted that reliable and relatively comprehensive information on emission sources is currently not available for most PTS. Therefore, an assessment of long-range atmospheric transport was undertaken for substances for which emission source information is sufficient to meet modeling requirements, namely, mercury (Hg), polychlorinated biphenyls (PCBs) and γ-hexachlorocyclohexane (γ-HCH). It was considered that modeling results obtained for these contaminants could be extrapolated to give a general overview on the situation with respect to long-range atmospheric transport of other PTS in the study.

An assessment of mercury, PCB and γ-HCH pollution arising from emission sources in the Northern Hemisphere and affecting regions of the Russian North inhabited by indigenous peoples, was carried out for the reference year 1996. This assessment included an evaluation of air concentrations and deposition levels, as well as source-receptor relationships for selected regions and for the Arctic as a whole. Particular attention was given to the fate of contaminants in different environmental compartments (air, soil, water, etc.). The effect of PCBs and γ-HCH transport via ocean currents, ice cover dynamics, and 'Mercury Depletion Event' (MDE) (Schroeder *et al.*, 1998) chemistry on Arctic pollution were also examined.

4.2.1. Climate conditions and atmospheric circulation patterns

The climate of the Russian Arctic is characterized by a lack of solar radiation during the winter, which leads to very low temperatures. In contrast, solar radiation flux in the summer is significant, but temperatures are still not high, as most incoming solar energy is utilized in the melting of ice and snow. Atmospheric circulation is characterized by cyclonic activity in all seasons, which promotes the exchange of air masses between the middle and high latitudes. As a result of the prevailing westerly airflows, the Russian Arctic experiences the moderating influence of the Atlantic (North Atlantic Current). This influence is stronger in western parts than in central and eastern parts. The western Russian Arctic is therefore warmer, with a much lower temperature variation between winter and summer than that found in the eastern part of the Russian North, which is characterized by the more severe climatic conditions.

Atmospheric circulation in the Arctic region differs between winter and summer (Figure 4.1) with the prevailing atmospheric currents in the lower Arctic troposphere depending upon the location of quasi-stationary pressure systems in the Northern Hemisphere, the Icelandic and Aleutian Lows, and Siberian and North American Highs.

In winter, due to the geographical position of these systems, air masses move into the Arctic from Europe in a northeasterly direction, or from central Asia and Siberia. Western regions of the Russian North – Murmansk Oblast and the Nenets Autonomous Okrug (AO) – are affected mainly by southwesterly or westerly airflows, bringing air masses from Eastern and Central Europe, as well as from central Russia. In the central regions – Yamalo-Nenets AO, Taymir AO, and the Republic of Sakha (Yakutia) – southerly airflows prevail, transporting air masses from central Russia, the Urals, the south of Siberia and central and eastern Asia. Over the easternmost region – the Chukchi AO – northerly airflows predominate in winter.

In summer, the continental high-pressure systems disappear and oceanic low-pressure systems weaken. Over the Arctic Ocean, high-pressure systems occur more frequently than in winter, causing an outflow of Arctic air in the meridional direction. The European region comes under the impact of the Azores anticyclone. Over central Eurasia and the central part of North America, low-pressure systems dominate. The influx of air masses to the Arctic mainly occurs over the Aleutian Islands/Bering Sea region in the east, and from the North Atlantic, along the north-western periphery of Azores anticyclone, in the west. Compared with winter, the northerly component is more frequent in atmospheric transport in summer across all regions of the Russian Arctic except for Chukotka. Chukotka, during the summer, is predominantly affected by transport either from the Pacific Ocean, or from Eastern Asia and the Russian Far East, some transport from the north still occurs however.

Atmospheric circulation is also responsible for the precipitation pattern in the Russian Arctic. The most abundant annual precipitation takes place in the western part and can reach 500-600 mm/y. Annual precipitation decreases from the west towards the east, and over the north of the Republic of Sakha (Yakutia) is mainly within the range of 100-150 mm/y. In the easternmost part of the Russian Arctic, precipitation is relatively high (300-600 mm/y), and caused by the southerly transport of air masses from the Pacific Ocean, especially during summer.

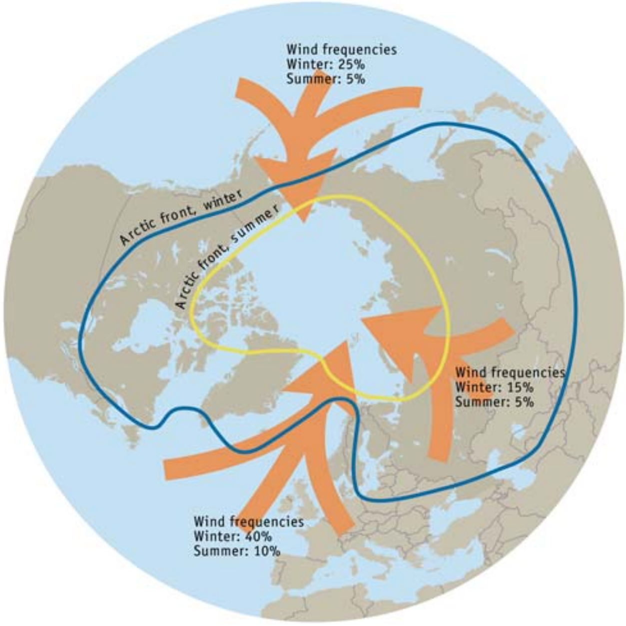


Figure 4.1. Mean position of the Arctic air mass in January and July, and the winter and summer frequencies of winds (AMAP, 1997).

4.2.2. Emission sources

Emission sources of Hg, PCBs and γ-HCH were divided into several groups according to their geographical location (Figure 4.2). The key criterion used for the selection of a specific region as an aggregate emission source was the possible influence of emissions from this region on the Russian North.

Figure 4.2. Source regions of the Northern Hemisphere considered in the source-receptor analysis.

The number of the selected regions varies for different pollutants. For simplicity, generalized names were used for some regions, e.g., the region identified as ‘Central Asia’ actually includes central, western, and southern Asia. Selected emission sources regions for the pollutants under consideration are presented in Table 4.1. Source region boundaries also vary depending upon the contaminant in question. For example, China and Japan are considered as separate sources for mercury, but included in larger Asian source regions for the other contaminants. For γ-HCH, China and India are important enough sources to consider their emissions separately, whereas Northern Europe was omitted as γ-HCH emissions in this region in 1996 were insignificant. The Americas (North and Central) are included as a single source region, due to their greater distance from the Russian North.

Hg	PCBs	γ-HCH
1. Russia	1. Russia	1. Russia
2. Northern Europe	2. Northwestern Europe	2. Western Europe
3. Western Europe	3. Southeastern Europe	3. Eastern Europe
4. Eastern Europe	4. Americas	4. Southern Europe
5. Southern Europe	5. Southeastern Asia (including China and Japan)	5. Americas
6. Americas	6. Central Asia (including India) and Africa	6. China
7. Central Asia (including India)		7. India
8. China		8. Asia (Central and South-eastern Asia)
9. Japan		9. Africa
10. Southeastern Asia		
11. Africa		

Table 4.1. Regions of the Northern Hemisphere selected as source areas for long-range transported pollutants.

Due to their proximity to the Russian North and the significant polluting influence of some regions of the Russian Federation, the territory of Russia was subdivided into twelve source regions according to current administrative boundaries and to their potential impact on Arctic ecosystems. The Location of these regions and abbreviated identification codes is shown in Figure 4.3. The first five regions (MUR, NEN, YNT, YAK, and CHU) are also considered as the receptor regions.

MUR – Murmansk Oblast;	**NWK** – North-Western region and Kaliningrad Oblast;
NEN – The Nenets AO;	**CVV** – Central and Volgo-Viatsky regions;
YNT – The Yamalo-Nenets AO and Taymir AO;	**CVN** – Central-Chernozem, Volga and Northern Caucasus regions;
YAK – The Republic of Sakha (Yakutia);	**URL** – Ural region;
CHU – The Chukchi AO;	**WSB** – West Siberian region;
NRT – Northern region;	**ESB** – East Siberian and Far-Eastern regions.

Figure 4.3. Aggregated regions of the Russian Federation chosen for source-receptor analysis. The first five regions listed (MUR, NEN, YNT, YAK, and CHU) are considered as both source and receptor regions, the rest are considered as source regions.

Mercury

The industrial and urbanized regions of the world account for the majority of anthropogenic mercury emissions to the atmosphere. To evaluate the anthropogenic input of mercury to the Northern Hemisphere, the most recently available global emission inventory, that for 1995, (Pacyna and Pacyna, 2002) was used. The original global emissions dataset has a resolution of 1°x1° lat./long., with mercury emissions speciated into three chemical forms: gaseous elemental mercury (Hg^0), gaseous oxidized mercury (Hg^{2+}), and particulate mercury (Hg_{part}). These emission data were redistributed to a lower resolution (2.5°x2.5°), suitable for input to the air transport model employed, assuming uniform distribution over each grid cell.

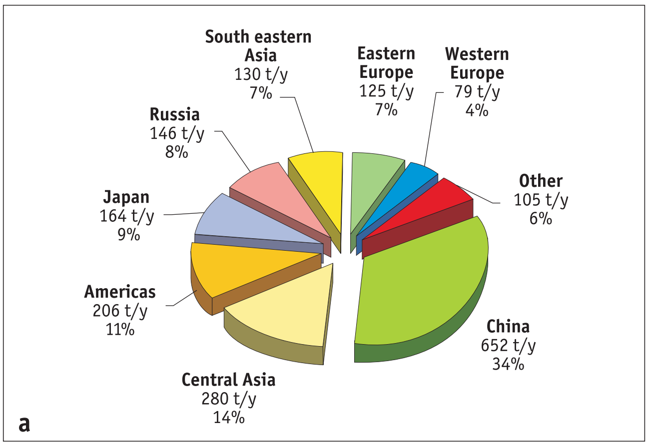
The most significant emission sources are in Eastern Asia, Europe and the eastern part of North America. Considerable emissions also occur in the Indian subcontinent and the Arabian Peninsula. The total amount of anthropogenic mercury emissions in 1995 from the Northern Hemisphere was estimated as 1887 tonnes.

In order to assess the impact of different mercury emission sources on the contamination of the Russian North, the entire hemispheric emission field was divided into 11 regions: Russia, China, Central Asia, the Americas, Japan, Southeast Asia, Africa, Eastern Europe, Western Europe, Southern Europe, and Northern Europe. The relative contribution of each region to total mercury emissions in the Northern Hemisphere is presented in Figure 4.4(a).

This diagram shows that more than one third (34%) of the total mercury emissions originate in China. Considerable emissions also originate in Central Asia (14%), the Americas (11%), Japan (9%), and Russia (8%). The contribution of other regions specified does not exceed 7%.

Figure 4.4(b) shows total mercury emissions from different regions of the Russian Federation. The most significant emission sources are located in the Central-Chernozem, Volga, and North-Caucasian regions (CVN), the Ural region (URL), and the Central and Volgo-Viatsky regions (CVV).

Mercury emissions from natural sources contribute a significant proportion of the total mercury input to the atmosphere. Estimates for the value of natural emissions and re-emissions were based on a literature survey. Mercury emissions from natural sources were apportioned over the Northern Hemisphere on the basis of the nature of the underlying land/sea surface. Five surface categories were distinguished: ice covered land (glaciers, etc), seawater, soil developed from geochemical mercury belts, soils in areas of mercury deposits, and other (background) soils. It was assumed that there is zero mercury emission from ice caps/gla-



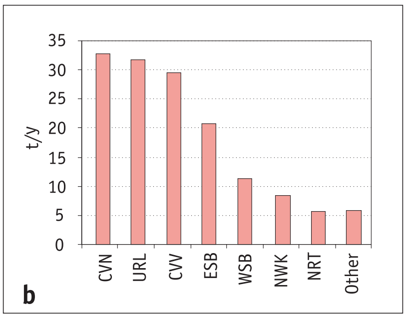


Figure 4.4.
(a) Contribution of different regions of the Northern Hemisphere to total anthropogenic mercury emissions, (b) total anthropogenic mercury emissions from different regions of the Russian Federation.

ciers. Natural emissions from seawater were distributed proportionally to the ocean's primary production of carbon. Emissions from soil are most significant from soils occurring over mercury deposits and lowest for background soils. In addition, the temperature dependence of emission fluxes was also calculated, based on data obtained through measurements.

PCBs

Modeling long-range transport of individual PCB congeners to the Russian North was made using a global emission inventory concerning 22 individual PCB congeners covering the period 1930-2000 (Breivik *et al.*, 2002b). This inventory is based on estimates of the global production and consumption of these PCBs in 114 countries (Breivik *et al.*, 2002a). The emissions were distributed to the (2.5° x 2.5° lat./long.) model grid using (as a proxy for emission distribution) a 1990 population distribution data set obtained from the CGEIC website (http://www.ortech.ca/cgeic).

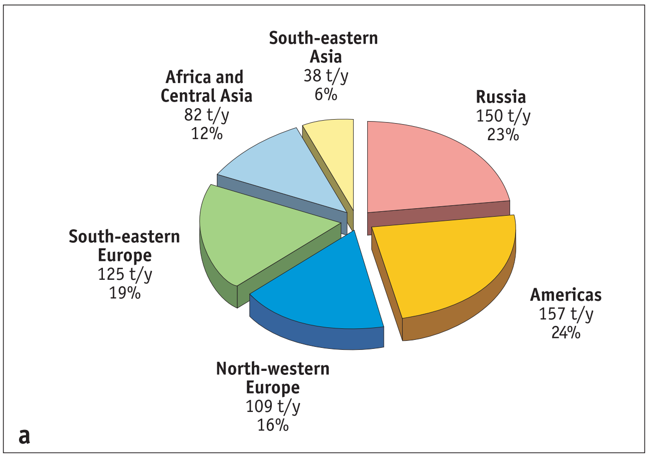
The total global production of PCBs from 1930-1993 amounted to approximately 1.3 million tonnes. Almost 97% of intentionally produced PCBs were used in the Northern Hemisphere. Emission data for individual congeners for 1996 were used in all model calculations and, according to the high emission scenario discussed by Breivik *et al.* (2002b), total emissions of the 22 PCB congeners in the Northern Hemisphere in 1996 amounted to about 662 tonnes. Total emissions of PCB-28, -118, -153, and -180 from the Northern Hemisphere in 1996 were about 80, 23, 16, and 4.5 tonnes, respectively. Congener composition of PCB emissions varies between source regions.

In order to study the contributions of different source regions in the Northern Hemisphere to the contamination of the receptor-regions in the Russian Arctic, six main regional sources were identified, based on the emission distribution: Russia, Northwest Europe, Southeast Europe, the Americas, Southeast Asia, and Central Asia and Africa.

The major emission sources of PCBs in the Northern Hemisphere in 1996 were the Americas (24%), Russia (23%), Southeast Europe (19%), and Northwest Europe (16%) (Figure 4.5(a)). The main Russian emission sources are located in Central-Chernozem, Volga and North-Caucasus regions (CVN) as well as in Central and Volgo-Viatsky regions (CVV) (Figure 4.5(b)).

γ-HCH

The scenario for γ-HCH emissions in the Northern Hemisphere was based on official data submitted to the UN ECE Secretariat in 2002 (Vestreng and Klein, 2000) and available expert estimates (Pacyna *et al.*, 1999). In addition, γ-HCH emissions for 1990-1996 from the Russian Federation, and some other countries in the Northern Hemisphere were estimated from information in a range of literature sources (Revich *et al.*, 1999, Year-books, 1992, 1993 1999,



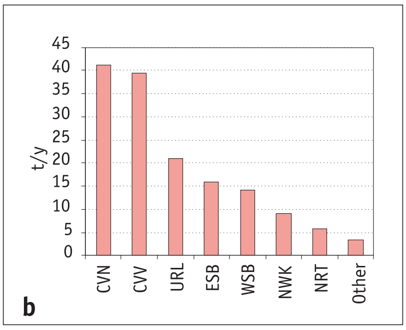
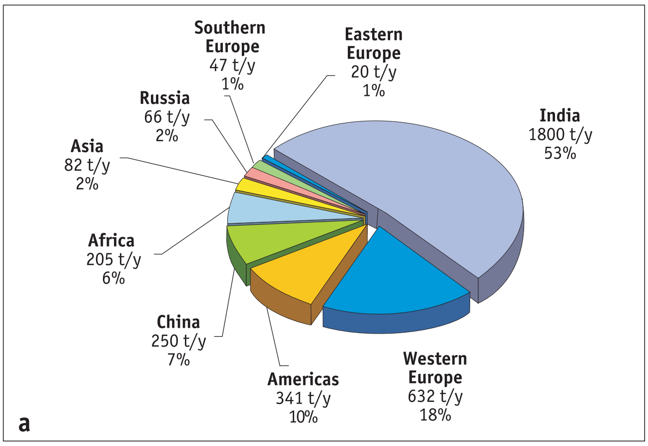


Figure 4.5.
(a) Contribution of different regions to PCB emissions (22 congeners) in the Northern Hemisphere for 1996, (b) PCB emissions (22 congeners) from different regions of the Russian Federation in 1996.



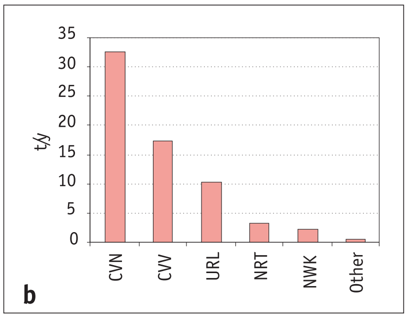


Figure 4.6.
(a) Contribution of different regions to γ-HCH emission in the Northern Hemisphere for 1996, (b) γ-HCH emissions from different regions of the Russian Federation in 1996.

Ananieva *et al.*, 1990, Li *et al.*, 1996, 1998,1999, and Macdonald *et al.*, 2000) regarding the use of this insecticide. To estimate emissions from data on insecticide use, the emission factor for lindane in agricultural use (0.5) (Guidebook, 1999) was applied. The resulting estimate for total γ-HCH emissions from the Northern Hemisphere in 1996 was about 3445 tonnes. The spatial distribution of these γ-HCH emissions in the Northern Hemisphere, for modeling purposes, was made using crop area as a surrogate parameter (Pacyna *et al.*, 1999).

To model long-range atmospheric transport of γ-HCH to the Russian North, nine source regions were identified in the Northern Hemisphere: Russia, Western Europe, Eastern Europe, Southern Europe, the Americas, China, India, the rest of Asia, and Africa. China and India were considered as individual source regions due to their high use of this insecticide compared to the rest of Asia. Estimates of the contribution of main source regions to total γ-HCH emissions in the Northern Hemisphere in 1996, based on the selected emission scenario, is shown in Figure 4.6(a). γ-HCH emissions from Russian regions in 1996 are shown in Figure 4.6(b).

The main contribution to γ-HCH emissions in the Northern Hemisphere, was made by India (53%) and Western Europe (18%). The contribution from Russia is only 2%. Major Russian γ-HCH emissions in 1996 originated from the European part of the Russian Federation. The highest Russian γ-HCH contributions were made by sources located in the Central-Chernozem, Volga and North-Caucasian regions (CVN).

4.2.3. Contamination levels in the Arctic resulting from long-range atmospheric transport

To evaluate levels of contamination of the Arctic region by global pollutants (mercury, PCBs, and γ-HCH) resulting from long-range atmospheric transport, a hemispheric modeling approach was employed. For this purpose, the EMEP Meteorological Synthesizing Centre-East (MSC-E) have developed hemispheric multi-compartment transport models 'MSCE-Hg-Hem' and 'MSCE-POP'.

Mercury, PCB and γ-HCH concentrations in air and their deposition loads as evaluated for the Northern Hemisphere and the Arctic for 1996, are discussed below in the relevant subsections. Particular attention has been given to atmospheric long-range transport to, and deposition of these pollutants in the Russian Arctic. For mercury, the effect of Mercury Depletion Event (MDE) chemistry on Arctic deposition was considered. In addition, for the assessment of environmental pollution by PCBs and γ-HCH, the role of transport via sea currents and ice cover dynamics were taken into account. The marine environment is particularly important in relation to the transport and fate of γ-HCH. Characteristic values of mean annual air concentrations and deposition fluxes of mercury, PCBs and γ-HCH over the Arctic area are summarized in Table 4.2. The consistency of the modeling results was verified by comparison with available measurements.

Pollutant	Air concentrations, ng/m^3			Deposition flux, g/km^2/y			Total deposition, t/y
	Min	Max	Average	Min	Max	Average	
Hg	1.11	1.76	1.47	1.6	29.9	7.2	240
PCB-28	0.0003	0.0186	0.0014	0.002	0.320	0.021	2.7
PCB-118	0.0002	0.0057	0.0006	0.003	0.377	0.026	1.1
PCB-153	0.0002	0.0041	0.0008	0.007	0.367	0.043	1.15
PCB-180	0.0001	0.0012	0.0003	0.004	0.204	0.025	0.5
γ-HCH	0.009	0.113	0.023	0.159	3.140	0.671	78

Table 4.2. Characteristic values of mean annual air concentrations and annual deposition fluxes for mercury, selected PCBs, and μ-HCH over the Arctic in 1996.

Mercury

Figure 4.7 shows the annual deposition flux of mercury in the Northern Hemisphere. Highest deposition levels are in those regions with considerable emissions: i.e. Southeast Asia, Europe, and the eastern part of North America. For other areas, the deposition pattern, to some extent, corresponds to annual precipitation values, since wet deposition plays a dominant role in removing mercury from the atmosphere. From the model results, total deposition over the Arctic region in 1996 amounted to 240 tonnes. The influence of MDEs on deposition fluxes within the Arctic region has been the subject of considerable research in recent years. The postulated MDE mechanism (Lindberg *et al.*, 2002) includes complicated chemistry, involving the formation of halogen related radicals. The development of a detailed model component for MDE chemistry is the subject of a separate study. For the purposes of this study, an attempt was made to qualitatively estimate the effect of MDE on Arctic Hg contamination by using a simplified set of parameters.

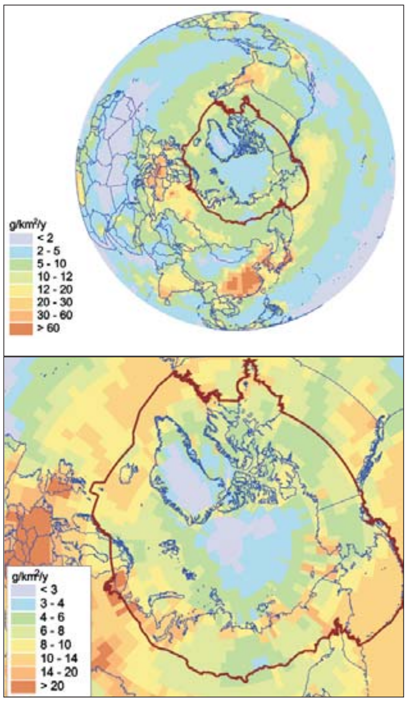
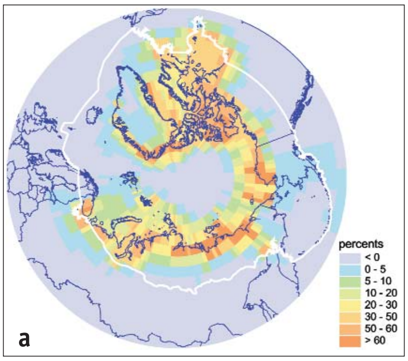


Figure 4.7. Annual deposition of total mercury in the Northern Hemisphere. The enlarged panel shows elevated mercury deposition over the Arctic coast due to MDEs.

As illustrated in the enlarged panel in Figure 4.7, even short-term phenomena such as MDEs, which occur during only a few weeks of the year, can considerably increase the annual deposition of mercury in some regions of the Arctic, in particular coastal areas. The influence of MDEs on total annual mercury deposition is illustrated in Figure 4.8(a). Additional contributions of mercury as a result of MDEs can amount to more than 50 percent of total deposition values in areas adjacent to Arctic coasts (i.e. within about 300 km of the coast inland and offshore). These areas include the Queen Elizabeth Islands, Hudson Bay, the White Sea, the Gulf of the Ob river, and the Laptev Sea coast, among others. Negative values (for percentage increase in deposition due to MDEs) show that increased deposition fluxes due to MDEs in some regions, lead to decreased fluxes in other areas. A part of the mercury transported by the air therefore does not enter the High Arctic during springtime, due to it being scavenged during MDEs over coastal and contiguous regions.

Figure 4.8(b) shows the seasonal variation in total mercury deposition in the Arctic. The model predicts that the most pronounced MDE effect is in May and June (taking into account a temporal shift due to the model parameters used), when monthly deposition in the Arctic increased two-fold or greater. The calculations predict that MDE are responsible for deposition of about 50 tonnes of mercury per year in the Arctic – about 20% of the total annual deposition.

Due to the high transport potential of mercury in the atmosphere, many anthropogenic and natural sources from different regions of the Northern Hemisphere contribute to Arctic pollution. The contribution from



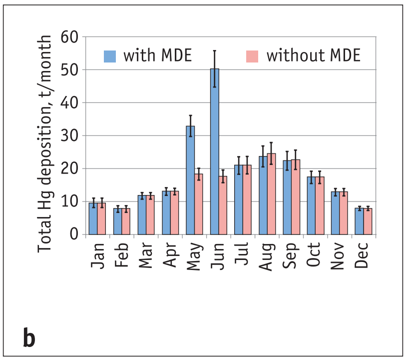
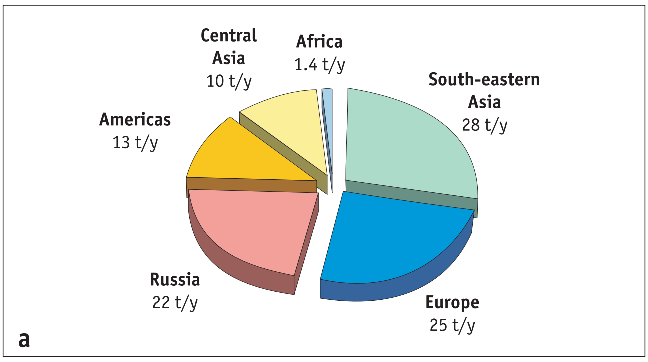


Figure 4.8. (a) Influence of MDEs on total annual mercury deposition in the Arctic (area defined by the white (AMAP area) boundary), and (b) seasonal variation in total mercury deposition to the Arctic with and without MDEs. The figures present the difference between two model computational runs – one with and one without MDEs included.



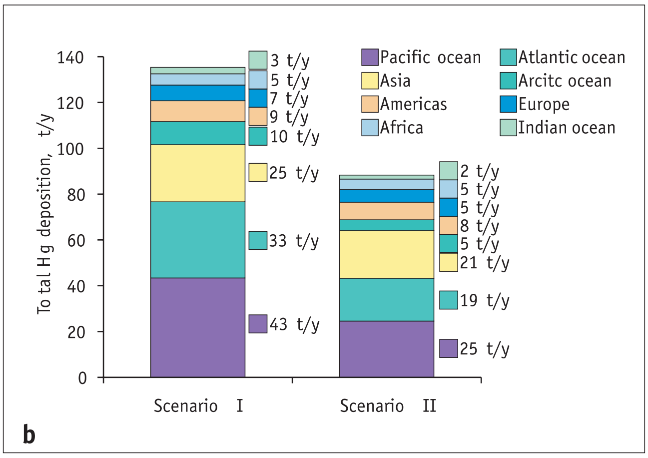


Figure 4.9. Contribution of different source regions to the annual deposition of mercury in the Arctic arising from (a) anthropogenic sources and (b) natural sources and re-emissions.

the various regions of the Northern Hemisphere to total annual mercury deposition in the Arctic from anthropogenic and from natural sources is shown in Figures 4.9(a) and 4.9(b), respectively for the upper (Scenario I) and lower (Scenario II) limits of emission estimates.

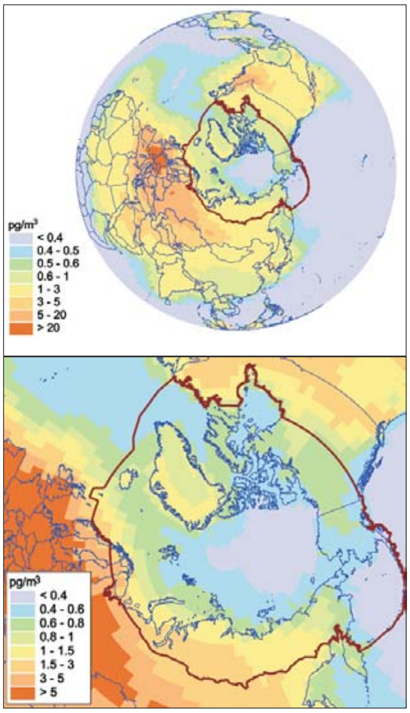


Figure 4.10.
Mean annual air concentrations of PCB-153 over the Northern Hemisphere. The enlarged panel shows the air concentration pattern over the Arctic region.

The most significant contribution to anthropogenic mercury deposition in the Arctic come from sources located in Southeast Asia, Europe and Russia. The most significant contributions to the natural component of annual deposition in the Arctic are from the Pacific and Atlantic Oceans, and from Asia. Bearing in mind that there is still

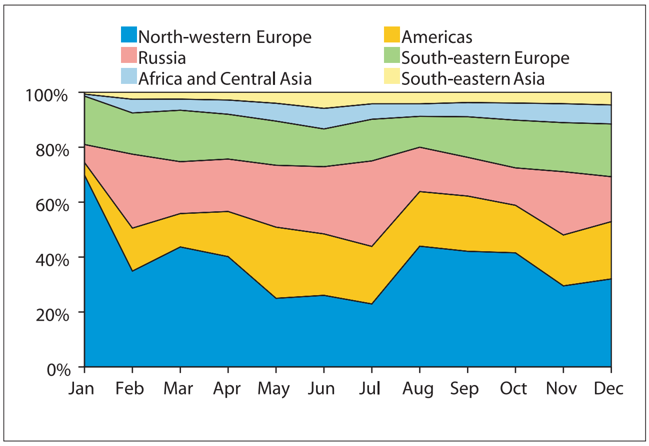


Figure 4.11.
Seasonal variation in the relative contributions of different source regions to PCB-153 deposition in the Arctic.

considerable uncertainty regarding the input parameters used for the modeling of natural emission and re-emission processes, and that natural emissions cannot be controlled by political decisions, attention should be focused on deposition from anthropogenic sources.

PCBs

Levels of PCB contamination are exemplified by PCB-153. Figure 4.10 shows that areas with the highest air concentrations of PCB-153 are located close to European and North American source regions. Air concentrations range from 5 to 20 pg/m³ in contaminated areas of North America, and can exceed 20 pg/m³ in Europe. European sources make the largest contribution to the contamination of the Arctic region. The mean annual air concentration of PCB-153 over the Arctic ranges from 0.2 to 4 pg/m³.

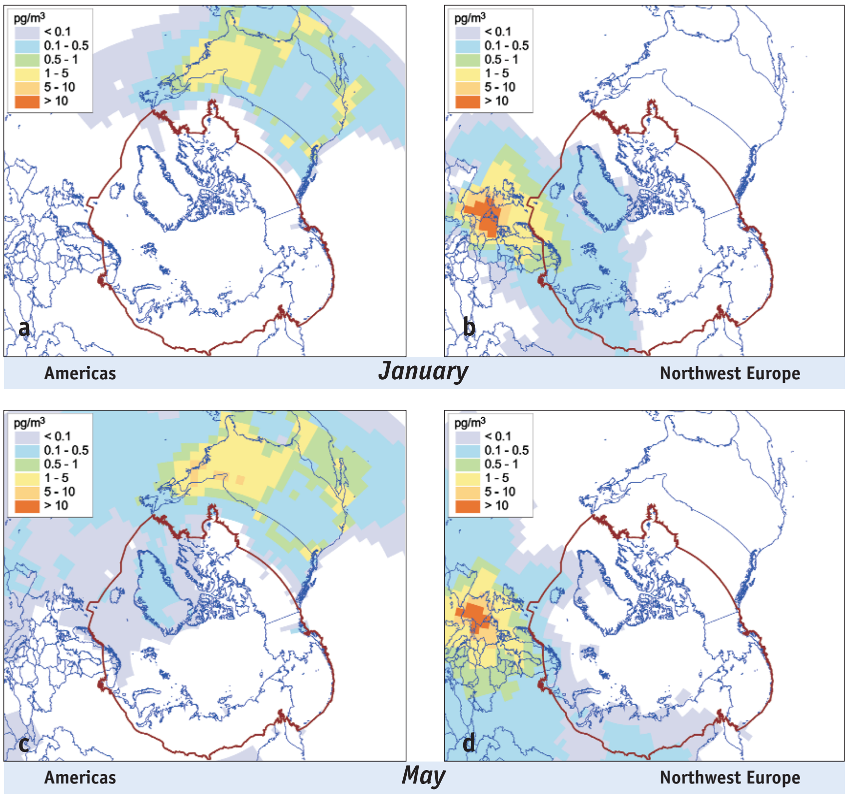


Figure 4.12.
Air concentrations of PCB-153 emitted in January and May from sources in the Americas and Northwest Europe. respectively, from modelling results for 1996.

The relative contributions made by different source regions to PCB-153 deposition in the Arctic are subject to seasonal variations, as shown in Figure 4.11. The contribution from sources in Northwest Europe is the most variable, varying from about 70% in January, to about 25% in May. The amount contributed by the Americas is only about 5% in January, but in May it amounts to 26%, and is comparable with the contribution from sources in Northwest Europe.

These noticeable variations are explained by the peculiarities of atmospheric circulation in the Arctic during various seasons, and also by seasonal variations in temperature, precipitation, and degradation rates. Seasonal variation of emissions are not taken into account in this assessment. To illustrate pathways of atmospheric transport, simulation results of PCB-153 transport from two source regions (the Americas and Northwest Europe) for 1996 were examined. Figures. 4.12 show air concentrations of PCB-153 emitted in the Americas and Northwestern Europe in January. The air concentrations of PCB-153 originating from the same sources in May are given in Figures. 4.12.
Figure 4.13 shows the contribution of different source regions to PCB-153 deposition in the Arctic. The major contribution is from sources in Northwest Europe (about 40%). Other significant contributors are Russia (19%), the Americas (17%) and Southeast Europe (16%). For PCB-28 and PCB-118, Northwest Europe and Russia are the main contributors. However, for PCB-180, main contributors are Northwest Europe and the Americas.

The total amount of PCB-153 deposited in the Arctic region from emissions in 1996 was estimated at 527 kg. The contribution from re-emission of PCB-153 accumulated in the environment in the period preceding 1996 equals 629 kg. Therefore, the estimated total PCB-153 deposition to the Arctic in 1996 was 1.15 tonnes.

On the basis of the transport simulations for the four congeners (PCB-28, -118, -153, and -180), and taking into account the fractions of these congeners in the typical PCB mixture in air, a rough estimate of total PCB deposition in the Arctic in 1996 of approximately 40 tonnes was made.

γ-HCH
Figure 4.14 represents the spatial distribution of γ-HCH concentrations in the air over the Northern Hemisphere and the Arctic. High concentrations (up to 5 ng/m^3 or more) are mainly characteristic of regions with high emissions. However, in spite of the fact that there are no significant sources in the Arctic region, relatively high concentrations (from 0.01 to 0.11 ng/m^3) are also observed there. These concentrations result from long-range transport of γ-HCH from remote sources, mainly in Western Europe, India, and the Americas.

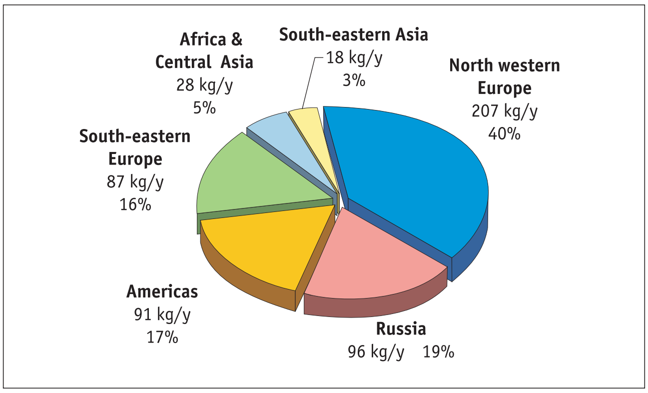


Figure 4.13. Contributions of different source regions to PCB-153 deposition in the Arctic region in 1996.

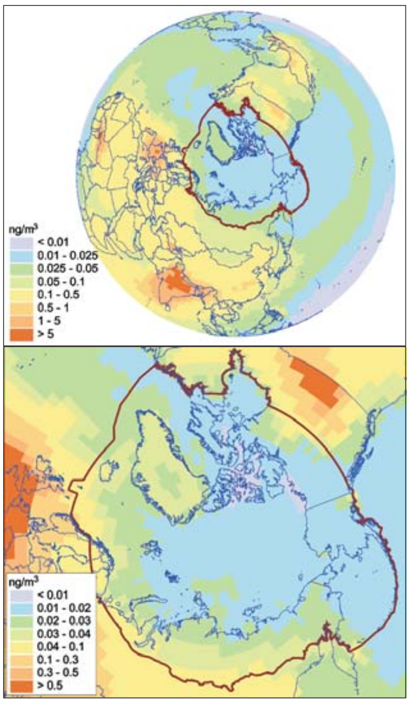


Figure 4.14.
γ-HCH concentrations in air of the lower atmosphere over the Northern Hemisphere and the Arctic.

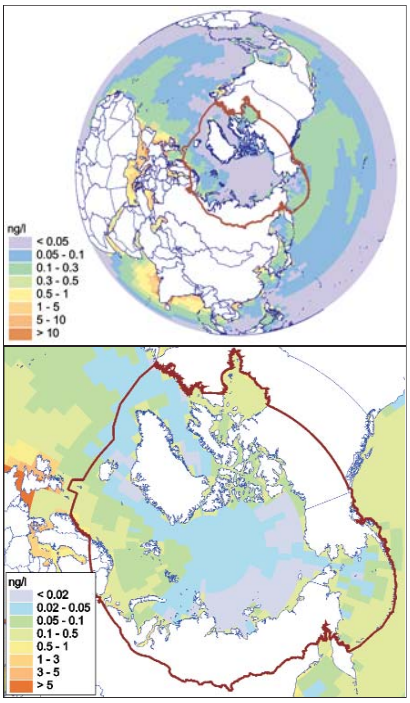


Figure 4.15.
Mean annual concentrations of γ-HCH in seawater in the Northern Hemisphere. The enlarged panel shows the seawater concentrations pattern over the Arctic Ocean.

Since γ-HCH tends to accumulate in seawater (which accounts for about 80% of the overall environmental pool of this substance), the spatial distribution of γ-HCH in seawater is of interest. The distribution of γ-HCH in seawater (Figure 4.15) reveals that maximum concentrations are found in the Indian Ocean, the Mediterranean Sea, and the East Atlantic. Considerable amounts of γ-HCH flow into the Arctic Ocean from the North Atlantic, as reflected in the higher seawater concentrations in the Barents Sea in the region between northern Norway and Svalbard. Seawater concentrations in the seas along the coast of northern Russian are in the range 0.01–2 ng/L.

The total amount of γ-HCH deposited in the Arctic region in 1996 from the atmosphere was estimated to be 78 tonnes. Due to high deposition rates over the sea (the models assume this rate to be twice as high over sea as on land), and taking into account the large proportion of the Arctic area that is covered by ocean (about 60%, according to figures provided by AMAP, 1998), this equates to an estimate for γ-HCH deposited to the Arctic Ocean in 1996 of 58 tonnes.

Modeling results have been used to indicate contributions of different emission sources to the contamination of the Arctic region by γ-HCH (Figure 4.16). Western Europe is the largest contributor to this region (about 40%), followed by India (19%), the Americas (17%), China (10%), and Russia (6%), with other source regions responsible for the remaining 8%.

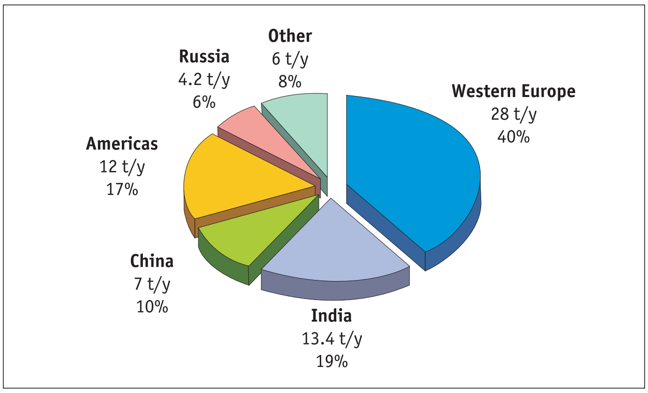


Figure 4.16. Contributions of different source regions to γ-HCH deposition in the Arctic in 1996.

4.2.4. Contamination levels and deposition loads resulting from long-range atmospheric transport to the Russian North

Mercury

Figure 4.17 shows the modeled spatial distribution of mean annual concentrations of total gaseous mercury (TGM) in the air in northern Russia, which are fairly constant across the territory (from 1.4 to 1.8 ng/m^3) (see also Table 4.3). Concentration levels over Murmansk Oblast and in the central Republic of Sakha (Yakutia) are slightly elevated, mainly due to local emission sources. There is also a weak decreasing gradient in mercury concentrations to the north over

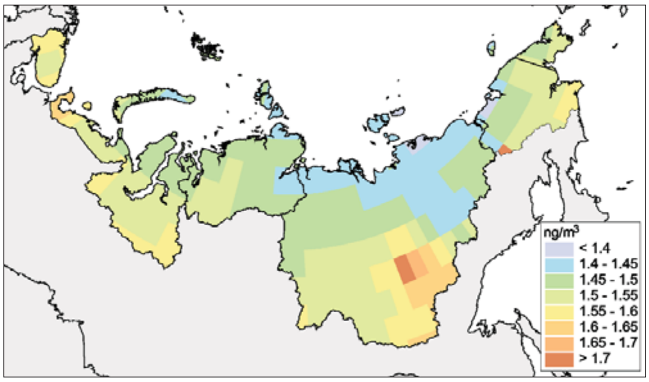


Figure 4.17. Spatial distribution of mean annual air concentrations of total gaseous mercury in the Russian North.

regions including the Yamalo-Nenets AO, the Republic of Sakha (Yakutia), and the Chukchi AO. A possible reason for this, in addition to distance from main emissions areas, is the decrease in elemental mercury concentration over the Arctic coast during springtime, as a result of MDEs.

Table 4.3. Characteristic values of mercury air concentrations in the Russian North, ng/m^3.

Region	min	max	average
MUR	1.52	1.62	1.56
NEN	1.44	1.66	1.52
YNT	1.43	1.58	1.5
YAK	1.38	1.75	1.5
CHU	1.38	1.71	1.5

The spatial distribution of annual deposition loads of total mercury in the Russian North is shown in Figure 4.18. The highest depositions, exceeding 20 g/km^2/y, are observed over the coast of the Arctic Ocean, due to MDEs (Table 4.4). The lowest depositions (less than 5 g/km^2/y), are in Central Yakutia, an area of low annual precipitation. Values of total mercury deposition for regions of the Russian North and the Arctic as a whole are given in Table 4.5.

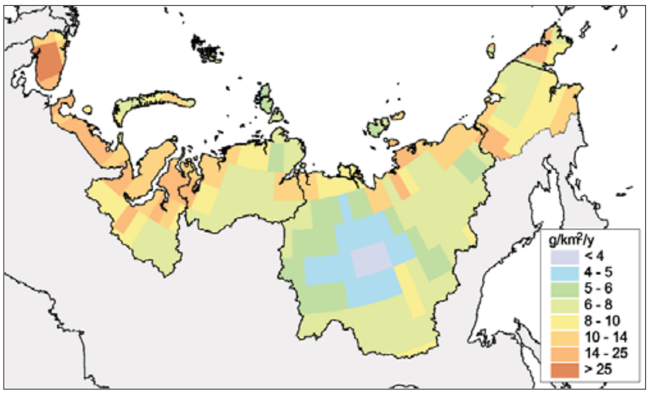


Figure 4.18. Annual deposition of total mercury in the Russian North.

Table 4.4. Characteristic values of total annual mercury deposition loads in the Russian North, g/km^2/y.

Region	min	max	average
MUR	8	30	21
NEN	6	26	14
YNT	5	15	10
YAK	3	17	7
CHU	6	18	10

Region	MUR	NEN	YNT	YAK	CHU	Arctic
Mercury deposition	3	4	15	21	7	240

Table 4.5. Total deposition of mercury in 1996 in different regions of the Russian North, and the Arctic as a whole, t/y.

PCBs

Figures 4.19 and 4.20 show the spatial distributions of mean annual air concentrations and annual deposition loads of PCB-153 over selected regions of the Russian North for 1996. There is a clear decrease in PCB-153 air concentrations from western to eastern areas of the Russian North, with increasing distance from source areas in Europe. Relatively high air concentrations (up to 4 pg/m³) occur in Murmansk Oblast, the Nenets AO, and the southern part of the Yamalo-Nenets and Taymir AOs (Table 4.6). Moderate values (1–2 pg/m³) are characteristic of the northern part of the Yamalo-Nenets AO, the Taymir AO, and the Republic of Sakha (Yakutia). The Chukchi AO is characterized by low values (<1 pg/m³).

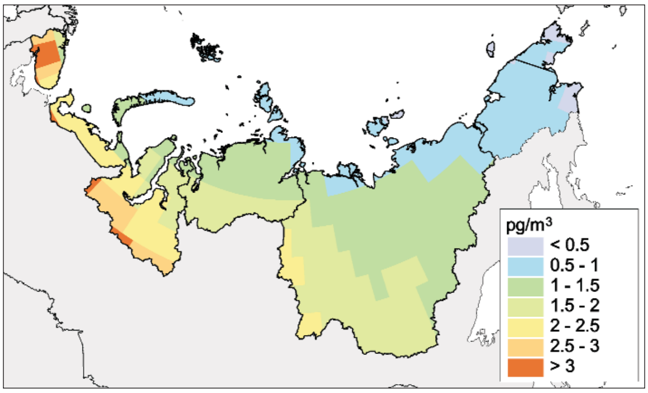


Figure 4.19. Spatial distribution of mean annual air concentrations of PCB-153 in the Russian North, calculated for 1996.

Table 4.6. Characteristic values of PCB-153 air concentrations in the Russian North, pg/m³.

Region	min	max	average
MUR	1.3	4.1	2.6
NEN	0.5	3.8	1.7
YNT	0.5	3.3	1.8
YAK	0.4	2.3	1.4
CHU	0.4	1	0.7

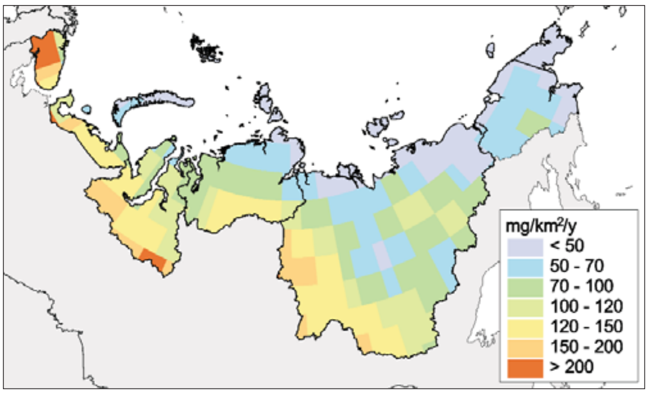


Figure 4.20. Annual deposition of PCB-153 in the Russian North, calculated for 1996.

A similar pattern is seen for deposition loads. Substantial values (>150 mg/km²/y) are estimated for Murmansk Oblast, the Nenets AO and the southern part of the Yamalo-Nenets and Taymir AOs as well as for the western part of the Sakha Republic. Moderate values (70-150 mg/km²/y) are obtained for the northern part of the Yamalo-Nenets and Taymir AOs, the Republic of Sakha (Yakutia), and the western part of Chukchi AO. The northern parts of the Russian North are characterized by lower values for deposition loads (<70 mg/km²/y) (Table 4.7).

Region	min	max	average
MUR	70	333	208
NEN	27	373	97
YNT	27	216	106
YAK	16	224	89
CHU	16	74	51

Table 4.7. Characteristic values of PCB-153 annual deposition loads in the Russian North, mg/km²/y.

Depositions of PCB-153 and of total PCBs to the Russian North and the Arctic are given in Table 4.8. To calculate these depositions, emissions of the 22 PCB congeners considered, from all source regions, were divided into four groups: di- plus tri-chlorinated PCBs, tetra- plus penta-chlorinated PCBs, hexachlorinated PCBs, and hepta- plus octa-chlorinated PCBs. It was assumed that these groups are transported in a similar way to PCB-28, -118, -153 and -180, respectively. Together, these 22 congeners represent about one half of total PCB emissions, a fact that was taken into account in the calculation.

Region	MUR	NEN	YNT	YAK	CHU	Arctic
PCB-153	0.020	0.031	0.095	0.038	0.012	1.15
Σ PCB	1.6	1.7	4.8	4	0.46	40

Table 4.8. Total deposition of PCB-153 and total PCB in 1996 in different regions of the Russian North, and the Arctic as a whole, t/y.

By undertaking simulations of long-range transport and the accumulation of four PCB congeners (PCB-28, -118, -153 and -180), it was possible to compare the congener compositions in the air of different regions of the Russian North (Figure 4.21).

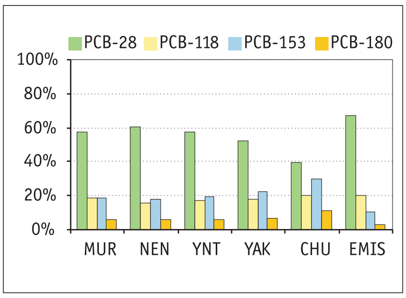


Figure 4.21. PCB congener composition in air of different regions of the Russian North.

For all receptor regions, the fraction of PCB-28 is the highest and PCB-180 the lowest, with other congeners falling between, however, the congener patterns vary noticeably between the regions.

γ-HCH

Mean annual air concentrations of γ-HCH in the receptor regions of the Russian North, for 1996, are illustrated in Figure 4.22. Higher air concentration levels (from 0.02 to 0.07 ng/m³) are characteristic for Murmansk Oblast, the Nenets AO, the south of the Yamalo-Nenets AO, and the Republic of Sakha (Yakutia). Lower levels (from 0.01 to 0.3 ng/m³) are characteristic for the Taymir AO, the Chukchi AO, and the north of the Republic of Sakha (Yakutia) (Table 4.9).

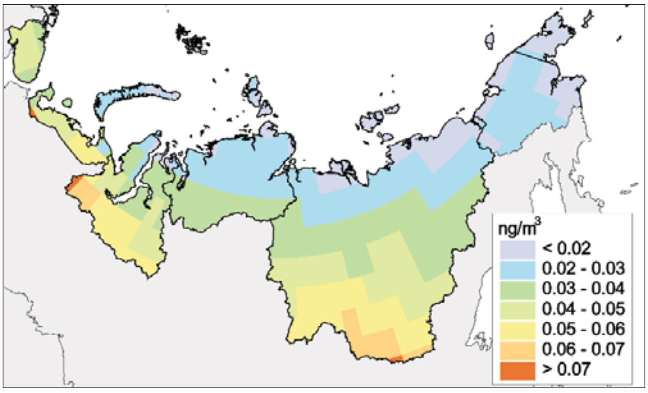


Figure 4.22. Spatial distribution of mean annual air concentrations of γ-HCH in the Russian North, calculated for 1996.

Table 4.9. Characteristic values of γ-HCH air concentrations in the Russian North, ng/m³.

Region	min	max	average
MUR	0.029	0.066	0.043
NEN	0.016	0.082	0.038
YNT	0.018	0.071	0.036
YAK	0.014	0.072	0.038
CHU	0.013	0.027	0.02

The spatial distribution of γ-HCH annual deposition loads is shown in Figure 4.23. Deposition loads are larger for Murmansk Oblast, the Nenets AO, and the Yamalo-Nenets AO (from 2 to 7 g/km²/y or more) and

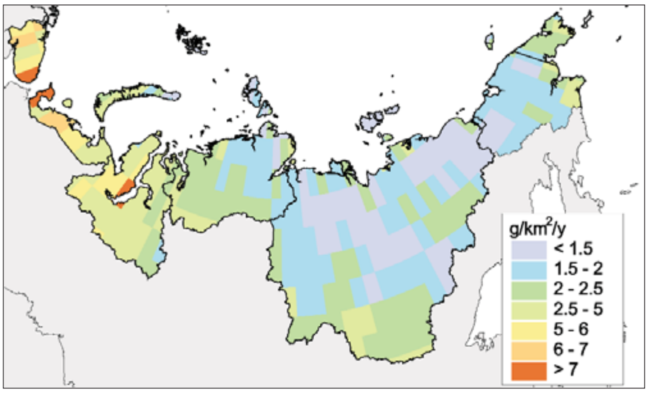


Figure 4.23. Annual deposition of γ-HCH in the Russian North, calculated for 1996.

Table 4.10. Characteristic values of γ-HCH annual deposition loads in the Russian North, g/km²/y.

Region	min	max	average
MUR	3.5	14	6
NEN	0.9	9.7	4.3
YNT	0.8	8	2.7
YAK	0.5	4.3	1.8
CHU	0.7	4.6	1.9

lower for the Taymir AO, the Republic of Sakha (Yakutia), and the Chukchi AO (0.1–3 g/km²/y). Annual deposition loads vary from region to region (Table 4.10). This is mainly due to different precipitation levels in these regions.

Estimated values for total deposition of γ-HCH in the regions of the Russian North and the Arctic as a whole are given in Table 4.11.

Regions	MUR	NEN	YNT	YAK	CHU	Arctic
Total depositions	0.8	1.1	4	5.4	1.3	78

Table 4.11. Total deposition of γ-HCH in 1996 in different regions of the Russian North, and the Arctic as a whole, t/y.

4.2.5. Source-receptor relationships for the selected pilot study regions.

4.2.5.1. Murmansk Oblast

Mercury

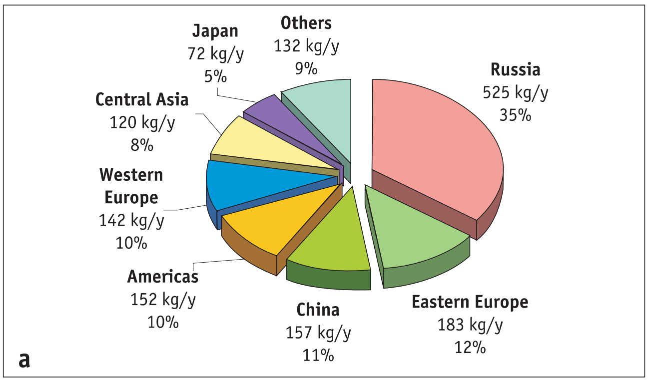
Murmansk Oblast is the most westerly region of Russia and is located on the Kola Peninsula. This explains the greater influence of European sources of mercury on this region (including sources both inside and outside the territories of Russia). Figures 4.24(a) and 4.24(b) illustrate the contributions of major Northern Hemispheric and Russian anthropogenic mercury source regions to annual mercury deposition in Murmansk Oblast. The largest contribution is made by Russian sources (35%). Among these, about 13% is from Murmansk Oblast itself (MUR) and 18% from other Russian European regions (NRT, NWK, CVV, CVN and URL). The most important sources outside of Russia are those in Eastern Europe (12%), China (11%), the Americas (10%), and Western Europe (10%). The 'other' category (defined in this and other sections addressing mercury source-receptor relationships) includes Northern and Southern Europe, Southeast Asia (excluding China and Japan), and Africa, due to their relatively small contributions to depositions in the receptor area.

PCB

The largest contributions to PCB-153 deposition in Murmansk Oblast are from emission sources in Russia (44%), Northwest Europe (35%) and Southeast Europe (14%) (Figure 4.25(a)). Contributions from sources located in the Americas, Africa, and Central Asia are less significant due to their considerable distance from the Oblast. Amongst Russian sources (Figure 4.25(b)), the major contribution is made by emissions from Murmansk Oblast itself (22%).

γ-HCH

γ-HCH sources in Western Europe make the largest contribution to deposition in Murmansk Oblast (more than 50%). Other significant contributors are Russia (17 %) and India (9%) (Figure 4.26(a)).



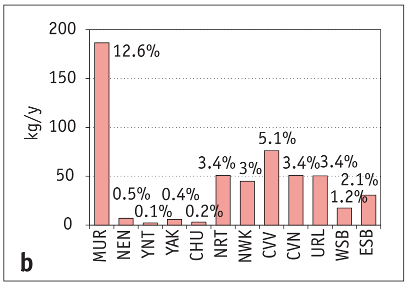
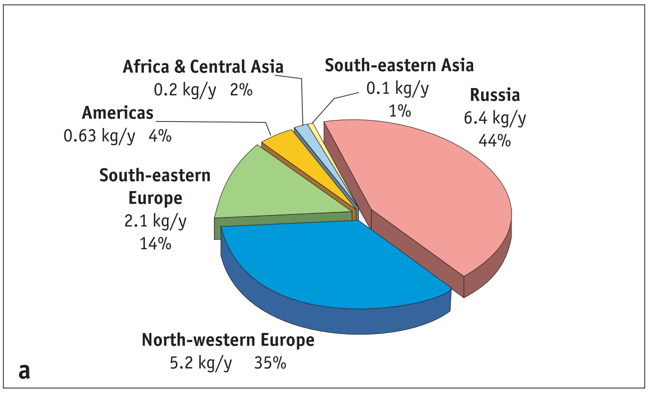


Figure 4.24. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual mercury deposition in Murmansk Oblast.



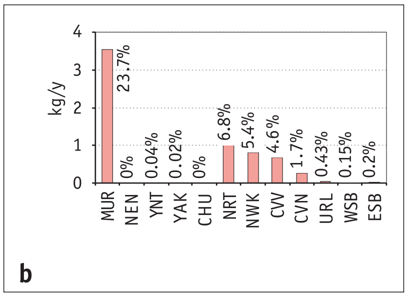
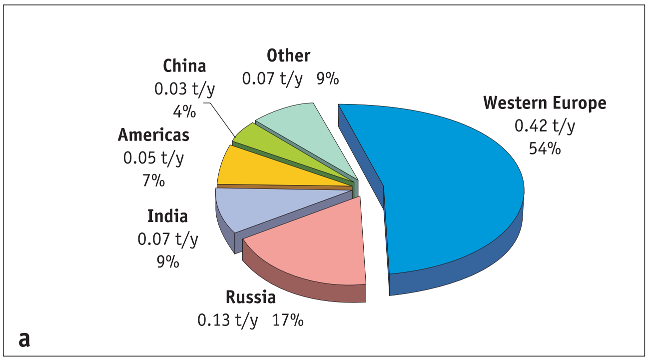


Figure 4.25. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual PCB-153 deposition in Murmansk Oblast.



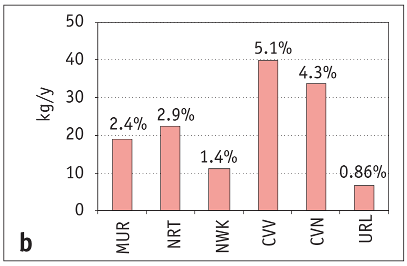


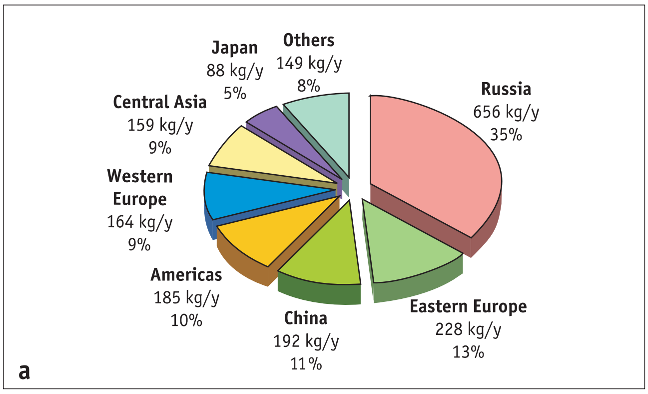
Figure 4.26. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, and (b) regions of Russia to annual γ-HCH deposition in Murmansk Oblast.

Russian contributions to γ-HCH depositions in Murmansk Oblast are mostly made by the Central and Volgo-Viatsky regions (CVV) and the Central-Chernozem, Volga, and North-Caucasian regions (CVN), 5% and 4%, respectively. The inputs from other regions are comparatively small (Figure 4.26(b)). For the purposes of this report, contributions from Russian emission sources to γ-HCH depositions in receptor areas are shown only for those regions with significant emissions of γ-HCH.

4.2.5.2. The Nenets Autonomous Okrug

Mercury

The Nenets AO is located in the northern part of European Russia. Therefore the main source areas of long-range atmospherically transported pollution affecting the region are similar to those affecting Murmansk Oblast. Differences in deposition are associated mainly with the greater significance of Russian emission source regions. Figures 4.27(a) and 4.27(b)



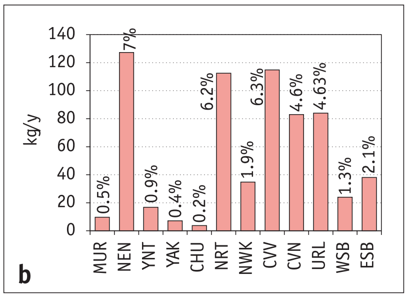


Figure 4.27. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual mercury deposition in the Nenets AO.

show the relative contribution of the different regions to the total annual deposition of mercury in the Nenets AO from anthropogenic sources. The largest contribution is from Russian sources (35%). However, sources within the Nenets AO itself only contribute 7%, whereas the combined contribution of regions in European Russia make up 24% of the deposition. The most important of these are the Northern region (NRT) and the Central and Volgo-Viatsky regions (CVV). The most significant external contributors are Eastern Europe (13%), China (11%), the Americas (10%), Western Europe (9%), and Central Asia (9%).

PCB

The largest contributions to PCB-153 depositions are made by Russia (41%), Northwest Europe (31%) and Southeast Europe (18%) (Figure 4.28(a)). The main contributions among Russian sources (Figure 4.28(b)) are made by the Central and Volgo-Viatsky regions (CVV) and the Northern region (NRT), with values of 15% and 10%, respectively.

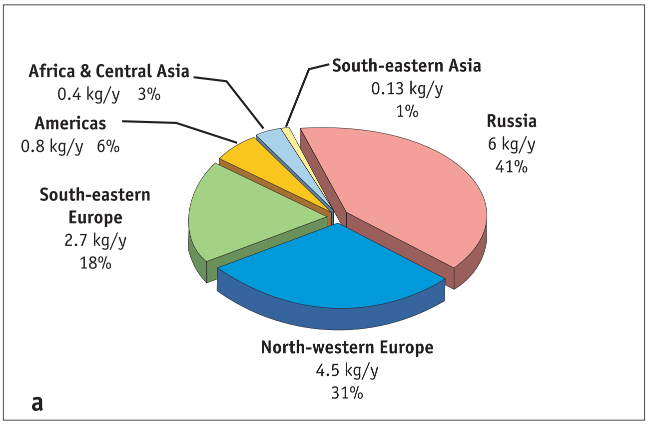
γHCH

The major contributions to the contamination of the Nenets AO by γ-HCH are from emission sources in Western Europe (49%), Russia (23%), and India (9%) (Figure 4.29(a)). The main sources within the Russian Federation are the Central and Volgo-Viatsky regions (CVV) and the Central-Chernozem, Volga, and North-Caucasian regions (CNV), contributing 8% each (Figure. 4.29(b)).

4.2.5.3. The Yamalo-Nenets and Taymir Autonomous Okrugs

Mercury

The location of the Yamalo-Nenets AO and the Taymir AO in the northern part of western Siberia, accounts for the fact that Asian sources play a noticeable role in their contamination. European sources, however, still continue to exert a considerable influence. Up to 30% of all mercury annually deposited in these two regions is from Russian sources (Figure 4.30(a)). The contribution from sources within the Yamalo-Nenets and



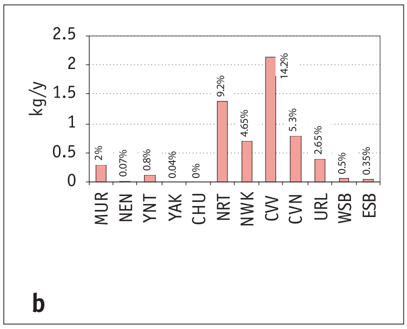
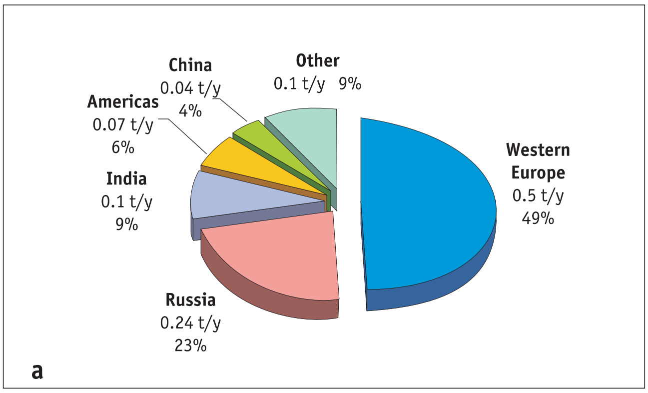


Figure 4.28. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual PCB-153 deposition in the Nenets AO.



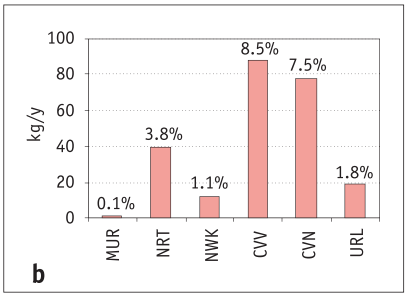
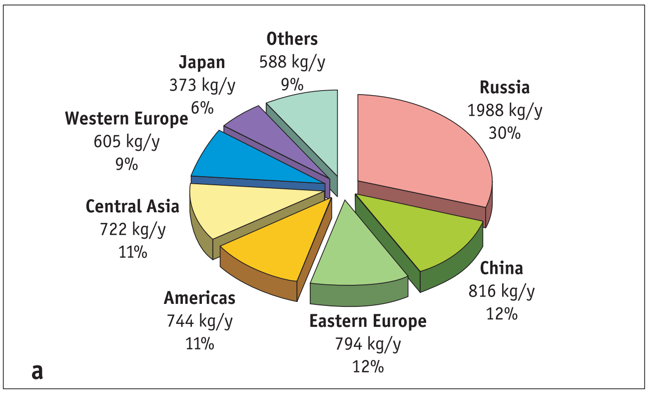


Figure 4.29. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual γ-HCH deposition in the Nenets AO.



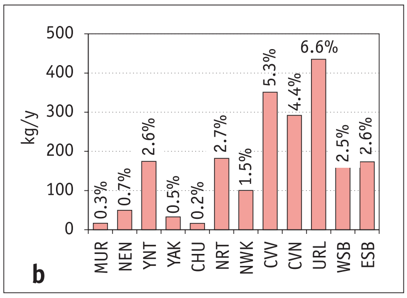
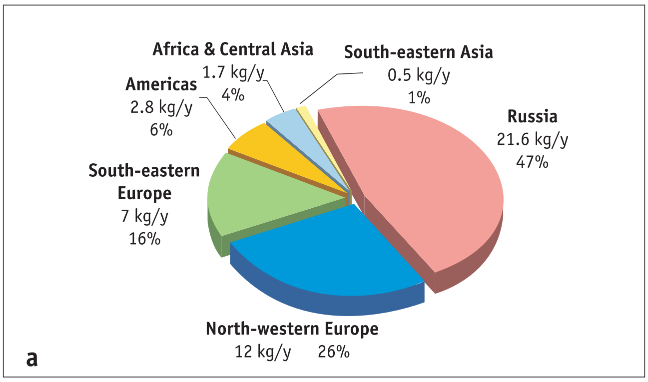


Figure 4.30. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual mercury deposition in the Yamalo-Nenets AO and the Taymir AO.



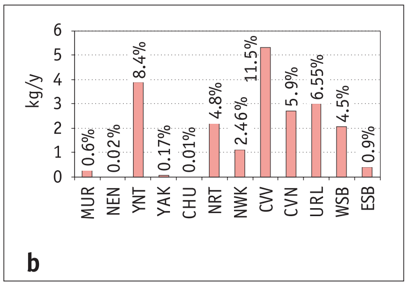
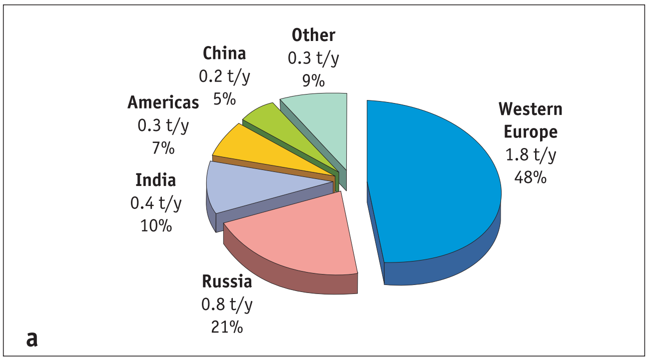


Figure 4.31. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual PCB-153 deposition in the Yamalo-Nenets AO and the Taymir AO.



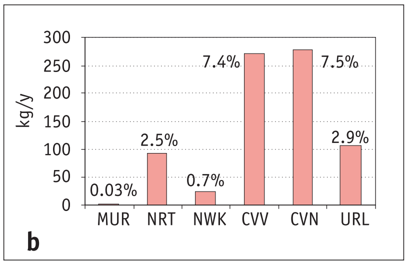
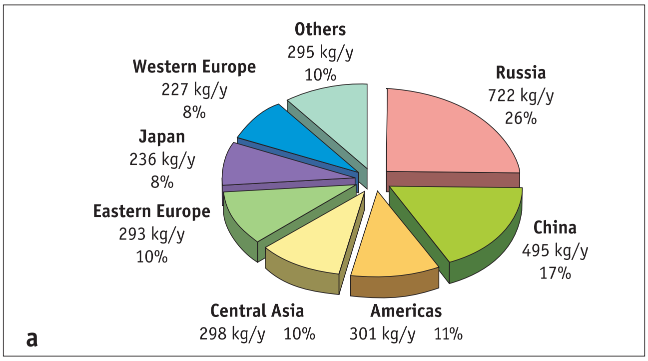


Figure 4.32. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual γ-HCH deposition in the Yamalo-Nenets AO and the Taymir AO.



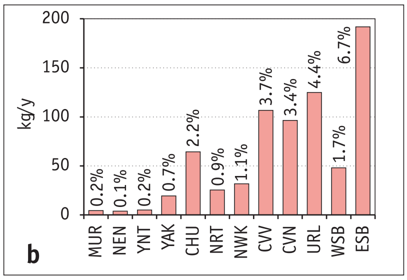


Figure 4.33. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual mercury deposition in the Chukchi AO.

Taymir AOs themselves is comparatively low (only about 3%), whereas three major Russian contributors (CVV, CVN, and URL) make up 16% of total deposition (Figure 4.30(b)). The two major external contributors are China (12%) and Eastern Europe (12%). Some impact is also made by the Americas (11%), Central Asia (11%) and Western Europe (9%).

PCB

Major contributions to PCB deposition in the Yamalo-Nenets and Taymir AOs are made by sources in Russia (47%), Northwest Europe (26%) and Southeast Europe (16%) (Figure 4.31(a)). Among Russian sources (Figure 4.31(b)), the largest contribution (12%) to depositions are made by the Central and Volgo-Viatsky regions CVV). The contribution of emission sources located within the Yamalo-Nenets and Taymir AOs is 9%.

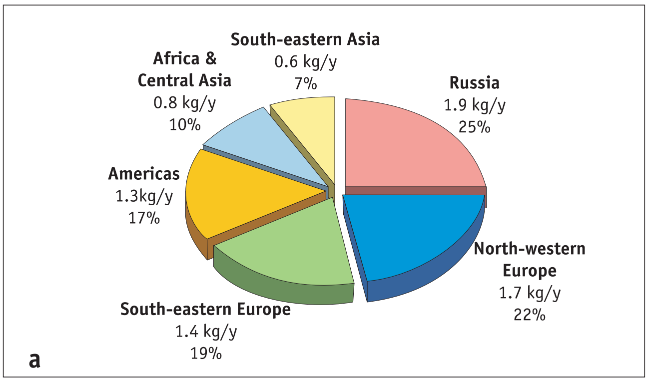
γ-HCH

Main contributors to depositions of γ-HCH in the Yamalo-Nenets and Taymir AOs are similar to those for the Nenets AO. Sources in Western Europe make the largest contribution to ongoing deposition in these territories (48%). Russia is responsible for 21% and India, for 10% (Figure 4.32(a)). Russian contributions to depositions in the Yamalo-Nenets and Taymir AOs are mainly from the Central and Volga-Viatsky regions (CVV) and the Central-Chernozem, Volga, and North-Caucasian regions (CVN), 7% and 8% respectively (Figure 4.32(b)).

4.2.5.4. Chukchi Autonomous Okrug

Mercury

The Chukchi AO is the most eastern and remote region of the Russian North. Its location, far from major industrial regions, accounts for the fact that the global background pool of atmospheric mercury is the main source of mercury contamination in this region. Figure 4.33(a) demonstrates the relative contributions of different source regions to annual mercury deposition in the Chukchi AO. The main contributor is Russia (26%), however, contributions from China are also considerable (17%). Among other sources, the Americas (11%), Central Asia (10%), and Eastern Europe (10%) are of note. The contribution from the Chukotka AO itself is insignificant compared to emission sources located in Eastern Siberia and the Far East (Figure 4.33(b)). However, the influence of major emission regions in European Russia (CVV, CVN, URL) are also apparent.



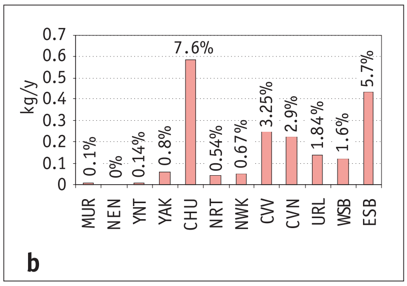
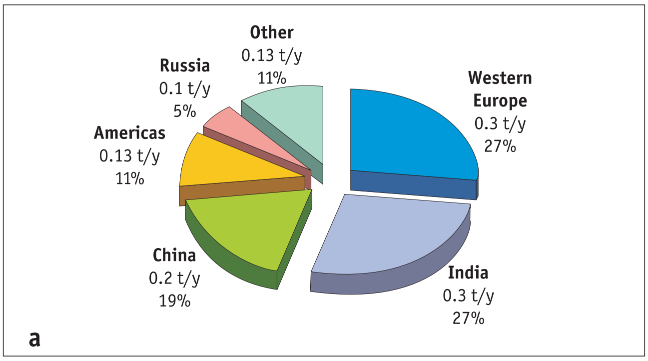


Figure 4.34. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual PCB-153 deposition in the Chukchi AO.



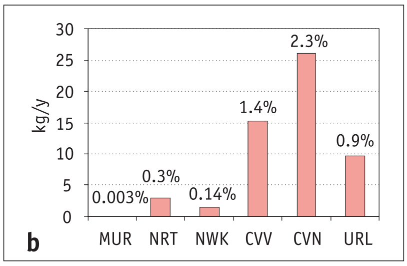


Figure 4.35. Contributions from anthropogenic sources in (a) regions of the Northern Hemisphere, (b) regions of Russia to annual γ-HCH deposition in the Chukchi AO.

PCB

The most important contributions to PCB-153 deposition in the Chukchi AO are made by sources located in Russia (25%), Northwest Europe (22%), and Southeast Europe (19%), followed by American sources (17%). (Figure 4.34(a)). The main contribution from the Russian source regions (Figure 4.34(b)) is made by emissions from the Chukchi AO itself (8%).

γ-HCH

For the Chukchi AO, the main contributions to γ-HCH contamination are made by India (27%), Western Europe (27%), China (19%), and the Americas (11%) (Figure 4.35(a)). The contribution from all Russian sources accounts for only 5% (Figure 4.35(b)).

4.2.6. Conclusions

Murmansk Oblast

The largest contribution to anthropogenic mercury deposition in the Oblast is made by Russian sources (35%) of which 13% is from sources within Murmansk Oblast itself. The most important external sources are Eastern Europe (12%), China (11%), the Americas (10%), and Western Europe (10%). Total annual deposition of mercury is around 3 t, including 1.5 t from anthropogenic sources.

A major contribution to PCB deposition is made by Russian sources (44%) including 22% from sources within Murmansk Oblast itself. Among other emission sources, significant contributions originate in Northwest Europe (35%), and Southeast Europe (14%). Total annual deposition of PCB-153 in Murmansk Oblast amounts to 20 kg, and of total PCBs, 0.7 t.

Main contributions to γ-HCH deposition are made by sources within Western Europe (54%), Russia (17%), and India (9%). Russian contributions to deposition are mainly from sources located in the Central and Volgo-Viatsky regions (5%), and Central-Chernozem, Volga, and North-Caucasian regions (4%). Total annual deposition of γ -HCH amounts to 0.8 t.

The Nenets Autonomous Okrug

The most important contribution to anthropogenic mercury depositions in the Nenets AO is made by Russian emission sources (35%). As well as deposition from sources within the Nenets AO itself (7%), emissions from regions in the European part of Russia contribute considerably to the pollution of this region (24%). The most important external contributors are Eastern Europe (13%), China (11%), and the Americas (10%). Total annual deposition of mercury in the Nenets AO amounts to 4 t, of which 1.8 t is from anthropogenic sources.

Main contributions to PCB deposition in the Nenets AO are from sources in Russia (41%), Northwest Europe (31%), and Southeast Europe (18%). Major contributions from sources within the Russian Federation are made by the Central and Volgo-Viatsky regions (15%), and the Northern region (10%). The contribution of local sources to deposition in the Nenets AO is negligible. Total annual deposition of PCB-153 in this Okrug amounts to 31 kg, and of total PCBs, 1 t.

γ-HCH pollution of the Nenets AO is due to emission sources in Western Europe (49%), Russia (23%), and India (9%). The main sources within the Russian Federation are the Central and Volgo-Viatsky regions

(8%), and the Central-Chernozem, Volga, and North-Caucasian regions (8%). Total annual deposition of γ-HCH to this Okrug is 1.1 t.

The Yamalo-Nenets and Taymir Autonomous Okrugs

The major contribution to anthropogenic mercury deposition in these regions is from emissions sources in Russia (30%). Among Russian sources, the main contributors are sources in the Ural, Central and Volgo-Viatsky regions, and the Central-Chernozem, Volga, and North-Caucasian regions (16% in total). Main external contributors are China (12%), Eastern Europe (12%), the Americas (11%), and Central Asia (11%). Total annual deposition of mercury is estimated at 15 t, of which 6.6 t is from anthropogenic sources.

Major contributions to PCB depositions are made by sources located in Russia (47%), Northwest Europe (26%) and Southeast Europe (16%). Among Russian sources, the largest contribution to deposition is made by the Central and Volgo-Viatsky regions (12%). Total annual deposition of PCB-153 is 95 kg, and 3.2 t for total PCBs.

Main contributions to γ-HCH depositions are made by Western Europe (48%), Russia (21%), and India (10%). Main sources within the Russian Federation are the Central and Volgo-Viatsky regions (7%) and the Central-Chernozem, Volga, and North-Caucasian regions (8%). Total annual deposition of γ-HCH amounts to 4 t.

The Chukchi Autonomous Okrug

The main contributions to anthropogenic mercury deposition in this Okrug originate from Russian sources (26%). Emission sources from Eastern Siberia and the Far East are the dominant influences on mercury contamination of the Chukchi AO. The main external contributor to the region's pollution is China (17%), with a contribution comparable to that of Russian sources, although this varies slightly during the year. Among others, the Americas contribute 11% and Central Asia 10% to the deposition. Total annual deposition of mercury is estimated at 7 t, of which 2.9 t is from anthropogenic sources.

The main contributors to PCB deposition are the following: Russia (25%), Northwest Europe (22%), and Southeast Europe (19%), followed by American sources (17%). The Chukchi AO itself contributes 8%. The total annual deposition of PCB-153 amounts to 11.8 kg, and of total PCBs, 0.4 t.

Main contributions to γ-HCH deposition are made by India (27%), Western Europe (27%), China (19%), and the Americas (11%). The contribution from Russian sources accounts for 5%. Total annual deposition of γ-HCH in the Chukchi AO is estimated at 1.4 t.

In addition, the following general conclusions can be made, based on the studies undertaken:

- Europe, North America, and Southeast Asia are the most significant emission source regions for mercury, PCBs and γ-HCH. The main Russian emission sources are located in the European part of the Russian Federation. Due to their geographical location, and to meteorological conditions, European sources make the greatest contribution to the contamination of the western regions of the Russian North. Asian and North American sources play a more significant role in the pollution of the eastern territories of the Russian Arctic, although the contribution of European sources is still considerable.

- The results obtained make it possible to make some predictions for the near future regarding contamination levels in the Russian Arctic. An analysis of emission data shows that mercury emissions are decreasing in Europe and North America, whereas emissions from Southeast Asia are increasing. Asian sources may eventually become the more significant, thus contamination levels of this pollutant in some regions of the Russian North, in particular the Chukchi AO, may increase in the future. Regarding γ-HCH, use of technical-HCH (a mixture of HCH isomers, including γ-HCH) is now banned in most western countries, and in Russia since the late-1980s; China, a major user, also switched to lindane (pure γ-HCH) in 1984. Although restricted in most countries, lindane is still widely used in North America, Europe and Asia, for seed treatment and other applications (AMAP, 2002). Thus the relative influence of Asian countries on pollution of the Russian Arctic by γ-HCH is likely to increase. PCB contamination levels are expected to decrease with emission reductions resulting from bans and controls on use of PCBs. However PCB contamination is likely to continue for many years as a result of re-emissions from PCBs accumulated in the general environment over the last 50-years.

4.3. Preliminary assessment of riverine fluxes as PTS sources

4.3.1. Introduction

Flows of large Arctic rivers are considered one of the most significant pathways by which contaminants reach the Arctic. Riverine transport is particularly relevant for PTS, as potentially PTS contamination within the entire catchment areas of these rivers can be transported to the Arctic through watershed runoff, and these catchments include heavily industrialized areas and agricultural regions (Figure 4.36).

Riverine PTS transport is particularly important for two of the study areas selected for project implementation: the lower Pechora basin, and the eastern part of the Taymir Peninsula, in the area of the Yenisey river.

Figure 4.36. Arctic Ocean watershed, and catchment areas of the largest Arctic rivers (AMAP, 1998).

The Yenisey is one of the world's ten largest rivers, with a catchment area of 2.59 million km² (world ranking: 7) and mean long-term annual runoff of 603 km³ (world ranking – 5) (GRDC, 1994). Its basin incorporates the East-Siberian economic region, parts of which, particularly those located in the upper and central parts of the Yenisey basin, are heavily industrialized. Industrial enterprises within these areas include non-ferrous metallurgy, pulp and paper manufacture, chemical industries, and mining, etc., which are recognized as significant sources of PTS emissions and discharges.

The catchment area of the Pechora river comprises 0.325 million km² (world ranking – 46), with a mean long-term annual runoff of 141 km³ (world ranking: 30). The Pechora river basin, including the catchments of its primary and secondary tributaries the Vorkuta, Bol'shaya Inta, Kolva, Izhma and Ukhta rivers, contain areas rich in mineral resources, with associated oil, gas and coal extraction activities.

4.3.2. Objectives and methodology of the study

The objective of this study was to estimate PTS fluxes in the flows of the Pechora and Yenisey rivers to areas inhabited by indigenous peoples. Calculations of PTS loads in the lower reaches of the Pechora and Yenisey rivers used a range of data, included hydrometric measurements at the closing cross-sections of the Roshydromet basic hydrological network (in the area of Oksino settlement on the Pechora River and Igarka settlement on the Yenisey River), and at the lowermost cross-sections in the delta apexes, upstream of the rivers' main branching points (in the vicinity of Andeg settlement, on both the Large and Small Pechora rivers, and of Ust'-Port settlement, on the Yenisey River) (Figures 4.37 and 4.38). In addition, data were obtained from analysis of pooled water and suspended matter samples collected during periods of hydrological observations.

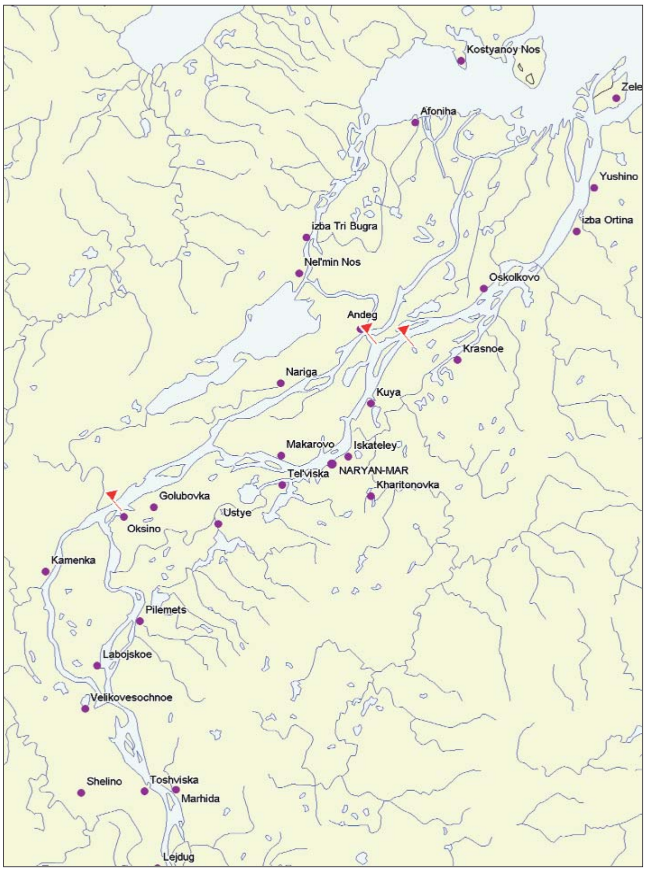


Figure 4.37. Location of hydrometric cross-sections on the Pechora river.

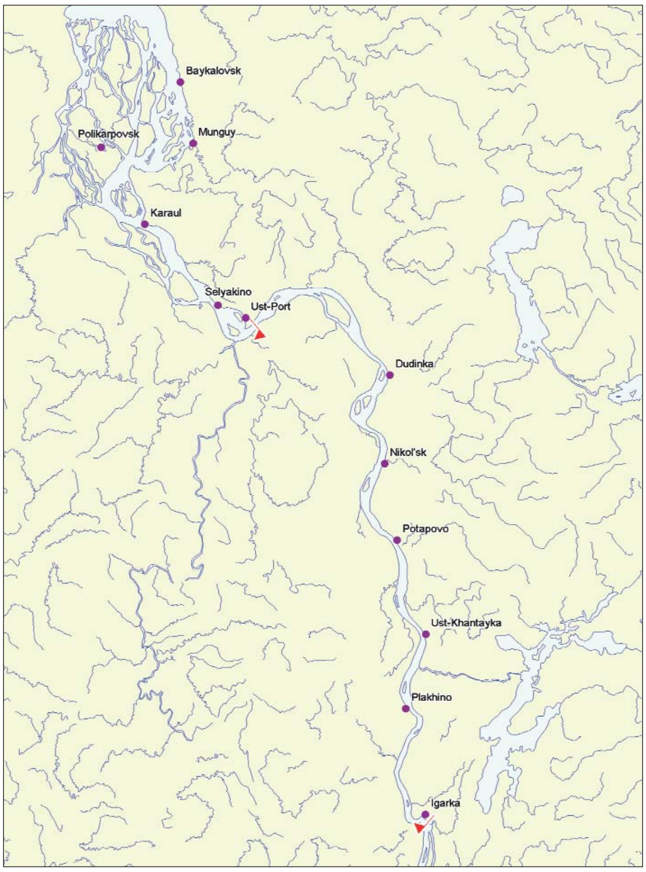


Figure 4.38. Location of hydrometric cross-sections on the Yenisey river.

Hydrometric measurements and water sampling at each of the cross-sections were carried out according to internationally accepted methodologies (GEMS, 1991; Chapman, 1996) during four typical hydrological water regime phases: during the spring flood fall period (late-June to early-July), during the summer low water period (late-July to early-August), before ice formation during the period of rain-fed floods (late-September to October), and during the winter low water period (March to April).

During each field survey period, measurements of flow velocity at various sampling points in the channel profile were made every 6 hours, for 3 days. Water level observations were conducted every 2 hours. Water sampling was carried out twice during the first observation day and once a day during the next two days (a total of 4 single samples for each sampling point). The volume of each pooled sample was not less than 20 litres.

Initial data for each water regime phase included:

- For the Pechora river at the closing cross-section near Oksino settlement (see Figure 4.39):
  - 15 flow velocity measurements (3 horizontal levels on each of 5 vertical profiles);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations in 11 pooled water and 11 pooled suspended matter samples collected over a 3-day period in 11 cross-section segments;
  - suspended matter concentrations for samples taken at the flow velocity measurement points, in 11 pooled water samples, collected over a 3-day period in 11 cross-section segments.

- For the Large and Small Pechora rivers at the downstream cross-sections near Andeg settlement (see Figures 4.40 and 4.41):
  - 12 flow velocity measurements (3 horizontal levels on each of 4 vertical profiles, in both rivers);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations in 3 pooled water samples and 3 pooled suspended matter samples from the surface, middle and near-bottom horizons collected over a 3-day period;
  - suspended matter concentrations in 3 pooled water samples collected over a 3-day period from the surface, middle and near-bottom horizons.

- For the Yenisey river at the closing cross-section near Igarka settlement (see Figure 4.42):
  - 15 flow velocity measurements (3 horizontal levels on each of 5 vertical profiles);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations in 11 pooled water samples and 11 pooled suspended matter samples collected over a 3-day period in 11 cross-section segments;
  - suspended matter concentrations for the flow velocity measurement points in 11 pooled water samples, collected over a 3-day period from 11 cross-section segments.

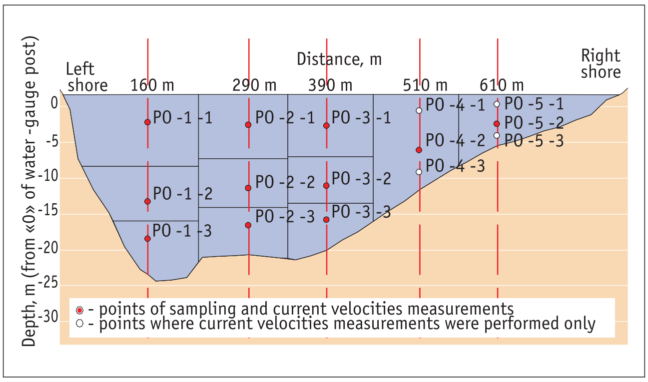


Figure 4.39. Channel profile and sampling/measurement points on the Large Pechora river at the closing cross-section near Oksino settlement.

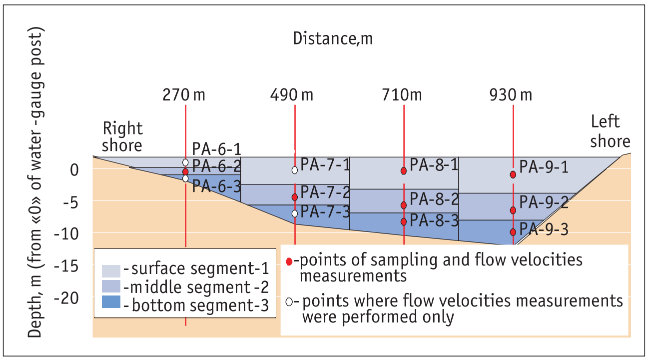


Figure 4.40. Channel profile and sampling/measurement points on the Large Pechora river at the downstream cross-section near Andeg settlement.

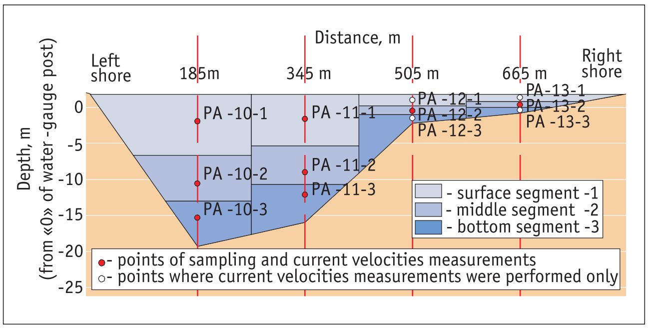


Figure 4.41. Channel profile and sampling/measurement points on the Small Pechora river at the downstream cross-section near Andeg settlement.

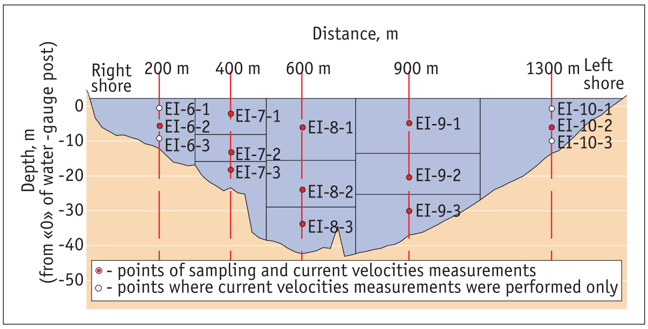


Figure 4.42. Channel profile and sampling/measurement points on the Yenisey river at the closing cross-section near Igarka settlement.

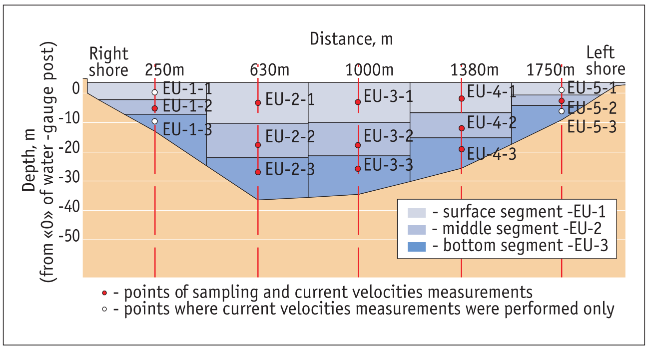


Figure 4.43. Channel profile and sampling/measurement points on the Yenisey river at the downstream cross-section near Ust'-Port.

- For the Yenisey river at the downstream cross-section near Ust'-Port settlement (see Figure 4.43):
  - 15 flow velocity measurements (3 horizontal levels on each of 5 vertical profiles);
  - measurement of the channel profile;
  - 36 measurements of the river water level;
  - analytical data on PTS concentrations for 3 pooled water samples and 3 pooled suspended matter samples from the surface, middle and near-bottom horizons collected over a 3-day period;
  - suspended matter concentrations in 3 pooled water samples collected over a 3-day period from the surface, middle and near-bottom horizons.

During the winter low water period, ice thickness was also measured at each of the cross-sections.

For calculations of mean monthly and annual PTS fluxes through the closing and downstream cross-sections for the year in which the observations were made, operational data consisting of water discharge measurements at river cross-sections in the area of Oksino and Igarka settlements were used. These data were provided by the Northern (Pechora river) and Central Siberian (Yenisey river) Territorial Branches of Roshydromet.

In order to calculate mean monthly and annual PTS fluxes through the closing cross-sections of the rivers for a year with 'average' runoff, and to assist in the preparation of a brief review of the inter-annual variability in water runoff via the Pechora and Yenisey rivers, published hydrographical data from 1932-1998, obtained from the Roshydromet hydrological network, were used.

Calculation of mean daily PTS fluxes over the 3-day observation periods was undertaken in several stages:

1. evaluation of the river channel profiles at the cross-sections where hydrometric measurements were taken;
2. division of the cross-sectional area into segments, for calculation of partial discharges and PTS fluxes;
3. calculation of the partial mean daily water and suspended matter discharges (for each segment identified) and total water and suspended matter discharges (for the whole cross-section) during each of the typical water regime phases;
4. calculation of partial and total mean daily fluxes of PTS in dissolved form during the typical water regime phases;
5. calculation of partial and total mean daily fluxes of PTS in suspended matter during the typical water regime phases.

The river channel profiles used in the hydrometric measurement cross-sections were evaluated on the basis of depth measurements and water level observations. Depth measurements (at various points across the channel) were taken once, prior to the start of the 3-day observation period. Water level observations were then made every two hours for three days. To model the channel profile, an averaged single value for water level above the original gauging station datum was applied across the river cross section. Thus, 16 profiles were evaluated (one for each of the four cross-sections in each of the four water regime phases) on the basis of average 'effective' cross-sectional areas during the 3-day observational periods. Ice thickness was taken into account in the construction of the channel profile during the winter low water period.

The cross-section areas were subdivided into segments corresponding to the points of flow velocity measurements and sampling. The profile schemes for each cross-section showing segments are presented in Figures 4.39 to 4.43. The numbers of segments coincides with the number of observations points.

In order to calculate partial and total mean daily PTS fluxes in dissolved and suspended form during the typical water regime phases, the following assumptions were made:

- At the closing cross-section, within a given segment, the PTS concentrations in water and suspended matter do not vary over the time period being represented, and are equal to the measured concentration at the corresponding observation point.
- At the downstream cross-section, within the combined segments identified, the PTS concentrations in water and suspended matter do not vary over the time period being represented, and are equal to the measured concentrations in the corresponding pooled samples.
- Any PTS that were either not found in any of the samples during the entire observation period, or were found in less than 10% of the total number of samples collected at both the closing and the more downstream cross-sections of a river, were excluded from PTS flux calculations for the given hydrological phase.
- Edge effects are not taken into account.

An assessment of mean monthly PTS flux (μ_y) in dissolved and suspended form was made according to the calculation method proposed by E.M.L. Beal (Frazer and Wilson, 1981).

$$\mu_y = \mu_x \frac{m_y}{m_x} \frac{\left(1 + \frac{1}{n}\frac{S_{xy}}{m_y m_x}\right)}{\left(1 + \frac{1}{n}\frac{S_x^2}{m_x^2}\right)} \qquad (4.1)$$

where:

μ_x – mean daily water discharge for the given month (L/day);

m_y – mean daily flux of the substance under consideration in the dissolved or suspended forms (kg/day), obtained for a 3-day observation period;

m_x – mean daily water discharge (L/day), obtained for a 3-day observation period;

n – number of observation days in a month (using our assumptions – three).

$$S_{xy} = \frac{\sum_{i=1}^{n} X_i Y_i - n \cdot m_y \cdot m_x}{n-1} \qquad S_x^2 = \frac{\sum_{i=1}^{n} X_i^2 - n \cdot m_x^2}{n-1}$$

and:

X_i, Y_i – values of the water discharge and flux of the substance under consideration for each specific day when measurements were conducted.

In our case Y_i=m_y and X_i=m_x, as the concentration of suspended matter and PTS concentrations were determined from a single integral sample collected during the 3-day observation period and the water discharges were calculated on the basis of the average flow velocity for a 3-day period.

In this case, equation (1) above for the calculation of mean monthly PTS flux can be simplified to:

$$\mu_y = \mu_x \frac{m_y}{m_x} \qquad (4.2)$$

In applying this, the following assumptions were adopted:

- Values of my and mx were assumed to be constant for the months which fall within each hydrological season: i.e., May-July (spring flood); August-September (summer low water period); October (period before the onset of ice formation); November-April (winter low water period).
- The ratio of the PTS fluxes in dissolved and particulate associated phases is constant inside the cross-section and during the hydrological season represented.
- The ratio of the PTS fluxes in dissolved and particulate associated phases during the spring freshet is assumed to be equal to the ratio during periods of low discharge.

As mentioned above, mean monthly water discharges at the closing cross-sections of the Pechora and Yenisey rivers (near Oksino settlement and Igarka, respectively) for both the observation year and an ‘average’ water discharge year, for use in the calculations, were provided by Roshydromet. For the two downstream cross-sections, similar data were not available. Consequently, the following assumptions were adopted for calculation purposes:

Congener	Form	R. Pechora (at Oksino)		R. Yenisey (at Igarka)	
		2001-2002	Long-term	2001-2002	Long-term
CB28	Dissolved	115	122	125	107
	Suspended	639	678	609	520
	Total	**754**	**800**	**734**	**627**
CB31	Dissolved	93	99	102	87
	Suspended	692	734	727	621
	Total	**785**	**833**	**829**	**708**
CB52	Dissolved	187	198	146	125
	Suspended	274	291	465	398
	Total	**461**	**489**	**611**	**523**
CB99	Dissolved	10	11	324	277
	Suspended	85	90	232	198
	Total	**95**	**101**	**556**	**475**
CB101	Dissolved	5	5	214	183
	Suspended	49	52	36	31
	Total	**54**	**57**	**250**	**214**
CB105	Dissolved	13	14	243	208
	Suspended	48	51	48	41
	Total	**61**	**65**	**291**	**249**
CB118	Dissolved	12	13	75	64
	Suspended	8	8	349	298
	Total	20	21	424	362
CB128	Dissolved	0	0	118	101
	Suspended	1	1	51	44
	Total	**1**	**1**	**169**	**145**
CB138	Dissolved	10	11	102	87
	Suspended	27	29	265	227
	Total	**37**	**40**	**367**	**314**
CB153	Dissolved	3	3	1	1
	Suspended	0	0	58	50
	Total	**3**	**3**	**59**	**51**
CB156	Dissolved	2	2	0	0
	Suspended	0	0	34	29
	Total	**2**	**2**	**34**	**29**
CB170	Dissolved	0	0	2	2
	Suspended	0	0	2	2
	Total	**0**	**0**	**4**	**4**
CB183	Dissolved	6	6	9	8
	Suspended	0	0	55	47
	Total	**6**	**6**	**64**	**55**
CB187	Dissolved	3	3	0	0
	Suspended	4	4	0	0
	Total	**7**	**7**	**0**	**0**
Σ PCB	Dissolved	456	484	1460	1250
	Suspended	1830	1940	2930	2510
	Total	**2280**	**2420**	**4390**	**3760**

Table 4.12. PCB flux (kg/y) at the closing cross-sections of the Roshydromet network, calculated for the period of observations (2001-2002), and for the long-term mean annual water discharge.

- For the Pechora, mean monthly water discharges at the Andeg cross-section were assumed to be equal to the discharges at the Oksino cross-section.
- For the Yenisey, mean monthly water discharges at the Ust’-Port cross-section were assumed to be 3% higher than the discharges at the Igarka cross-section.

Analytical studies covered the whole range of PTS included within the project scope, with the exception of dioxins and brominated compounds, which were excluded due to their extremely low levels in abiotic freshwater environments. However, analysis of samples collected during field work also showed that levels of toxaphene compounds in all samples from the Pechora and Yenisey were lower than effective detection limits (0.05 ng/L for water, and 0.01 ng/mg for suspended matter), therefore toxaphene was also excluded from the assessment of fluxes.

4.3.3. Overview of the assessment results

PCB

Estimated PCB fluxes via the Pechora and Yenisey rivers are presented in Table 4.12. It is worth noting that the estimated fluxes of specific PCB congeners through both the closing cross-sections of the regular hydrometric network and the downstream cross-sections are very similar (Figure 4.44). Based on this information, the overview of assessment results for other contaminant groups, below, focuses mainly on fluxes in the closing cross-sections of the rivers.

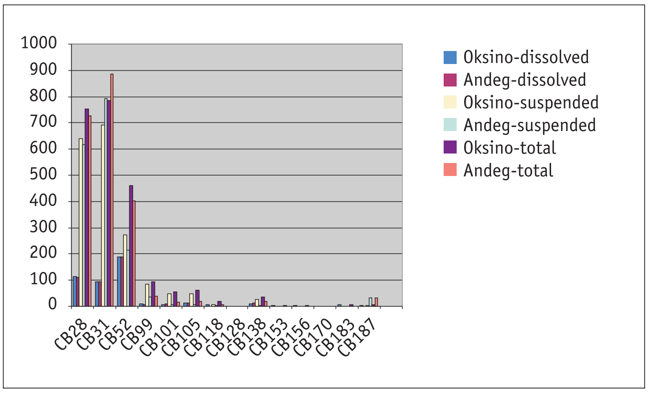
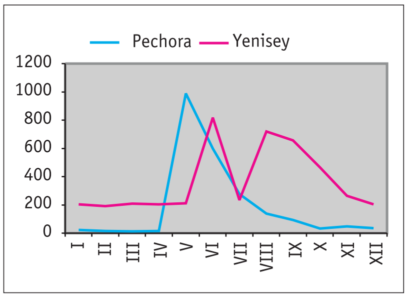


Figure 4.44. Estimated fluxes (kg/y) of PCB congeners at the closing (Oksino) and downstream (Andeg) cross-sections of the Pechora river.

The total PCB flux in the Pechora river consists almost entirely of tri- and tetra-chlorobiphenyls. Fluxes of the heavier PCB congeners are negligible. This is consistent with information presented to the OSPAR Commission by Sweden (Axelman, 1998).

The structure of PCB fluxes in the Yenisey river are more complex. As expected, peak PCB fluxes in both rivers coincide with springtime peaks in water discharge, which occur later in the lower Yenisey than in the lower Pechora. However, flux values for the Yenisey river also exhibit a distinct second peak in the late summer-autumn period (Figure 4.45).

Figure 4.45. Monthly fluxes (kg) of PCB in the Pechora and Yenisey rivers.



Two possible explanations for the second peak are:

- instrumental/procedural errors during analysis of the samples;
- accidental PCB release from some unknown pollution source.

Although it is difficult to make a definite conclusion regarding the cause of this peak appearance, the following information should be noted:

- the peak was observed not only during the summer low water period, when it was detected for the first time, but also during the period before ice formation in October (Figure 4.62);
- the peak is due to increased fluxes in PCB congeners associated with suspended matter, with dissolved forms showing practically unchanged fluxes;
- compared to the spring flood peak, which, as in the case of the Pechora, is a result of fluxes of tri- and tetra-chlorobiphenyls, the second flux peak has a higher contribution of penta- and hexa-chlorobiphenyls, particularly CB118 and CB138 (Figure 4.46).

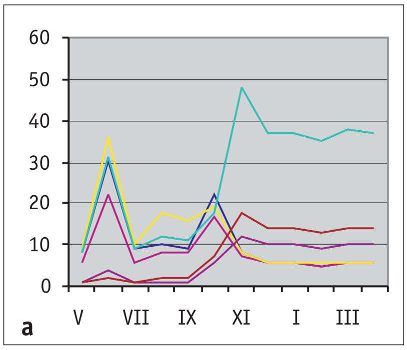
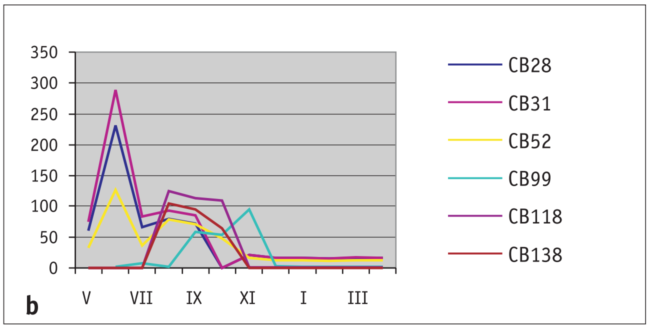


Figure 4.46. Monthly fluxes (kg) of selected PCB congeners in (a) dissolved (b) suspended form in the Yenisey river.



Compound	Form	Pechora 2001-2002	Pechora Long-term	Yenisey 2001-2002	Yenisey Long-term
1234-TeCBz	Dissolved	6.6	7	0	0
	Suspended	2.4	2.5	16	12
	Total	**9**	**9.5**	**16**	**12.7**
1235-TeCBz	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
1245-TeCBz	Dissolved	8.8	9.7	138	112
	Suspended	5.9	6.3	170	131
	Total	**14.7**	**16**	**308**	**242**
QCB (PeCBz)	Dissolved	8.7	9.4	29.7	24.7
	Suspended	59.7	65.1	189	171
	Total	**68.4**	**74.5**	**218**	**196**
HCB (HxCBz)	Dissolved	73.8	79.1	200	175
	Suspended	143	155	161	139
	Total	**217**	**235**	**362**	**314**
ΣPCBz	Dissolved	97.9	105	368	311
	Suspended	211	229	536	454
	Total	**309**	**335**	**904**	**765**

Table 4.13. Fluxes of polychlorinated benzenes (kg/y) in flows of the Pechora and Yenisey rivers, calculated for the period of observations (2001-2002), and for the long-term mean annual water discharge.

This evidence, whilst indirect, argues for the likely explanation being an accidental PCB release from a non-identified local source. However, in case of a short-term release, estimation of the annual flux based of this data can be overestimated.

Polychlorinated benzenes
Estimates of annual fluxes of polychlorinated benzenes (PCBz) in the flows of the Pechora and Yenisey rivers are presented in Table 4.13. As expected, hexachlorobenzene (HCB) is the main compound in this contaminant group, with relatively high fluxes in both rivers. Although tetra-chlorinated benzenes (TeCBz) have occasionally been found in both water and suspended matter of both rivers, their concentrations were close to detection levels, and as such they cannot be considered contaminants that pose a significant threat to either the aquatic environment or humans. Seasonal distribution of fluxes exhibit the a typical pattern of a peak during the spring flood period (Figure 4.47).

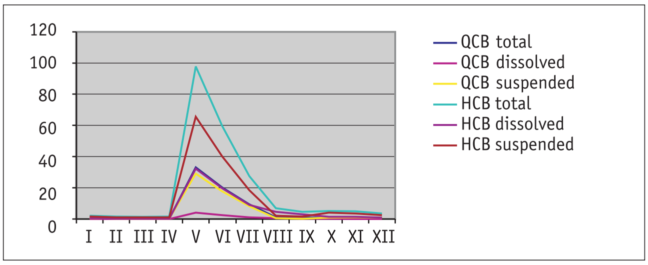


Figure 4.47. Monthly fluxes (kg) of QCB and HCB in the Pechora river.

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
α-HCH	Dissolved	98.4	157	71.6	60.2
	Suspended	85.4	351	699	271
	Total	**184**	**509**	**771**	**210**
β-HCH	Dissolved	14.8	34.5	16.4	16.9
	Suspended	71.6	158	161	0
	Total	**86.4**	**192**	**177.6**	**16.9**
γ-HCH	Dissolved	109	190	109	47.2
	Suspended	159	721	751	218
	Total	**267**	**912**	**859**	**265**
Σ HCH	Dissolved	222	382	197	123
	Suspended	316	1230	1610	488
	Total	**537**	**1610**	**1810**	**612**

Table 4.14. Fluxes of HCH compounds (kg/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

Organochlorine pesticides and their metabolites

(a) Hexachlorocyclohexane (HCH)
Data on HCH fluxes in the Pechora and Yenisey rivers are presented in Table 4.14. For both rivers, total HCH fluxes are dominated by α- and γ-HCH isomers, with γ-HCH the most prevalent. However, the two rivers do not show consistent trends between the closing cross-sections of the regular observation network and the more downstream cross-sections, established close to areas inhabited by indigenous population. Fluxes of all

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
o,p'-DDT	Dissolved	18.0	20.7	93.2	115
	Suspended	55.9	476	417	93.1
	Total	**73.9**	**497**	**511**	**209**
p,p'-DDT	Dissolved	33.8	90.8	247	200
	Suspended	119	855	835	238
	Total	**153**	**945**	**1080**	**438**
Σ DDT	Dissolved	51.8	112	340	315
	Suspended	175	1440	1250	331
	Total	**227**	**1554**	**1590**	**646**
o,p'-DDE	Dissolved	5.5	3.7	10.9	8.7
	Suspended	30.2	59.2	155	73.2
	Total	**35.7**	**62.9**	**166**	**81.9**
p,p'-DDE	Dissolved	14.7	21.2	46.4	30.8
	Suspended	75.6	93.7	354	137
	Total	**90.3**	**115**	**400**	**168**
Σ DDE	Dissolved	20.2	24.9	57.3	39.5
	Suspended	106	153	509	210
	Total	**126**	**178**	**566**	**250**
o,p'-DDD	Dissolved	20.2	13.3	127.3	68.0
	Suspended	30.1	45.3	24.5	6.5
	Total	**50.3**	**58.6**	**151.8**	**74.5**
p,p'-DDD	Dissolved	5.6	~0	333.0	229.7
	Suspended	0.5	94.9	84.8	~0
	Total	**6.1**	**94.9**	**418**	**230**
Σ DDD	Dissolved	25.8	13.3	460	297
	Suspended	30.6	140	109	6.5
	Total	**56.4**	**154**	**570**	**303**
Σ DDTs	Dissolved	97.8	146	857	652
	Suspended	311	1740	1870	548
	Total	**409**	**1880**	**2730**	**1200**
DDE:DDT ratio	Dissolved	0.39	0.22	0.17	0.13
	Suspended	0.6	0.11	0.41	0.63
	Total	**0.55**	**0.12**	**0.36**	**0.39**

Table 4.15. Fluxes of DDT compounds (kg/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

HCH compounds increase downstream in the Pechora river, while the Yenisey shows the opposite trend. A possible explanation is that the downstream section of the Pechora rivers shows the impact of local HCH usage, while HCH fluxes in the lower Yenisey river are the result of long-range transport alone, and thus the downstream section of the river has lower loads due to self-purification processes in the aquatic environment. It should be noted however that in case of short-term environmental releases annual fluxes can be overestimated.

(b) DDTs
Fluxes of DDTs in flows of the Pechora and Yenisey rivers show similar trends as for HCHs (Table 4.15), with a strong increase in concentrations between the Oksino and Andeg cross-sections of the Pechora, and a decrease between the Igarka and Ust'-Port cross-sections of the Yenisey. This can be explained by a large local input of DDT into the lower part of Pechora, particularly during the spring flood period (Figure 4.48), whereas in the Yenisey, the contamination is the result of long-range transport of contaminants in the Yenisey, with fluxes decreasing downstream due to self-purification. This conclusion is supported by the significant change seen in the composition of the total DDTs flux at the downstream Andeg cross-section when compared to Oksino. At Andeg, the proportion of the DDT

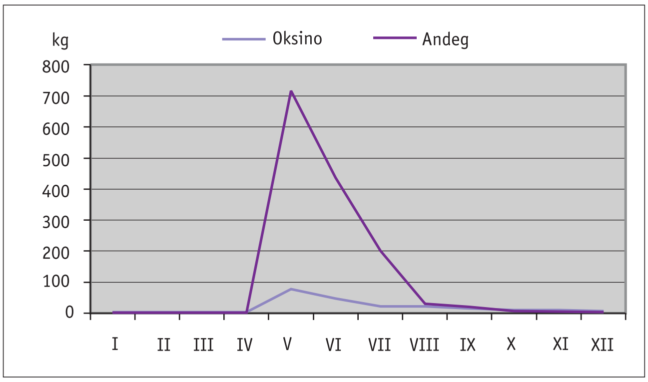


Figure 4.48. Monthly fluxes (kg) of DDT in the Pechora river.

component is far greater (Figure 4.49). Considering that the absolute value of Σ DDD, which is a dechlorinated DDT analog in the technical DDT mixture (AMAP, 1998), also shows an almost three-fold increase, it is reasonable to assume that the DDT flux increase is due to fresh local input of DDT. For the Yenisey river, the Σ DDT flux composition did not alter between the two cross-sections. In this case, like in case of HCH, annual fluxes can be overestimated.

It should be noted that the increase in DDT flux at the

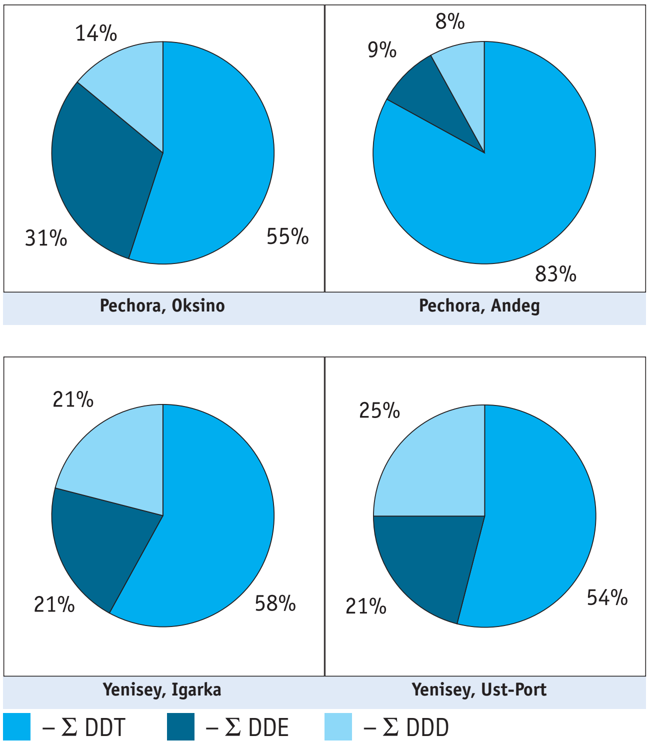


Figure 4.49. Composition of total DDT fluxes in the Pechora and Yenisey rivers.

Andeg cross-section is mostly determined by an increase in its suspended form. Data quality can be verified from the comparability of data obtained for the suspended matter flux in different layers of the Andeg cross-section (Figure 4.50). The ratio of *o,p'*-DDT to *p,p'*-DDT in the surface, middle and bottom layers of the river flow remains constant, however, the surface layer shows lower levels of DDT when compared to the middle and bottom layers.

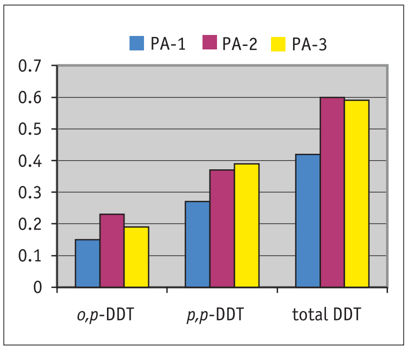


Figure 4.50. DDT concentrations (ng/mg) in suspended matter of the Pechora river at the Andeg cross-section (PA-1: surface layer, PA-2: middle layer, PA-3: bottom layer) (see Figures 4.40 and 4.49).

(c) Other chlorinated pesticides

Other chlorinated pesticides included in the priority list of PTS considered in the project were either found only at levels below detection limits, or had fluxes that would not be expected to have any noticeable impact on the health of indigenous human populations (Table 4.16).

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
Heptachlor	Dissolved	11.9	21.2	7.0	1.1
	Suspended	0.5	0	2.7	0
	Total	**12.4**	**21.2**	**9.7**	**1.1**
Heptachlorepoxide	Dissolved	0	0	0	0
	Suspended	0.9	0	1.5	0
	Total	**0.9**	**0**	**1.5**	**0**
***Cis*-chlordane**	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
***Trans*-chlordane**	Dissolved	6.6	17.4	117	99
	Suspended	0.5	0	0.3	0
	Total	**7.1**	**17.4**	**118**	**99**
***Cis*-nonachlor**	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
Trans-nonachlor	Dissolved	10.3	19.5	7.2	0
	Suspended	1.3	0	7.9	0
	Total	**11.6**	**19.4**	**15.1**	**0**
Photomirex	Dissolved	0	0	0	0
	Suspended	0	0	0	0
	Total	**0**	**0**	**0**	**0**
Mirex	Dissolved	0	0	0	0
	Suspended	2.6	3.1	0	0
	Total	**2.6**	**3.1**	**0**	**0**

Table 4.16. Fluxes of other chlorinated pesticides (kg/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

Polycyclic aromatic hydrocarbons (PAHs)

The list of PAHs included in the scope of the preliminary assessment of riverine fluxes included 20 compounds. Annual fluxes of 10 PAHs in the Pechora and Yenisey are presented in Figures 4.51 and 4.52, respectively. However, fluxes of several PAHs could not be assessed, as their concentrations in water and suspended matter in both rivers were below detection limits. These were:

acenaphthene, benzo[*a*]anthracene,
benzo[*b*]fluoranthene, benzo[*e*]pyrene, perylene,
benzo[*k*]fluoranthene, benzo[*a*]pyrene,
dibenzo[*a,h*]anthraceneindeno[1,2,3-*c,d*]pyrene,
and benzo[*ghi*]perylene.

In both rivers, PAH fluxes are dominated by the more soluble 2-cyclic PAHs (naphthalene, 2-methylnaphthalene, biphenyl) and, to certain extent, 3-cyclic PAHs (fluorene, phenanthrene). At the downstream Ust'-Port cross-section of the Yenisey river, PAH fluxes are significantly lower. This confirms an absence of additional PAH sources between the two cross-sections along this part of the river. However, fluxes of some PAHs at the downstream Andeg cross-section of the Pechora river are significantly higher than at the upstream Oksino cross-section. This is true not only for 2- and 3-cyclic PAHs, such as 2-methylnaphthalene, fluorene and phenanthrene, but also for the heavier PAHs (fluoranthene and pyrene). Increase in fluxes of these less readily transported 4-cyclic PAHs provides additional evidence of local pollution sources between the Oksino and Andeg cross-sections of the Pechora river.

Contaminant	Form	Pechora		Yenisey	
		Oksino	Andeg	Igarka	Ust-Port
Lead	Dissolved	89.2	77.1	624	375
	Suspended	77.2	24.4	114	535
	Total	**166**	**101**	**738**	**911**
Cadmium	Dissolved	6.77	3.31	124	122
	Suspended	22.05	9.90	4.34	26.98
	Total	**28.8**	**13.2**	**129**	**149**
Mercury	Dissolved	1.02	0.472	0	0
	Suspended	1.82	1.75	2.79	9.10
	Total	**2.84**	**2.22**	**2.79**	**9.10**

Table 4.17. Fluxes of heavy metals (t/y) in flows of the Pechora and Yenisey rivers for 2001-2002.

Heavy metals.
Data on annual fluxes of heavy metals that were included in the study (lead, cadmium, and mercury) are presented in Table 4.17.

(a) Lead
The intra-annual distribution of lead fluxes in flows of the Pechora and Yenisey rivers are presented in Figures 4.53 and 4.54. For both rivers, peaks of lead fluxes coincide with the peak of the spring flood. It is noticeable that the composition and annual distribution of lead flux in the Yenisey river has a more complicated pattern than that of the Pechora river. During low-water periods, and particularly during the ice cover season, lead flux at both the Igarka and Ust'-Port cross-sections is dominated by the dissolved form of the metal, with levels almost twice as high at the upstream cross-section. However, during the flood period, the flux at the Ust'-Port cross-section is significantly higher than at Igarka, and is mostly due to suspended forms of lead.

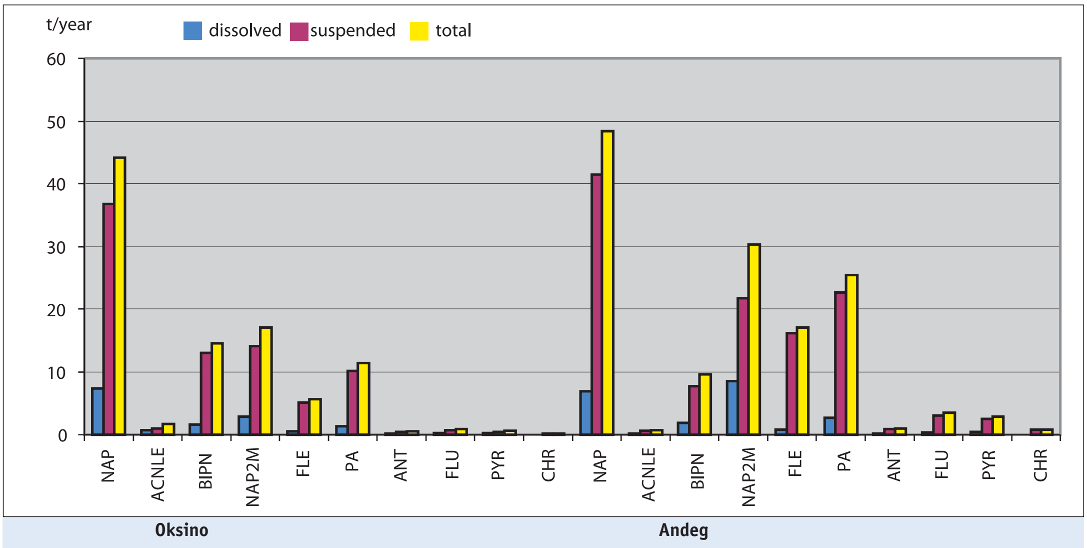


Figure 4.51. Estimated fluxes (t/y) of PAHs in the flow of the Pechora river.

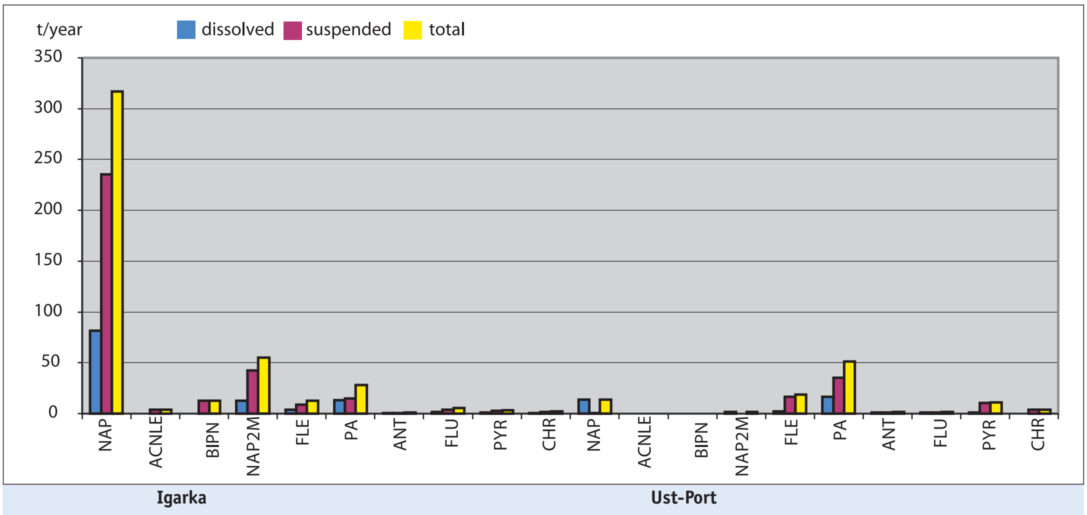


Figure 4.52. Estimated fluxes (t/y) of PAHs in the flow of the Yenisey river.

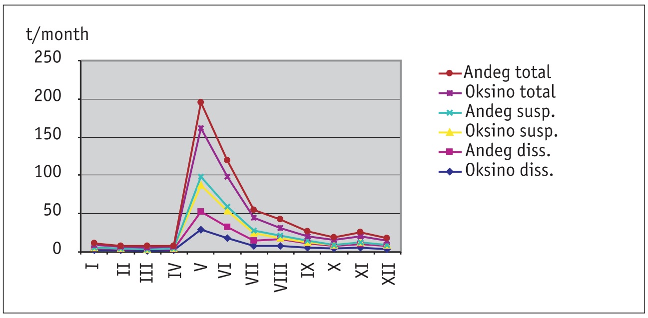


Figure 4.53. Monthly fluxes (t) of lead in the Pechora river.

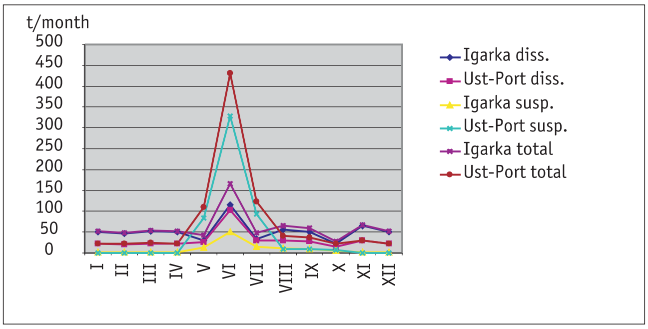


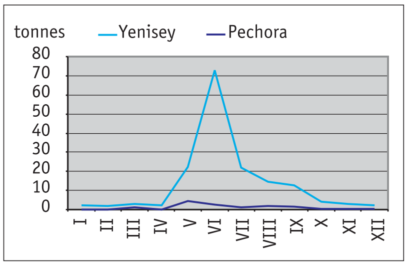
Figure 4.54. Monthly fluxes (t) of lead in the Yenisey river.

This suggests that during the ice cover season, lead flux is almost totally determined by long-range transport of the more mobile dissolved form of lead, from industrialized regions in the central part of the Yenisey basin; whereas, during the flood period, lead flux is dominated by local runoff from the area between Igarka and Ust'-Port, which can be significantly affected by the Norilsk industrial region.

(b) Cadmium

Compared to the other PTS, the difference in cadmium fluxes seen in the flows of the Pechora and Yenisey rivers is much more pronounced (Figure 4.55). It is also notable that the composition of cadmium fluxes in the two rivers are different (Figures 4.56 and 4.57). The Pechora river flux has a much greater proportion of the suspended form of cadmium, particularly during the spring flood period. During the ice cover season, this difference is not so noticeable. This could be explained by the higher sediment load of the Pechora, compared to the Yenisey.

Figure 4.55. Monthly fluxes (t) of (dissolved+suspended) cadmium in the Pechora and Yenisey rivers.



(c) Mercury

In general, the intra-annual distribution of mercury fluxes in the Pechora and Yenisey correspond to the respective river hydrographs, with the highest fluxes during the spring flood period (Figures 4.58 and 4.59). The Yenisey river mercury flux almost totally consists of suspended forms of the metal. The composition of the mercury flux of the Pechora river is more complicated, and differs between the Oksino and Andeg cross-sections (Figure 4.60). Total flux at the upstream Oksino cross-section is higher relative to that at Andeg (Figure 4.61). During the spring flood period, suspended forms of mercury are dominant in the flux, particularly at

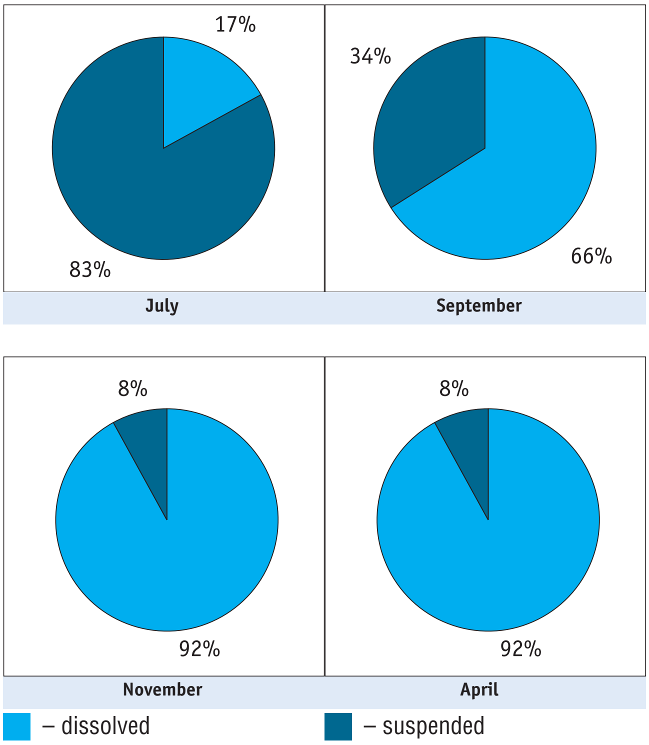


Figure 4.56. Seasonal changes in the ratio of dissolved and suspended fluxes of cadmium in the Pechora river flow.

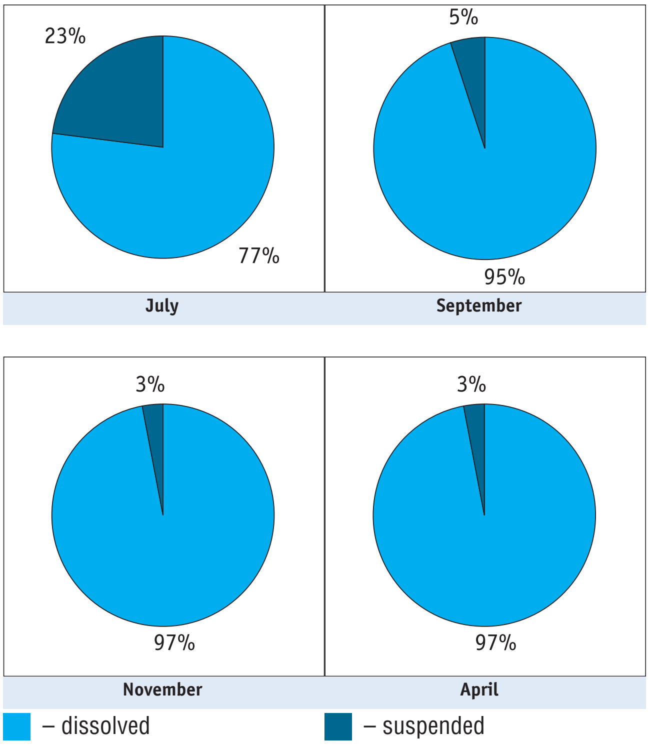


Figure 4.57. Seasonal changes in the ratio of dissolved and suspended fluxes of cadmium in the Yenisey river flow.

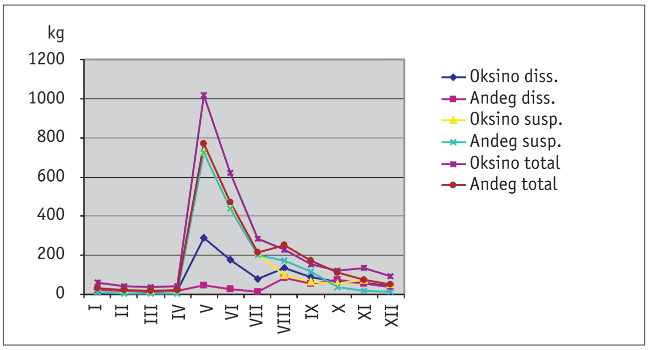


Figure 4.58. Monthly fluxes (kg) of mercury in the Pechora river.

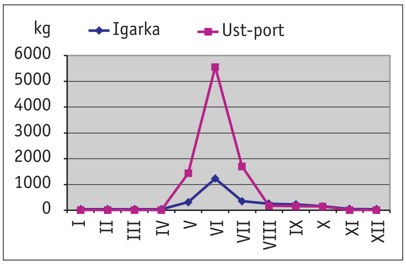


Figure 4.59. Monthly fluxes (kg) of mercury in the Yenisey river.

Andeg. During low water periods, the dissolved proportion of the total mercury flux is larger, amounting to 74% of the total at Andeg during the ice cover season. It should be also noted that during this period, the dissolved flux at these two cross-sections is fairly constant (17-20 kg), while suspended flux is noticeably lower at Andeg than at Oksino (Figure 4.61); this can be explained by sedimentation processes.

The significant difference in the composition of mercury fluxes in the Pechora and Yenisey rivers may be explained by differences in their water composition. Concentrations of total organic matter in the Pechora are almost twice as high as those in the Yenisey, reaching 13-15 mg/L Total Organic Carbon (TOC), 98% of which is in dissolved form (Kimstach *et al.*, 1998). As TOC in natural waters is mostly represented by humic and fulvic acids, which form strong complexes with mercury, the trends in the Pechora mercury fluxes are understandable.

4.3.4. Conclusions

1. In general, PTS fluxes in the Pechora and Yenisey river flows correspond to seasonal river discharges. Highest fluxes usually coincide with spring peak discharges.

2. Among the chlorinated persistent organic pollutants, the highest fluxes are observed for PCBs, HCH and DDTs. The amounts of these contaminants transported by river flows to areas inhabited by indigenous peoples are such that they could contribute to risks to human health.

3. Levels of other chlorinated organic pollutants are either below detection limits, or their fluxes are not sufficiently high to represent a significant risk to the indigenous population.

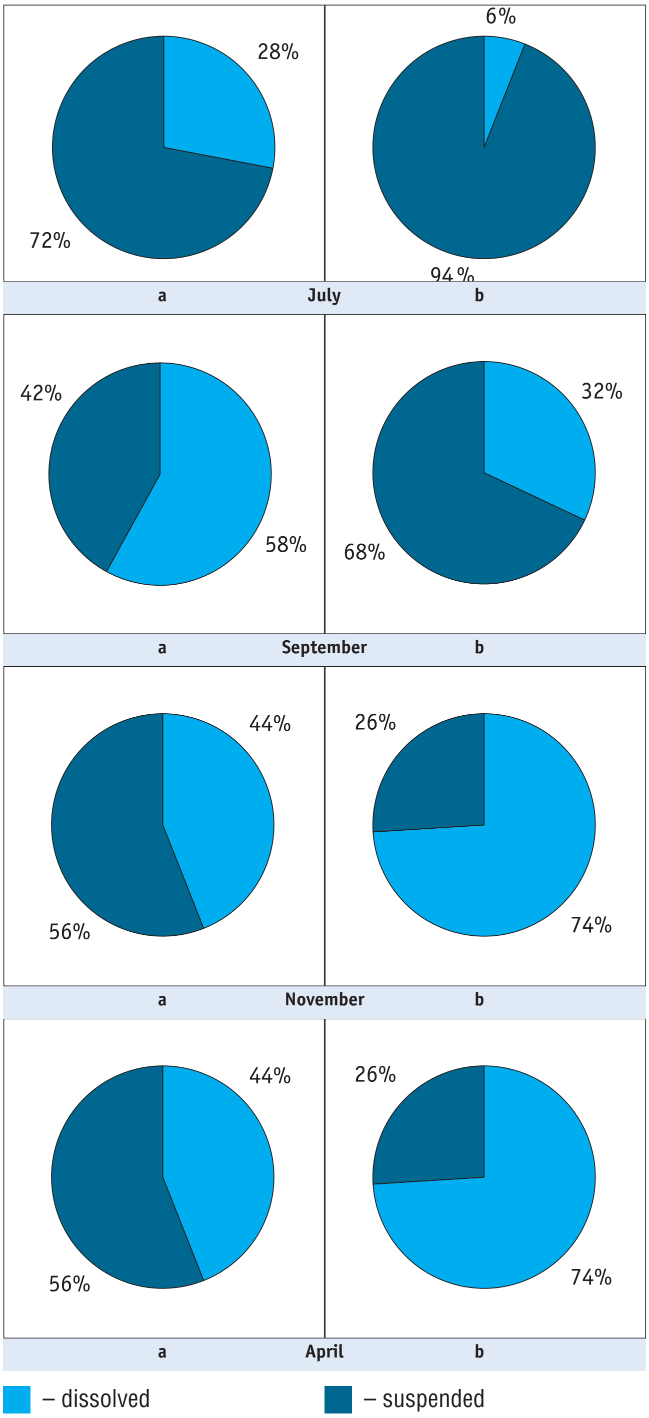


Figure 4.60. Ratio of dissolved and suspended fluxes of mercury at (a) the Oksino and (b) the Andeg cross-sections of the Pechora river

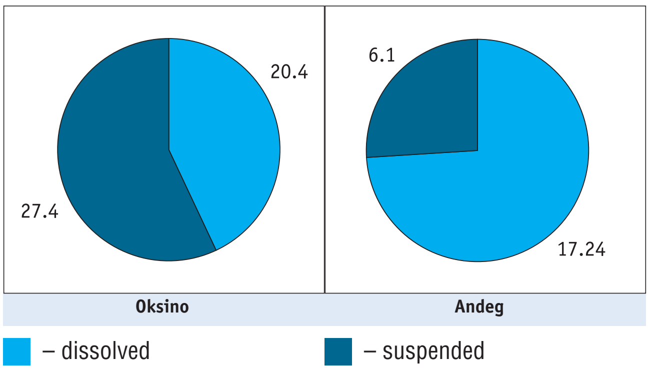


Figure 4.61. Mercury fluxes (kg) at two cross-sections in the Pechora river in April 2002

4. PCB fluxes are mostly in the form of tri- and tetra-chlorobiphenyls. Fluxes of the heavier PCB congeners are practically negligible.

5. HCH and DDT fluxes in the Yenisey river flow are the result of long-range transport. In the Pechora river, local sources may contribute to the fluxes of HCH and DDT in the lower reaches of the river. DDE to DDT ratios indicates that the increased DDT flux in the lower part of the river may be caused by fresh use of this pesticide. However, taking into account possible short-term environmental release of these substances, their annual fluxes can be overestimated.

6. Fluxes of polycyclic aromatic hydrocarbons (PAHs) in both rivers consist mostly of 2- and 3-cyclic compounds. In addition to contamination through long-range transport, the lower reaches of the Pechora river may also be affected by local sources of PAHs, which contribute some heavier compounds.

7. Fluxes of heavy metals (lead, cadmium and mercury) in the flow of the Yenisey river, are the result of local contamination, in addition to contamination from long-range transport, particularly during the spring flood period. This can be explained by the influence of pollution from the Norilsk industrial complex.

4.4. Local pollution sources in the vicinities of indigenous communities

4.4.1. Introduction

The main objectives of undertaking an assessment of local pollution sources were to determine their role in general environmental pollution, in the contamination of traditional food products and, accordingly, to determine their influence on human health. For inventory purposes, 'local sources' were taken to mean sources within an approximate maximum distance of 100 km of sites of residence of indigenous peoples. Specific boundaries for inventory zones, however, were defined more exactly in each case by taking account of local conditions (dominating winds, river flows and the scale of regional sources, etc.). As some of the pilot study areas within the project are affected by pollution which originates from large industrial complexes located in their vicinity, the pollution source inventory included such towns as Apatity, Monchegorsk, Olenegorsk, Revda, and Kirovsk (in Murmansk Oblast); Nar'yan-Mar (in the Nenets AO); Norilsk (located in the Taymir AO, but under the administrative authority of Krasnoyarsk Krai); and Anadyr (in the Chukotka AO).

The assessment was based on official data relating to PTS emissions, obtained from the various administrative territories and regions, representatives of the Russian Association of Indigenous People of the North (RAIPON), and also from expert estimates of PTS release resulting from use of organic fuel (as this information is not included in official statistical data on PTS emissions). This latter source of atmospheric PTS is important for pollutants such as heavy metals, PAHs, and dioxins. It should be mentioned that in Russia, dioxin emissions have not been recorded and, among PAHs, only benzo[*a*]pyrene emissions are recorded.

Under the study, expert estimates were made for emissions of the following PTS: lead, cadmium, mercury, benzo[*a*]pyrene, benzo[*k*]fluoranthene, indeno[1,2,3-*c,d*]pyrene, and dioxins. These estimates were made using statistical data relating to consumption of the various kinds of fuels and associated emission factors (for the amount of contaminants released to the atmosphere per tonne of a specific fuel). Emission factors were determined either in accordance with existing Russian methodology, or by adapting Western European emissions factors to take account of Russian technologies.

Statistical data were provided by the State statistic offices of the relevant administrative territories of the Russian Federation, environmental protection authorities, and reports by the Russian Federation's State Committee for Statistics (Goskomstat).

Regional Branches (Committees) of the Russian Federation's Ministry of Natural Resources were responsible for the initial collection and processing of data and information. The inventory of pollution sources was based upon the following sources of information:

- State Statistic Reports on emissions of gaseous pollutants discharges of waste waters, and solid waste from industrial, municipal and agricultural enterprises and transport;
- Ecological passports of industrial enterprises;
- Reports on environmental protection activities of the local environmental protection authorities, sanitary-epidemiological control services, agricultural administrative authorities, and other information sources (Murmansk, 1991-2000; Murmansk, 1996-2000; Murmansk, 2001; Murmansk, 1994-2000; Nenets, 1998; Nenets, 1999; Nenets, 2001);
- Annual reports and reviews of Federal Ministries and Departments (MNR, 2001; Roshydromet, 1995-2000);
- Other relevant official sources and literature.

It is necessary to mention, however, that there was variation in the completeness and volume of information provided by the various regions for the inventory, due to different technical, organizational, and other aspects of the relevant local services. Due to this, a certain amount of data are derived from expert estimates.

City/District (Rayon)	Total	SO_2	NO_x	CO	Dust
Murmansk	26.8	19.6	2.8	2.2	1.7
Apatity	21.9	12.0	3.9	0.2	5.8
Kirovsk	11.5	6.7	2.1	1.1	1.4
Kandalaksha	22.8	5.4	0.6	7.2	8.2
Monchegorsk	58.1	43.9	1.2	3.8	7.8
Olenegorsk	12.4	4.4	1.0	26	3.9
Severomorsk	10.2	6.4	0.6	2.3	0.7
Kovdorsky District	7.7	3.8	0.5	1.9	1.4
Kolsky District	5.0	2.3	0.3	1.7	0.7
Lovozersky District	2.0	1.3	0.2	0.3	0.1
Pechengsky District	137.9	124.4	0.6	2.2	10.6
Total emissions in Murmansk Oblast	332.5	240.1	14.7	29.8	43.7
Total emissions in inventory area	105.9	61.6	8.4	8.0	19.0
Percentage of the Oblast's emissions occurring in the inventory area	31.8	25.7	57.1	26.8	43.5

Table 4.18. Industrial air emissions of major contaminants in the cities and districts of the Murmansk Oblast in 2002, thousand tonnes (NEFCO, 2003).

4.4.2. Murmansk Oblast

4.4.2.1. General description

The inventory of PTS sources covered the territory within a radius of at least 100 km of the settlement of Lovozero. It includes the cities of Monchegorsk, Olenegorsk, Apatity, Kirovsk, and Revda.

Murmansk Oblast is one of the largest and most economically developed regions of Russia's European North. Almost the entire territory lies to the North of the Arctic Circle. The population amounts to 958,400 residents, of whom 91.7% are urban and 8.3% percent are rural. The northern indigenous peoples, mostly Saami, amount to 0.2% of the total population.

The economy of Murmansk Oblast is mainly oriented towards the extraction and reprocessing of natural resources. The region produces 100% of Russia's apatite concentrate, 12% of iron-ore concentrate, 14% of refined copper, 43% of nickel, and 14% of fish foodstuffs. Concerning production industries, 90% of the gross regional product is created by primary industrial enterprises.

Estimates of emissions of general air pollutants (SO_2, NO_x, CO, and dust) from industries in the region are presented in Table 4.18. Although these pollutants are not representative of any specific PTS, they do characterize levels of general environmental pollution, and thus are related to pollution impacts on human health. As shown, industrial enterprises located in the vicinity of the study area, which is densely populated by the Saami people, emit a significant part of the total industrial air emissions in Murmansk Oblast, particularly NO_x and dust.

Mining and processing plants provide the basis for the economies of the majority of the regions large towns and cities where a third of the Oblast's population live.

City/District	Enterprise	Total emissions	% in city/district
Apatity	Apatity heat and power plant	18.5	84
	'Apatit' JSC	3.5	16
Kirovsk	'Apatit' JSC	11.5	99.7
Monchegorsk	'Severonickel' NCS	51.8	89.2
Olenegorsk	'Olcon'JSC	10.9	87.9
Lovozersky District	Revda heat and power plant	0.8	40
	'Lovozero GOC' JSC	0.3	15

Table 4.19. Total air emissions of pollutants (thousand tonnes) from major industrial pollution sources in the inventory area in Murmansk Oblast, 2002, and their percentage contribution to emissions from the corresponding cities/districts.

Enterprise	Total dis-charge	Biode-gradable organic substances	Suspen-ded matter	SO_4^{2-}	Cl^-	Ni	Cu
'Severonickel' NCS	14.7	48.7	364	38780	6800	10.9	2.1
Lovozero GOC	13.6	21.0	200	82	76	-	-
'Apatit' JSC	145.5	288	514	8694	909	-	-

Table 4.20. Wastewater discharges (million m3) from selected large industrial enterprises in 2002, and associated discharges (tonnes) (NEFCO, 2002).

These include the Nickel and Copper Combined Smelter JSC GMK Pechenganikel, in the city of Zapolyarny and the town of Nikel; the Iron Ore Concentration Plant JSC Olkon, in the city of Olenegorsk; the Nickel and Copper Combined Smelter JSC Severonikel, in the city of Monche-gorsk; the Mining Plant Apaptit JSC, in the cities of Kirovsk and Apatity; the Iron Ore Kovdor Mining and Concentration Plant JSC, and the Concentration Plant Kovdorslyuda JSC, in the city of Kovdor; and the rare metals extraction and concentration plant Sevredmet JSC, in the settlement of Revda. The contributions made by the large enterprises located in the inventory area to total air emissions in the corresponding city/district are presented in Table 4.19.

Surface water bodies located close to settlements and industrial complexes have a high degree of pollution, as determined by their acidification (pH) and levels of fluorine (F), aluminium (Al), iron (Fe), and manganese (Mn), which all exceed maximum permissible concentrations. Data on wastewater discharges from the selected large industrial enterprises in the survey area are presented in Table 4.20.

Monchegorsk area

A zone of 'extremely unfavorable environmental pollution' lies within the area influenced by the cities of Monchegorsk and Olenegorsk. This zone occupies an area of about 1400 km^2, and has the form of an ellipse with the city of Monchegorsk at its epicenter and its long axis extending 48-50 km to the south (due to the prevailing wind direction). In the north, the zone extends as far as the city of Olenegorsk, incorporating the urban agglomeration, and in the south, it extends to Viteguba. The Monchegorsk area is characterized by extreme levels of annual deposition of nickel (Ni) and copper (Cu) (115.9 and 136.5 kg/km^2, respectively). Cadmium levels in the surface geological horizon in this area are five times higher than the background level for the region. These figures confirm the high environmental impact of the Monchegorsk 'Severonickel' combined smelter.

Kirovsk – Apatity
This area is located within the limits of the Khibiny Massif, which is a natural geochemical anomaly with respect to the vast number elements and the unique deposits of apatite and nepheline ores. 'Apatit' JSC, which processes and enriches deposits of apatite and nepheline ores, is considered as the main pollution source for this area. The plant is one of the world's biggest manufacturers of raw phosphate used in the production of mineral fertilizers. 'Apatit' JSC is a huge mining and chemical complex which currently includes four mines, a concentration plant, railway facilities, an automobile workshop, and about thirty other service workshops.

Since opening, the 'Apatit' plant has extracted and transported more than 1.4 x 10^9 tonnes of ore to the concentration plant, and produced about 520 million tonnes of apatite and more than 52 million tonnes of nepheline concentrates. The concentrates also contain fluorine, strontium oxide, and rare-earth elements, which may be separated as individual products during processing. Nepheline concentrate is used as a raw material for producing alumina, and in the glass and ceramic industries. It is also used as a raw material for producing soda, potash, cement, and other products.

Lovozero – Revda
This area is located in a zone of heavy metal contamination created by the 'Severonickel' combined smelter. The largest local pollution source is the rare metals combined enterprise JSC 'Lovozero GOC' (formerly known as – 'Sevredmet'), located in the settlement of Revda. The enterprise consists of two mines (Karnasurt and Umbozero) and two concentration plants. Tailings and rocks left after drifting and stripping are stockpiled in surface dumps and storage sites. Mining and drainage waters are discharged into surface water bodies.

The river with the highest anthropogenic load is the Sergevan, which receives untreated and poorly-treated mining, filtration, and domestic wastewaters from the Karnasurt mine and concentration plant. Fluorine, sulphates, and nitrates are typical constituents of the mining waters. Environmental and geochemical mapping of the northern part of the Lovozero Massif which was carried out between 1993 and 1996, (Lipov, 1997), depicted areas classed as extremely hazardous (125 km^2), hazardous (200 km^2), moderately hazardous (240 km^2) and acceptable (435 km^2) with respect to pollution of soils. The total area of polluted land amounted to 565 km^2. With increasing distance from the industrial pollution sources and the Lovozero Massif (an ore-rich feature, which itself creates a natural geochemical anomaly), a drastic reduction in the content of all polluting substances in soils, with the exception of sulphur, can be observed. Sulphur content in soils has a patchy occurrence, with localised 'hotspots', usually seen in remote places, far from the sources of gas and dust emissions.

As in the case of soils, the highest pollution levels in mineral bottom sediments of water bodies are observed in the area of the Lovozero Massif and its spurs, where the main mining and concentration plants are located. Similar to soils, the maximum levels of toxic elements (for the same group of main pollutants) found in bottom sediments generally correspond to the level of emissions. Contrary to its distribution in soils, however, maximum concentrations of sulphur are found in the bottom sediments of water courses in urban areas.

4.4.2.2. Inventory of PTS pollution sources

Pesticides
According to data provided by the Murmansk Territorial Station for Plant Protection, chlorinated pesticides that are the main subject of the PTS inventory have not been used, and are not currently used, in Murmansk Oblast. Other types of pesticides used over the last twenty years, according to the information available from this office, are shown in Table 4.21. The quantity of pesticides used on open ground varies from tens to a few hundred kilograms in weight, because the area of agricultural land is limited.

Enterprise	Pesticide	Amount used, kg	Treated area, hectares
Sovkhoz 'Industria', Apatity	Prometrin	3340	668
	Zenkor	70	100
	Fosulene	42	7
	Syrtin	500	100
	Licoprop	500	125
	Likmin	531	161
	Lontrel	90	90
	Bazargan	248	161
	Ramrod	50	5
Sovkhoz 'Monchegorsky', Monchegorsk	Licoprop	724	181
	Likmin	540	180
	Bazargan	370	185
	Ramrod	180	18
	Prometrin	24	9
Sovkhoz 'Tundra', Lovozero	Licoprop	80	20
	Likmin	60	20
Sovkhoz 'Revda', Revda	Licoprop	520	130
	Likmin	270	90
	Bazargan	184	92
POSVIR, Apatity	Prometrin	390	78

Table 4.21. Use of pesticides in 1990-2000 in the Murmansk Oblast inventory area, data from the Murmansk Territorial Station for Plant Protection.

Such agricultural enterprises as 'Industria', 'Revda', and 'Monchegorsky' and "POSVIR", store pesticides in standard or customized warehouses, which are registered by the sanitary and epidemiological surveillance bodies. The agricultural enterprise 'Tundra' has received one-off permissions for delivery and use of plant protection chemicals.

It should be noted that the table contains data on herbicides only, and that no other types of pesticides, particularly insecticides, are included. It is, therefore, likely that the data and information provided by the regional authorities responsible for pesticide use and handling is incomplete.

According to the Regional Veterinary Medicine Administration (pers. comm.: letter no. 38/482 of 08.04.2003), the pesticide 'Etacyde' was used in the 1960-1970s on reindeer farms in the Murmansk region to treat the animals against subcutaneous reindeer gadflies. From the early-1980s until the present, the pesticide 'Ivomex' has been used. According to the information received, there has been no treatment used against blood-sucking insects.

A tentative (but not comprehensive) inventory of stocks of obsolete pesticides in Murmansk Oblast, has identified a number of stocks in the study area (Table 4.22). It should be noted that this information also lacks data on stocks of chlorinated pesticides, except one enterprise in the city of Murmansk.

Location	Total	Chlorinated	Phosphorus-based	Mercury-based	Other	Poor state
Apatity	714	-	278	-	436	138
Tuloma, Kolsky District	995	-	-	-	995	-
Polyarnye Zori	7584	-	-	-	7584	-
Murmansk	195	13	75	-	107	-
Kirovsk	77	-	74	-	3	-
Murmashi, Apatitsky District	53	-	-	-	53	-
Total in Murmansk Oblast	9623	13	427	-	9183	138
Total in the inventroy area	8428	-	352	-	8076	138

Table 4.22. Stocks of obsolete pesticides in the Murmansk Oblast, kg. (in bold letters - the inventory area)

Polychlorinated biphenyls (PCBs)

There is no statistical registration or control of PCB release to the environment. Therefore, for the inventory of possible PCB pollution sources, all enterprises in the cities and villages mentioned above, plus the enterprises of the regional energy company 'Kolenergo' JSC were canvassed. According to data provided by these enterprises, the total number of power transformers in the survey area is 1590, including 1458 in operation and 132 in reserve. However, most of them are filled with the following mineral oils: T-1500, Tkp, Tk, T-750, GOST 982-56, GOST 10121-76, TP-22, and OMTI, which, according to available information, contain no synthetic PCB additives. The PCB-containing transformer fluid 'Sovtol' (total amount: 35.92 t) is used only in 13 transformers of the TNZ type at 'Apatit' JSC. The inventory did not find any other enterprises within Murmansk Oblast that use PCB-containing fluids in any type of electric equipment.

At the same time, it is notable that of the 180000 t of PCB that was produced in the former USSR/Russia, 53000 t were in the form of the product 'Sovol' that was used in the production of varnish and paint (37000 t) and lubricants (10000 t). In addition, ca. 5500 t were used by defence-related industrial enterprises for unknown purposes (AMAP, 2000) and tracing the fate of these PCB-containing products has proved problematic. In view of the fact that Murmansk Oblast is known to have a high concentration of defence-related activities, particularly in previous decades, it might reasonably be assumed that a considerable proportion of these products were used here, and probably contributed to PCB contamination of the area.

Dioxins and Furans

Data on emissions of dioxins and furans from industrial enterprises are not included in the state statistical reporting system, and therefore there is no information on their contribution to pollution of the survey area. Some enterprises, such as the combined nickel smelter 'Severonikel' are likely to be sources of dioxins, but there is no information available to confirm this assumption. Overall, there are a number of dioxin sources that are likely to affect the survey area (Table 4.23).

Dioxin sources	Emission factors (TEQ)
Incineration of domestic waste	38.2 ng/kg
Incineration of medical waste	589 ng/kg
Automobile transport:	
- leaded gasoline	45 pg/km
- diesel fuel	172 pg/km
- unleaded gasoline	1,5 pg/kg
Incineration of waste water residues	6.94 ng/kg d.w.
Cremation	17 µg/body
Burning of spent tires	0.282 ng/kg
Domestic burning of wood fuel	2 ng/kg
Cement kilns	
- with incineration of hazardous wastes	1.04 - 28.58 ng/kg cement
- without incineration of hazardous wastes	0.27 ng/kg cement
Coal re-activation	1.2 ng/kg
Smoking	0.43 - 2.9 pg/cigarette
Natural fires	2 ng/kg of biomass
Ferrous metallurgy	0.55 - 4.14 ng/kg agglomerate
Copper recycling	3.6 - 16600 ng/kg scrap
Aluminum recycling	21.1 ng/kg scrap
Open air burning of domestic waste	140 ng/kg
Industrial coal combustion	0.6 ng/kg
Domestic coal heating	6 ng/kg
Accidental fires	~66.5 µg/fire
Steel production	1.26 ng/kg raw materials
Asphalt production	14 ng/t

Table 4.23. Main sources of dioxin formation and emissions (Kluyev *et al.*, 2001).

Polyaromatic hydrocarbons (PAHs)
Of the large group of PAH compounds, only emissions of benzo[*a*]pyrene are documented. No instrumental control measurements of benzo[*a*]pyrene emissions are carried out, however. Emissions have therefore been estimated for heat and power plants using fossil fuels; metallurgical plants ('Severonikel' JSC, 'Olcon' JSC); and mining enterprises ('Apatit' JSC, 'Sevredmet' JSC).

In general, the two major PAH pollution sources are fossil fuel, including raw oil, combustion, and the incomplete incineration of organic materials such as wood, coal and oil. Usually, the heavier the fuel source, the higher the PAH content.

The main anthropogenic sources of PAH are:
- production of acetylene from raw gas;
- pyrolysis of wood, producing charcoal, tar and soot;
- pyrolysis of kerosene, producing benzene, toluene and other organic solvents;
- electrolytic aluminum production with graphite electrodes;
- coke production;
- coal gasification;
- production of synthetic alcohol;
- oil-cracking.

Large amounts of PAH can also be formed as a result of:
- incineration of industrial and domestic wastes;
- forest fires;
- energy production based on the incineration of fossil fuel;
- motor vehicles.

Benzo[*a*]pyrene emission data for the inventory area (Table 4.24), clearly show that information on emissions from industrial enterprises, even based on estimates, is extremely scarce.

Mercury
Intentional use of mercury in industrial production within Murmansk Oblast has not been documented. However, mercury-containing devices, luminescent lamps in particular, are widely used and contribute to environmental contamination, due to the lack of environmentally sound waste handling. Mercury-containing wastes (mostly discarded luminescent lamps), are the main contributors to wastes of the highest hazard class (31.7 t in 2001. There are two enterprises involved in the treatment of spent luminescent lamps:

- 'Rick-market' Ltd (Kolsky Distrikt), a new installation with environmentally sound recovery of mercury wastes;
- 'Ecord' Ltd (Kirovsk), an outdated installation that entered into operation in 1994. According to environmental protection authorities, this plant, although utilizing a proportion of lamps from Murmansk Oblast, actually contributes itself to mercury contamination of the environment. It should be stressed that this enterprise is located within the survey area.

Re-cycling of other equipment and instruments containing mercury, as well as of metallic mercury itself, is not systematically organized. Also, the two plants mentioned above only treat used lamps from industrial enterprises and not from the wider community.

Another significant source of mercury contamination is the mobilisation of mercury impurities within different industrial activities. According to expert estimates, the annual mobilization of mercury impurities within the Russian Federation comprises 83% of the annual intentional use of this metal. However, the amount of mercury released to the air through mobilisation is six times greater than that from intentional use (COWI, 2004).

Nickel and copper production are among the most important sources of mercury mobilisation. As one of the largest producers of primary nickel in the Russian Federation, the 'Severonickel' combined smelter (with annual production of 103000 t of nickel and 132700 t of copper in 2001) is located in Monchegorsk, it must be considered as a significant source of mercury contamination in the area. The average content of mercury in the sulphide copper-and-nickel ore that is used in this smelter is 1 mg/kg (Fedorchuk, 1983). However, this level can vary depending on the origin of the ore, from 0.05-0.11 mg/kg in ore from the Monchegorsk deposit to 2.78 mg/kg in ore from the Nittis-Kumuzhie (Kola peninsula) deposit. It should be noted that, in recent decades, the 'Severonickel' combined smelter has also used ore from different deposits, including those on the Taymir peninsula. Given this, the average content of 1 mg/kg provided above may be considered as a fair estimate. Expert estimates carried out within the ACAP project 'Assessment of Mercury Releases from the Russian Federation' concluded that mercury emissions from the 'Severonickel' combined smelter were 0.18-0.22 t in 2001. In addition, a further 0.075–0.111 t was accumulated in captured dust (COWI, 2004).

Table 4.24.
Trends in emissions of benzo[a]pyrene to the atmosphere in the Murmansk Oblast inventory area.

City/district	Emission, kg									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Kirovsk	29	27	na	na	na	na	9	na	na	na
Monchegorsk	na	na	na	na	na	na	14	22	19	27
Olenegorsk	6	9	na	na	na	na	na	7	6	4
Revda	na	na	na	na	na	na	na	3	na	10
Apatity	300	na	na	1	na	na	na	na	na	na
Lovozero District	na	na	na	na	na	na	na	5	1	3

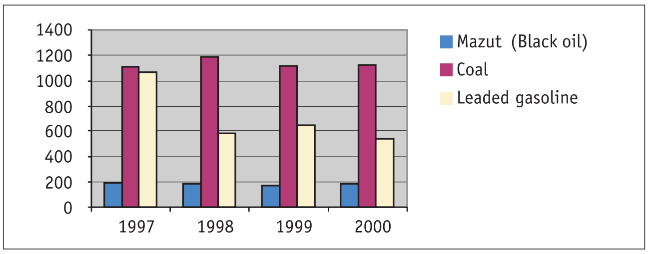


Figure 4.62. Trends in lead emissions from the combustion of fossil fuels in the Lovozero area, kg.

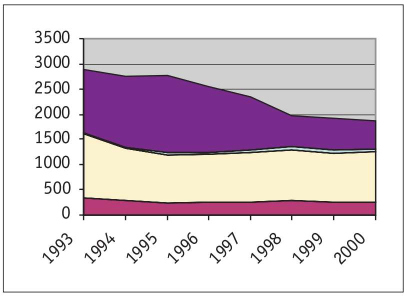


Figure 4.63. Contribution of different branches of economic activity to total lead emissions through the use of fossil fuels in the Lovozero area, kg.

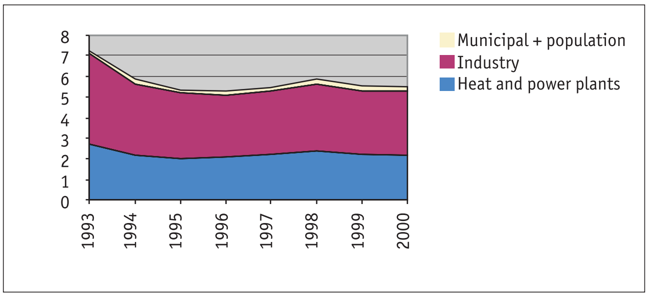


Figure. 4.64. Contribution of different branches of the economy to total mercury emissions through fossil fuel combustion in the Lovozero area, kg.

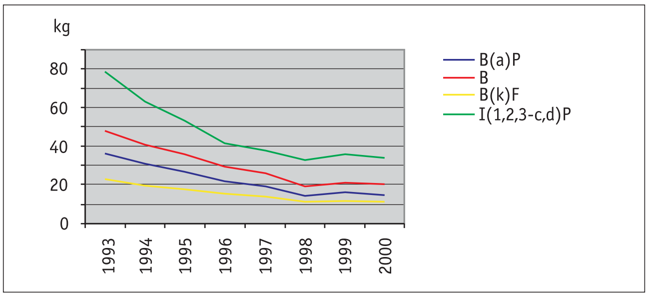


Figure 4.65. Mobilization of PAH compounds (benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]flouranthene, and indeno[1,2,3-c,d]pyrene) through the combustion of organic fuel in the Lovozero area.

4.4.2.3. PTS mobilization from combustion of fossil fuels

Official statistical data exists on the consumption of fossil fuels in Murmansk Oblast as a whole, but there are no data on organic fuel consumption in the survey area itself. According to statistics, about 23% of the total population of the Murmansk Oblast live in the survey area, and in order to estimate emissions from fossil fuel consumption it was therefore decided to assume that use of fuel is proportional to the share of the population. For calculation of dioxin and lead emissions from gasoline combustion, it was assumed that consumption of leaded gasoline in the survey area comprised about 20% of total gasoline consumption within the Oblast.

Lead

Coal combustion is considered a major contributor to lead emissions, along with the combustion of other fossil fuels. (Figure 4.62). In the middle of the 1990s, contributions from coal and gasoline combustion were comparable. However, in the late-1990s, due to the reduction in the use of leaded gasoline, coal became the dominant source of lead emissions. Total emissions from the combustion of fossil fuels in the area have decreased in recent years, mainly due to the reduction in emissions from motor vehicles (Figure 4.63).

Mercury

Mercury mobilization due to the use of fossil fuels is mostly determined by fuel combustion in industrial sectors and energy plants (heat and power plants, HPP). Fuel consumption by municipal services and the general population comprises only a minor part of total emissions (Figure 4.64). It should be noted that mercury emissions from this source have not changed significantly during recent years.

The role played by fossil fuel combustion in total mercury contamination arising from local sources, is significantly less than that due to mercury mobilization through nickel and copper production at the 'Severonickel' combined smelter (not more than 3%). However, given that domestic use of organic fuel, particularly coal, often contributes to the contamination of the indoor environment, its significance in terms of human intake may be much greater.

Polyaromatic hydrocarbons (PAHs)

Estimates of PAH mobilization through the use of organic fuel in the Lovozero area were made using methods similar to those for heavy metals (Figure 4.65).

PAH releases have gradually decreased since the early-1990s, possibly due to changes in the fuel types used. However, after 1998, the amount of PAH released stabilized, possibly due to the recovery of economy after the 1997 crisis.

Dioxins

The trend in dioxin emissions with organic fuel combustion in the Lovozero area is presented in Figure 4.66, which shows a decline during the early-1990s, but little change in emission levels since the mid-1990s.

Industrial enterprises are the main source of dioxin pollution from organic fuel in the Lovozero area according to Figure 4.67. However, it should be noted

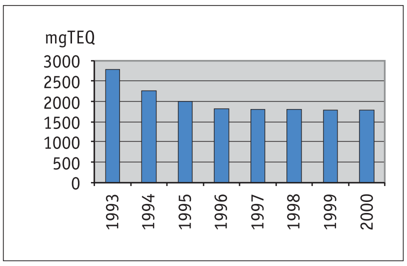


Figure 4.66. Dioxin emission trend in the Lovozero area from organic fuel combustion.

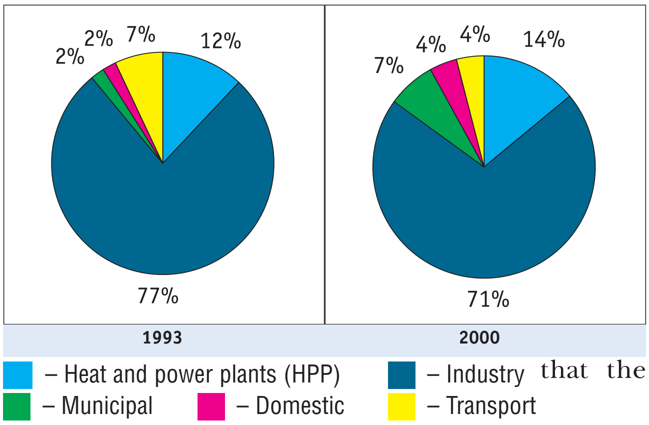


Figure 4.67. Contribution of different types of activities in the Lovozero area to dioxin emissions through the combustion of organic fuel.

contribution from the municipal sector, particularly from local boilers used for non-centralized heating, has significantly increased in recent years. Although still much less than emissions from industrial enterprises, the three-fold growth in dioxin emissions from municipal sources within seven years (from 42.23 mg TEQ in 1993 to 122 mg TEQ in 2000) is a matter of concern.

4.4.3. Nenets Autonomous Okrug (NAO)

4.4.3.1. General description

The main focus of the PTS source inventory within the NAO is data acquired from the city of Nar'yan-Mar, which is the most significant pollution source in the vicinity of the indigenous settlement of Nelmin-Nos.

Construction of various industrial facilities, and roads, as well as extraction and transportation of minerals (primarily oil and gas), have had a considerable impact on the environment in the NAO. A total of eighty-one deposits of petroleum hydrocarbons have been found in the territory of the NAO, of which seventy-eight are on land and three on the Barents Sea shelf. Among the terrestrial deposits, sixty-six are of oil; six of oil and gas condensate; four of gas condensate; one of gas; and one of gas and oil. The city of Nar'yan-Mar and the settlement of Harjaga could both be considered as regional pollution sources.

Growth of activities associated with the development of oil and gas deposits has been followed by an increase in anthropogenic pollution impacts on the environment, including:

- air pollution due to emissions of hazardous substances (including that from associated gas flaring);
- pollution of surface and ground waters through discharges of polluting substances;
- extraction, together with oil, of associated highly mineralized production water;
- changes in the landscape (excavations, extraction of materials for construction of the oil and gas production infrastructure, building, cargo transportation, construction of roads, etc.), deforestation, soil pollution by petroleum products, etc.;
- landfill disposal of drilling waste;
- oil spill emergencies.

In 2002, air emissions from stationary and mobile pollution sources amounted to 35.1 kt (in 2001 the total amount of emissions was 36.6 kt), including 1.47 kt of dust and 36.6 kt of gaseous and liquid pollutants. Gas emissions associated with oil extraction are very high, and methods of utilising the gas have not yet been developed in NAO.

In 2002, 24.5 kt of pollutants were emitted to the atmosphere by stationary pollution sources. The basic components of these air emissions were: ashes (720 t); soot (720 t); SO_2 (3750 t); CO (12200 t); NO_2 (4600 t) and hydrocarbons (2400 t). Although these pollutants cannot be considered as PTS, their emissions are a measure of total environmental stress in the region. The major polluters of the atmosphere are the energy producing companies: 'Total RRR', JSC 'Varandeygaz';

Table 4.25. Industrial emissions from major enterprises in the NAO in 2002, tonnes.

Enterprise	Total	Dust	SO_2	CO	NO_2	Hydro-carbons	Specific contaminants
'Total RRR' (Survey, exploitation, development)	4472.7	0.0	2126.8	1154.8	533.6	158.5	H_2S 1.1; methane 2.7
JSC 'Varandeygaz'	2597.7	210.5	50.2	1735.2	183.2	218.7	Acrolein 2.1
JSC 'Arcticneft'	2576.2	101.2	66.6	1718.1	246.3	203.2	Acrolein 2.4; vapours of benzene 33.9; V_2O_5 1.2; methane 23.2
Company 'Polyarnoye Siyanie' Ltd	1868.0	8.3	10.7	1350.3	304.0	193.7	Acrolein 1.1.
JSC 'Pechoraneft'	1686.2	170.1	5.0	14.8	55.8	1440.0	Acrolein 0.6
'Lukoil-Komi' Ltd	1528.2	59.7	0.0	715.6	332.7	311.1	Xylol 1.3; toluene 1.1; acetone 0.16; butanol 0.23; methane 104.7
Municipal service of the Nenets district	1210.8	324.5	297.6	160.3	379.7	48.7	
State industrial combine 'AMNGRE'	1018.4	7.6	18.2	7743.9	203.5	26.3	Acrolein 2.3; methane 16.5
JSC 'Severgeoldobycha'	957.0	33.2	73.4	178.2	586.0	78.3	Acrolein 7.7
Nar'yan-Mar heat and power plant	617.6	10.0	20.1	315.8	244.4	24.7	Acrolein 2.4; methane 0.3

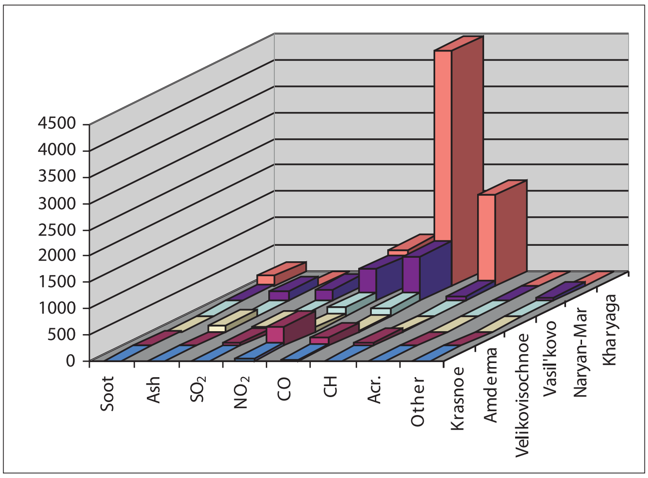


Figure 4.68. Air emissions in major NAO settlements in 1999, tonnes.

JSC 'Arcticneft'; 'Kompaniya Polyarnoye Siyanie' Ltd; JSC 'Pechoraneft'; and 'Lukoil-Komi' Ltd. (Table 4.25). Air emissions from the largest NAO settlements are shown in Figure 4.68.

Official statistics do not document any significant pollution sources in the lower part of the Pechora basin, although wastewater discharges have increased 1.7-fold since 1998, mostly due to water use in oil and gas production and by municipal services.

Nar'yan-Mar port is one of pollution sources and is located on the right bank of a narrow channel, the Gorodetsky Shar, which joins the Great Pechora river 1.5 km upstream of its mouth and 110 km from the Bolvansky cape. The port has no storage tanks and, therefore, wastewater is discharged directly into the Pechora river without treatment.

Levels of pollutants in the Pechora delta tend to be elevated. Contamination is connected, not only with the local activities, but also, to a large extent, with pollution due to wastewater discharges from enterprises located in the Pechora basin involved in gas and oil production (i.e, polluting substances transported with the Pechora flow). However, based on the data and information obtained from project activities concerned with the assessment of riverine pollution fluxes, it may be possible that there are also considerable sources of PTS located between the settlements of Oksino and Andeg (an area which includes Nar'yan-Mar and its suburbs) which contribute to PTS fluxes in the river flow.

The current system of handling solid household wastes in Nar'yan-Mar consists of the collection of waste in containers, cesspools, and auto-dumpers, followed by their transportation to landfill using specialized and other motor transport. In addition, household wastewater is also transported to landfills, since most existing housing is not connected to sewer systems, and the capacity of older treatment facilities is insufficient. However, due to the recently commissioned new treatment facilities, and work to increase the capacity of older sites, the volume of household wastewater entering landfills is decreasing every year. In other NAO settlements, solid and liquid household waste is removed not only to authorized sites, but also, to a large extent, to illegal landfills.

The system of solid household waste collection does not allow the separation of hazardous wastes (e.g., those containing mercury batteries, plastics, etc.) and dumping of such wastes at landfill sites results in environmental contamination by dangerous toxic substances, including dioxins, especially if fires occur. Communal solid waste, together with hazardous waste in landfills is also subjected to the effect of precipitation which washes pollutants down into the soil profile, and subsequently leads to their transport with ground waters. The situation is aggravated by a lack of landfill sites equipped with environmental facilities, and the low capacity of waste treatment facilities in Nar'yan-Mar and other NAO settlements. Existing landfills do not meet environmental or sanitary requirements as:

- they lack sanitary protection zones,
- they lack rainwater filtrate removal and treatment systems;
- they lack waterproof screens.

The most hazardous and widespread waste products are luminescent lamps containing mercury (2.49 t in 2000), obsolete accumulators (4.1 t), used motor oil (119.3 t), drilling sludge (7908 t) and oil-slime (329.2 t).

There are no facilities specifically designed for the processing or incineration of solid communal waste in NAO, and only a small amount of solid communal waste is incinerated at industrial sites, generally those involved in oil and gas development activities.

Processing of medical waste, rubber waste products, and ash-and-slag wastes from boiler-houses, has also not been developed in NAO. The medical institutions of the city of Nar'yan-Mar generated 16.8 t of waste products that were transported to the municipal landfill site in 2001.

4.4.3.2. Inventory of PTS pollution sources

Pesticides

According to information obtained from the Department of Agriculture and Foodstuffs of the NAO Administration, no chlorinated pesticides, insecticides, disinfectants, etc., have been used in the last ten years in the Pechora river flood-plain by any agroindustrial enterprises or related organizations. Hexachlorobenzene (HCB) has not been used as a disinfectant.

Industrial chemical compounds

According to information received, no enterprises exist in Nar'yan-Mar or in territories adjoining the settlement of Nelmin-Nos that could represent a potential

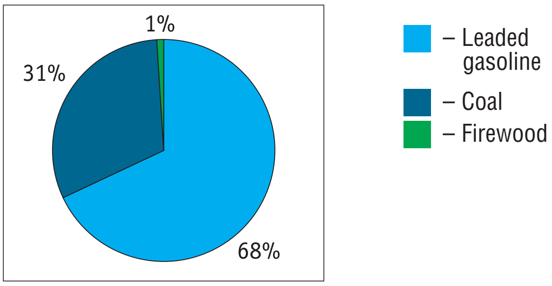


Figure 4.69. Lead emissions from organic fuel combustion in the Nelmin-Nos area.

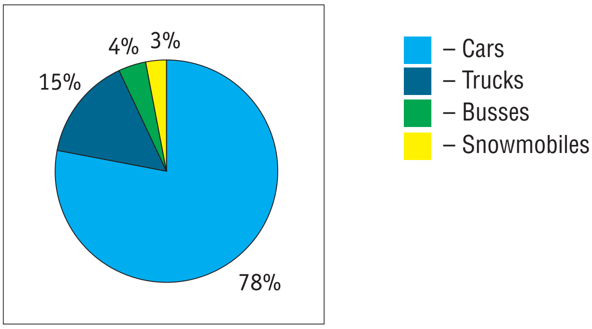
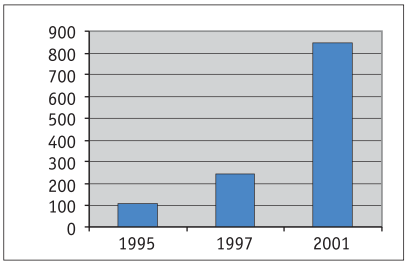


Figure 4.70. Lead emissions resulting from different means of transportation in the Nelmin-Nos area.

Figure 4.71. Lead emissions from the combustion of leaded gasoline in the Nelmin-Nos area, kg.



source of polychlorinated biphenyls (PCBs), originating from equipment containing PCBs, or brominated flame retardants.

4.4.3.3. PTS mobilization from combustion of fossil fuels

Official statistical data on fossil fuel consumption in the NAO was used to calculate PTS emissions. The fuel amount consumed in the NAO within the Nelmin-Nos area was estimated based on the assumption that the population of this area (including Naryan-Mar, the settlement of Krasny, and Nelmin-Nos itself), comprises 65% of the total NAO population. Account was also taken of the fact that that most of the population in the area (27000 out of 29300) live in Nar'yan-Mar.

Lead

In the Nelmin-Nos area, lead emissions from organic fuel combustion arise mainly from leaded gasoline (Figure 4.69) used by vehicles with internal combustion engines (Figure 4.70). However, the total annual emissions of lead from fossil fuel combustion are very low.

It should be noted that, due to a significant growth in the number of motor vehicles in the area in recent years, an increase in lead emissions has been documented, despite the introduction of unleaded gasoline (Figure 4.71).

Mercury

Mercury mobilization from the combustion of fossil fuels in the Nelmin-Nos area is rather small. For example, in 1997 it did not exceed 1 kg. Such low levels of mobilization can be explained by the widespread use of natural gas by major consumers, in particular the Nar'yan-Mar heat and power plant and municipal boilers.

Polyaromatic hydrocarbons (PAHs)

Data on PAH emissions from the combustion of various kinds of hydrocarbon fuels in the Nelmin-Nos area, including Nar'yan-Mar, are presented in Figure 4.72. A major contribution to total PAH emissions is made by the gasoline-fueled motor vehicles. It is notable that the role of gasoline in total PAH emissions has increased drastically in recent years, due to a significant growth in the number of cars in the area, particularly in Nar'yan-Mar. Before that, diesel fuel had played a dominant role (Figure 4.73).

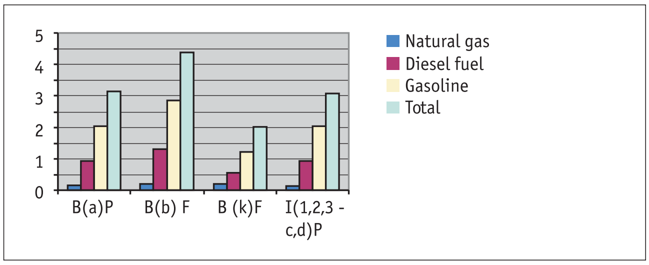


Figure 4.72. PAH (benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]flouranthene, and indeno[1,2,3-c,d]pyrene) emissions from the combustion of hydrocarbon fuel types in the Nelmin-Nos area in 2001, kg.

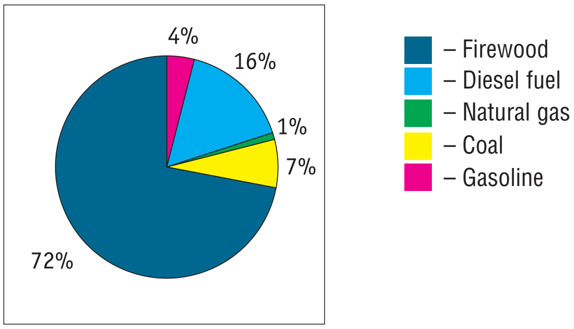


Figure 4.73. Contribution of different types of organic fuel to benzo[a]pyrene emissions in the NAO in 1995.

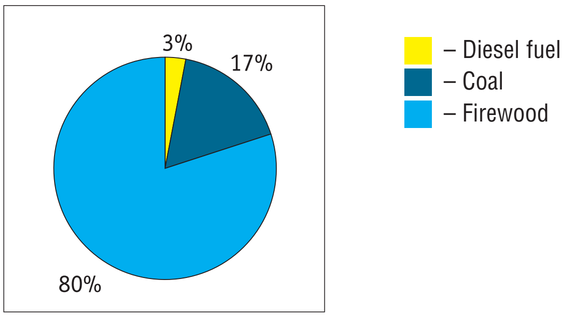


Figure 4.74. Contributions to total dioxin emissions from combustion of major organic fuel types in the NAO in 1997.

The contribution of coal to PAH emissions in this area is much lower than in other project pilot study areas, since petroleum hydrocarbon fuel types dominate in this oil and gas producing region. However, the largest contribution to PAHs comes from firewood. As firewood is mainly used for domestic heating, this fact is of particularly concern in relation to possible impacts on human health.

Dioxins

According to expert estimates, total dioxin emissions in the inventory area in 1997 were 687.15 mg TEQ. Contributions of different types of organic fuel to total dioxin emissions are shown in Figure 4.74. Fuels such as natural gas, gasoline, and kerosine contribute considerably less than 1% of total emissions.

Attention should be paid to the fact that a major contribution to total dioxin emissions arises from the use of firewood for heating and other domestic needs. As these emissions arise from the burning of organic fuels in the home, and particularly from open fires commonly used by indigenous peoples in their traditional dwellings, this fact is a matter of particular concern in the context of possible exposures to humans and related health implications.

4.4.4. Taimyr Autonomous Okrug (TAO)

4.4.4.1. General description

In the TAO, the inventory of local sources covered the vast territory around the city of Norilsk, which forms the main basis for the economy of the entire TAO. Norilsk has a dominating influence on the environment of adjacent territories, including the areas of the settlements Dudinka and Khatanga, which are the centers of residence for the indigenous population.

The TAO population, including the Norilsk Industrial Area (NIA), is 288600 (based on 1996 data). The population of the NIA itself is 44100. The population of the town of Khatanga is about 5000, and that of the town of Dudinka and settlement Dikson more than 31300. Most of the urban population resides in the city of Norilsk, however, this city is formally outside of the TAO jurisdiction, and administered as a subsidiary of the Krasnoyarsk Krai.

Annual industrial air emissions from enterprises located in the TAO territory amount to more than 2 million tonnes of pollutants. Thirty-nine different pollutants are monitored in these emissions. The bulk of the emissions comprise sulphur dioxide, followed by sulphuric acid, inorganic dust, carbon monoxide, and nitrogen dioxide. Emissions from stationary sources are dominant and amount to about 99% of total industrial emissions in the region. This equates to two-thirds of emissions in the Krasnoyarsk Krai, and 14% of all industrial emissions in the Russian Federation. 2309 stationary industrial emission sources have been registered in the TAO territory, of which only 318 are equipped with gas treatment facilities to reduce emissions.

The Norilsk Industrial Area, the largest copper and nickel producer in the Arctic and the Russian Federation, is located about 60 km from Dudinka, to the east of the river Yenisey, covering an area of about 60 thousand km^2 in the northwestern part of mid-Siberian plateau between longitudes 86–92°E, and latitudes 68-70°N. It is acknowledged as the largest single source of environmental pollutants, not only in the region, but in the whole circumpolar Arctic.

4.4.4.2. Geographical areas of concern

Norilsk Industrial Area (NIA)

The former Norilsk Mining and Metallurgical Combined Plant, now called ‘Norilsky Nickel’ JSC, is the main polluter in the territory.

In the 1980s, it began operating a number of plants producing elemental sulphur, which through recovery of sulphur (at a maximum recovery of 20%) substantially decreased SO_2 emissions and significantly improved the environment of the region. However, SO_2 is still the main contaminant emitted in the NIA, accounting for 96.7% of total emissions. In addition to SO_2, ‘Norilsky Nickel’ JSC emits a wide range of contaminants, among which are heavy metals, including those addressed in the project.

Automobiles are acknowledged as an important source of some PTS emissions. In this respect, the NIA is singular because it does not have any extensive railway network for passenger or cargo transport. To compensate for this drawback use of road vehicles is widespread, with associated negative impacts on air quality in residential areas. In winter, when temperature inversions are common, pollution of the lowermost atmospheric layer from vehicle exhausts often exceeds pollution from stationary emission sources.

High levels of sulphur dioxide in air are recorded in the city on about 350 days a year, including 120 to 150 days with levels from 5 to 10 times the Maximum Acceptable Concentration (MAC), and 40 to 60 days with a level exceeding 10 times the MAC.

The total duration of air pollution amounts to around 50% of the year, 80% of this time with a level of under 5 MAC, 15 to 17% of the time with a level from 5 to 10 MAC, and 2 to 4% of the time with levels of 10 MAC or more Due to the prevailing wind directions, the main pollution sources for the city’s atmosphere are the copper plant, the nickel plant, and the sinter plant. In spite of protection measures in place, the atmospheric air pollution level in the city is gradually increasing (Table 4.26).

About 20 million tonnes of solid waste are produced annually in the NIA (23.4 million tonnes in 2000). Over the entire period of industrial activities in the area, more than 400 million tonnes of mining and industrial

Table 4.26.
Average concentrations of air pollutants in the city of Norilsk (mg/m³), and their trend (mean annual change based on linear regression) over the period 1996-2000; and total emissions (thousand tonnes) from the combined smelter, 'Norilsky Nickel' JSC during the same period.

Pollutants	1996	1997	1998	1999	2000	Trend
SO_2	0.22	0.17	0.13	0.21	0.21	0.002
NO_x	0.03	0.02	0.04	0.05	0.05	0.007
NO	0.04	0.03	0.06	0.07	0.08	0.012
Phenol	0.002	0.003	0.002	0.004	0.006	0.001
Formaldehyde	0.022	0.017	0.006	0.011	0.040	0.003
Cl_2	0.01	0.03	0.00	0.00	0.00	-0.005
Total emissions from 'Norilsky Nickel' JSC	2155	2185	2139	2171	2145	

wastes have been accumulated, whilst no more than 5% of the existing waste have been recycled. The waste composition is 99% mining and industrial waste (of which 94% are bearing strata and overburden), and 1% waste from domestic consumption.

About 2400 hectares are occupied by rock dumps. In addition, 1500 hectares have been damaged by stripping. Tailing dumps occupy a further 1500 hectares. About 10 million tonnes of toxic waste containing more than 50 different components, and more than a million tonnes of slag are stockpiled in the territory each year. Almost no waste-storage sites conform fully to current legal and regulatory requirements.

The NIA drainage system falls mainly within the basin of lake Piasino. The bulk of 'Norilsky Nickel' JSC's wastewater is discharged into this hydrological system. The biggest water course in the region is the river Norilskaya, which connects the lakes Melkoye and Piasino. Secondary rivers, namely the Shchuchya, Kupets, Yergalakh, Ambarnaya, Daldykan, and others, are tributaries of the Norilskaya or flow directly into the lake Piasino, which is the biggest lake in the region (Figure 4.75).

Dudinka area

The town of Dudinka is located on the right bank of the river Yenisey at its confluence with the Dudinka river, 433 km upstream from the mouth of the Yenisey. Dudinka port works practically all year round and specializes in the offloading of imported cargo (petroleum products, food stuffs, and construction materials for the Norilsk plant and for the town of Dudinka), and the export of copper-nickel concentrate for the various mining and smelting companies and enterprises. The port is equipped with its own transport infrastructure, a large oil depot, and the facilities necessary for handling of contaminated bilge waters and household wastewater. In total, the port (based on data for the early-1990s) receives about 7600 t of waste products from vessels, including about 300 t of oil-containing waste.

Pollution of water around the port occurs a result of wastewater discharges from both the port, and from entities located nearby. More than two million m³ of wastewater is discharged to the waters around the port each year. A proportion of bilge and domestic wastewater from shipping is released directly into the waters of the port. Some of the polluting heavy metals (copper, nickel, cobalt, etc.) enter the water as a result of the wash-out from bulk copper-nickel concentrates.

Air operations are located in the Dudinsky area, and construction and geological prospecting organizations also operate from the city. The town infrastructure is maintained by the bodies responsible for municipal housing and communal services. These, the road department, trade organizations, and a smoke-house

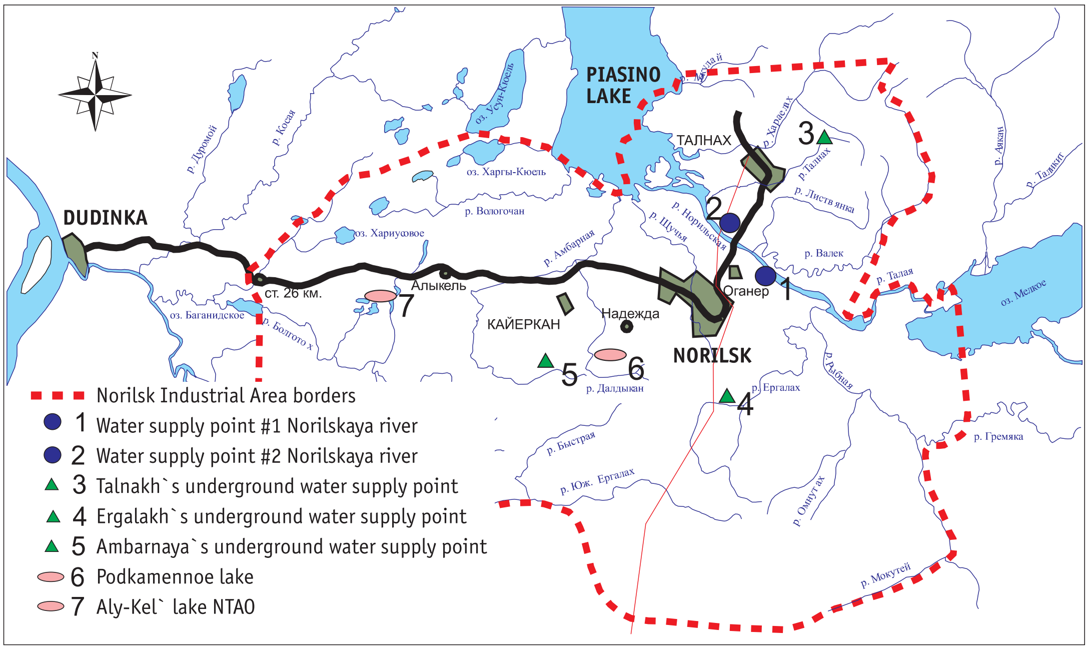


Figure 4.75.
The drainage network of the Norilsk Industrial Area.

are not formally considered as PTS sources under the inventory of local sources, but as a whole exert a very insignificant influence on the environmental state of the adjoining territories, when compared to the neighboring Norilsk smelter.

Khatanga area

The Khatanga settlement is located on the left bank of the river Khatanga, 110 km from its mouth. The population of the settlement numbers 5000. There are relatively few large enterprises based in the settlement. Those present include an aviation enterprise connected with the local airport, a sea cargo port, a fish-processing factory, housing and municipal services, three oil depots, a base for polar expeditions, and a number of state agricultural producers and co-operative enterprises, etc.

The settlement municipal services share a water supply and sewage network with the industrial enterprises, and water is taken from the river Khatanga upstream of the settlement. Wastewater enters a main settlement collector, and after mechanical treatment, is discharged back into the river Khatanga 1.5 km downstream of the settlement. Water consumption by the settlement and industrial enterprises has reduced over the last few years. According to figures from the Sea Inspectorate of the Krasnoyarsk Krai, wastewater discharge into the river Khatanga from the settlement collector in 1994 was about 1 million m^3. There are no data available, however, on the chemical composition of wastewaters.

Khatanga port, which is located at the left bank of the river Khatanga 112 km upstream from its mouth, operates for three to three-and-a-half months during the summer navigation period. There are 5 berths in the port adapted to serve sea vessels up to 5000 tonnes. Handling operations are carried out along the port road, and also along the road in Kozhevnikova bay. The port has no oil depot of its own, however, there are three depots near the harbour area, belonging to other departments.

The port itself consumes up to 400000 m^3 of water, including 140000 m^3 for industrial needs, and 260000 m^3 for economic and household needs. Wastewater is discharged into the main settlement collector. The total discharge of untreated waters is 6-8 million m^3 per year. The port has the technical capability to collect wastewater from sea-going vessels. After fuel and oil separation, remaining oil and slag are incinerated in boiler-houses and operational waste is transferred to landfill.

The main air pollution sources in the settlement are the eleven departmental boiler-houses utilizing local coal, and the airport facilities, which use diesel fuel. In total, heating the settlement of Khatanga requires about 45–50000 t of coal per year. About 3000 t of suspended substances, more than 500 t of sulphur dioxide, more than 750 t of carbon monoxide and approximately 180 t of nitrogen oxides are emitted into the atmosphere. About 85% of emissions deposit directly onto the area occupied by the settlement, over a radius of 3–3.5 km.

4.4.4.3. Inventory results

Pesticides

According to the TAO Veterinary Medicine Administration (pers. comm., letter no. 144 of 10.04.2003), the district veterinary service regularly used the insecticide dichlorodivinylphosphate (DDVP) against mosquitoes and gadflies in the summer, during the period 1980 to 1991. In total, up to 1270 litres of the insecticide were used on farms in Khatanga, Ust-Yenisey and Dudinka Districts. Currently, no pesticides are used in the TAO for agricultural purposes.

Polychlorinated biphenyls (PCBs)

The PCB inventory carried out in 1999 in the NIA revealed the presence of electric equipment, namely, transformers and capacitors, filled with the dielectric fluids, Sovtol-10, Askarel, and Pyralene. The quantity of these synthetic PCB-containing fluids amounts to 451.5, 145.0, and 10.38 t, respectively (Table 4.27). These figures have not changed since 1999.

Most pieces of equipment containing the above fluids are operative. Among 226 transformers, 222 are in service, three have been decommissioned, and one is held in reserve. Among 643 capacitors, 368 are in service, 246 have been decommissioned, and 29 are held as a reserve stock. Decommissioned equipment contains 5.64 t of Askarel and 0.89 t of

Enterprise	Transformers, pcs.				Capacitors, pcs.				Synthetic PCB-containing transformer oil, tonnes					
		Including				Including						Including		
	Total	In operation	In reserve	Decommissioned	Total	In operation	In reserve	Decommissioned	Total	Brandname	PCB content, %	In operation	In reserve	Decommissioned
'Norilsky Nickel' JSC	226	222	1	3	643	368	29	246	451	Sovtol-10	90%	448.32	3.14	-
									145	Askarel	N/A	139.36	-	5.64
									10	Pyralene	N/A	9.49	-	0.89

Table 4.27.
Inventory of PCB-containing electric equipment located at 'Norilsky Nickel' JSC (data for 1999).

Table 4.28.
Nomenclature and characteristics of PCB-containing waste at 'Norilsky Nickel' JSC (data for 1999). Wastes were generated for 1996-1999 as a result of the decommissioning of 3 transformers and 246 capacitors.

#	Waste type	Amount of waste, t/year	PCB amount, t/year,		Kind of waste handling (warehousing, landfill disposal, reprocessing, transfer to the third-part organizations)	Notes
			Content in waste, %	Total, t/year		
1	Askarel	5.64	100%	5.64	Warehousing (two imported transformers)	At the plant site
2	Pyralene	0.89	100%	0.89	Warehousing (1 imported transformer)	At the plant site
3	Sovtol-10	N/A			Warehousing (246 capacitors)	Indoors and at the plant site

Pyralene (Table 4.28), and is still located at the plant sites. There have been no documented discharges or incidents of site pollution from transformer oils.

The inventory of PCB discharges has shown that, during the operation and maintenance of transformers, about 10 litres of PCB per annum on average are spilled from each transformer (AMAP, 2000). According to these estimates, transformers used by the Norilsk Mining Plant discharge 3.33 t of PCB per annum. Over the whole operating period (the service life of transformers is assumed to be 25 years), 83.25 t of PCB will have been discharged to the environment.

Dioxins and furans
Within the TAO, unintentional formation of dioxins and furans is related to industrial production and may occur during thermal processes carried out at the metallurgical plants of 'Norilsky Nickel' JSC, which reprocess sulphurous ores in the production of non-ferrous metals. It is very likely that, regardless of the lack of studies to date on the presence of dioxins and furans in environmental emissions from its production lines, the plant may be a source of pollution in connection with these substances.

Other possible sources of these contaminants may include:
- incineration of fossil fuels in the boilers of public utilities in the studied localities;
- vehicles, mainly those running on leaded gasoline;
- sources related to fossil fuel burning for household heating;
- open uncontrolled burning of solid household waste at dumps.

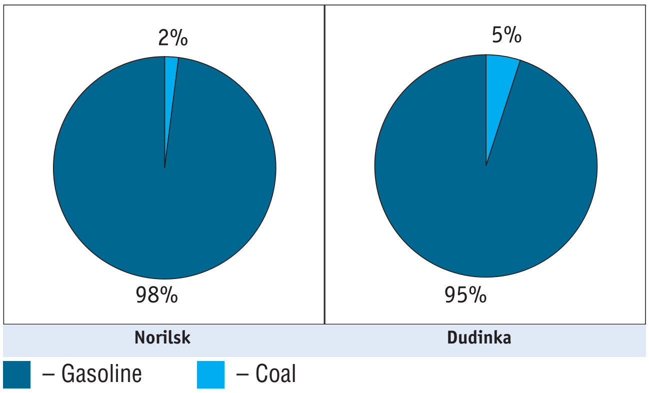


Figure 4.76. Lead mobilization through the combustion of coal and gasoline in the TAO in 1997.

The presence of Cl_2 in the air of Norilsk in previous years (see Table 4.26) could be an indicater of possible dioxin formation in the area, as there is no pulp and paper industry in the TAO territory and no community solid waste incineration plants or production of chlorinated organic products.

Mercury
As stated above, non-ferrous metal production is a significant source in the mobilization of mercury. In 2001, the NIA produced 120000 t of primary nickel and 357000 t of primary copper. According to expert estimates, production of these amounts of non-ferrous metals would be accompanied by the mobilization of 1.7–2.02 t of mercury, emitted to the atmosphere. In addition, 0.65–0.99 t of mercury would have accumulated in captured dust (COWI, 2004).

Lead
According to official statistics, annual emissions of lead in the inventory area vary from 26.5 to 32.8 t.

4.4.4.4. PTS mobilization from combustion of fossil fuels
As in the other pilot areas, estimates of PTS emissions were based on the consumption of different types of organic fuel. It is important to note, that the inventory areas of the TAO, and the NIA in particular, are characterized by high levels of coal consumption, and this essentially determines PTS mobilization associated with fossil fuel combustion.

Lead
Due to high coal consumption, and a decrease in the use of leaded gasoline, lead mobilization from coal dominates, particularly in the NIA (Figure 4.76). It should be noted that the annual amount of lead mobilized through coal combustion in the NIA is higher than lead emissions by the 'Norilsky Nickel' JSC in the production of non-ferrous metals due to lead mobilization from the ores (Figure 4.77). Total lead mobilization through coal combustion in Dudinka and Khatanga comprises about 0.5% of that in the NIA.

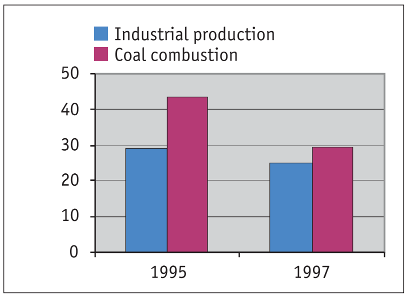


Figure 4.77. Lead emissions in the NIA from industrial production and coal combustion.

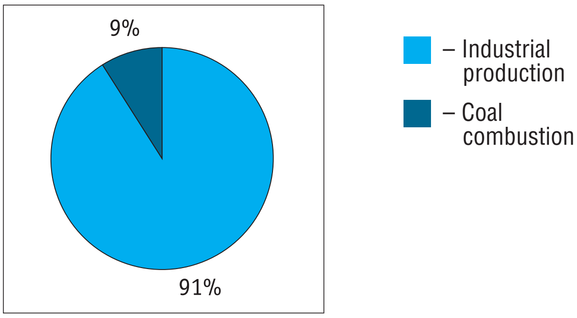


Figure 4.78. Sources of atmospheric emissions of mercury in the Norilsk Industrial Production in 2000.

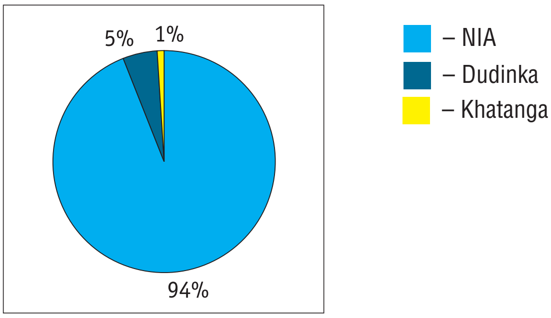


Figure 4.80. Contributions of different source regions to benzo[a]pyrene emissions from the combustion of hydrocarbon fuels in the TAO.

Mercury

Use of natural gas and other types of petroleum hydrocarbon fuels for energy production produces a relatively minor contribution to mercury mobilization. For example, use of natural gas in the NIA, contributes annually about 10g of mercury. A more significant contribution to mercury emissions is made by coal used for heat and power production. As almost 99% of total coal combustion in the TAO occurs in the NIA, and (in addition to the even more substantial emissions from production of non-ferrous metals) coal contributes 10% of the NAI emissions of mercury to the atmosphere (Figure 4.78), the NIA is clearly responsible for the greater part of the mercury contamination from the TAO.

Polyaromatic hydrocarbons (PAHs)

Total PAH emissions to the atmosphere due to the consumption of hydrocarbon fuels in the TAO, including the NIA, are presented in Figure 4.79. For all PAHs, as in the case of benzo[*a*]pyrene (Figure 4.80), the main contribution is made by the NIA. It should be noted that contributions from defense-related activities have not been included in the inventory estimates, since this information was not available to the assessment. Because of this, contributions from areas outside of the NIA, for example Khatanga, may be higher. However, the pre-eminent role of NIA will not change.

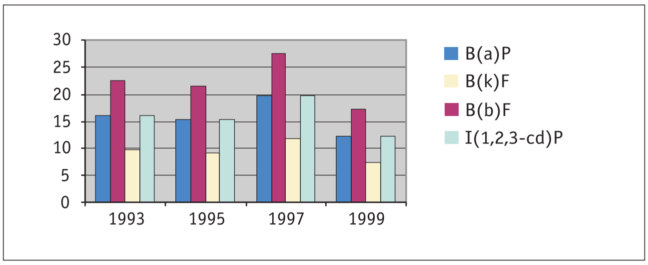


Figure 4.79. PAH (benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]flouranthene, and indeno[1,2,3-c,d]pyrene) emissions from combustion of hydrocarbon fuels in the TAO (including the NIA), kg.

As a rule, specific PAH emissions occurring through coal combustion are higher than those associated with combustion of petroleum hydrocarbon fuels. As coal consumption in the TAO is higher than, for example, in Murmansk Oblast, and the NAO even more so, coal combustion sources dominate PAH emissions from the TAO (Figure 4.81).

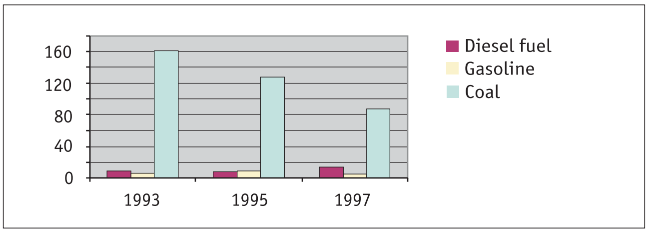


Figure 4.81. Contribution of different types of fossil fuel combustion to benzo[a]pyrene emissions in the NIA, kg.

Dioxins

The use of coal for heat and energy production is a dominant source of dioxin emissions when compared to other types of organic fuel in the TAO. As expected, the NIA is responsible for almost 99.5% of dioxin emissions from coal combustion in the TAO. However, the TAO dioxin emissions from petroleum hydrocarbon fuel combustion (including those from the NIA), are comparable to the dioxin emissions from coal combustion in the TAO when the NIA is excluded.

4.4.5. The Chukchi Autonomous Okrug (CAO)

4.4.5.1. General description

The CAO, which is located in the extreme far northeast of continental Russia, consists of eight districts. These are: Anadyrsky (settlement Ugolnye Kopi); Beringovsky (settlement Beringovsky); Bilibinsky (settlement Bilibino); Iultinsky (settlement Egvekinot); Provedensky region (settlement Provedeniya); Chaunsky (town of Pevek); Chukotsky (settlement Lavrentiya); and Shmidtovsky (settlement Mys Schmidta). The CAO capital, Anadyr, is located in the Anadyrsky District.

According to the census, the population of the CAO was 164783 persons in 1989. In recent years its population has decreased and, by the beginning of 2000, the figure was 72180 persons of whom 49106 are in urban areas and 23074 classed as rural.

The settlements involved in the inventory of local sources are located in three rayons: the city of Anadyr and settlement of Kanchalan in Anadyrsky District, the settlement of Provideniya in Providensky District, and the settlement of Uelen in Chukotsky District. Population characteristics of the inventory areas are presented in Table 4.29.

#	Settlements	Area, km^2	Population
1	City of Anadyr	20	11845
2	Anadyrsky Rayon Settlement of Kanchalan	249610	12500 665
3	Chukotsky Rayon Settlement of Lavrentiya Settlement of Lorino Settlement of Uelen Settlement of Neshkash Settlement of Enurmino Settlement of Inchown	30247	4657 1079 1404 844 693 293 344
4	Providensky region Settlement of Provideniya	27286	5067 2137

Table 4.29. Population characteristics of areas in the CAO included in the inventory of local sources.

Variable	1999	2000	Maximum annual discharge in the previous 7 years
Suspended matter	0.7	0.45	2.46
Dry residue	0.41	0.64	0.87
Organic matter (BOD)	2.22	2.29	3.46
Petroleum hydrocarbons	0.01	0.01	0.01
Chlorides	0.55	0.67	0.73
Sulphates	0.28	0.21	0.5
Ammonia nitrogen	0.11	0.12	0.14
Nitrites	0.002	0.001	0.007
Nitrates	0.013	0.029	0.029

Table 4.30. Discharges of contaminants with wastewater in the CAO, thousands of tonnes.

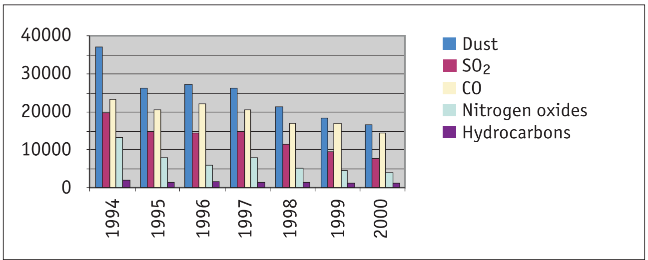


Figure 4.82. Atmospheric emissions of major pollutants from stationary sources in the CAO, t/y.

Main local pollution sources are related to the development of mineral resources such as gold, tin, tungsten, mercury, coal, and lignite. Together, in 1995, industrial entities emitted 72500 t of pollutants into the atmosphere, and discharged 39.3 million m^3 of sewage into surface water bodies (including 8 million m^3 of polluted wastewater). In 2000, these figures were, respectively, 35500 t, and 20.0 and 5.3 million m^3. The main pollution sources are the Pevek Mining and Concentration Plant, the Iultin Mining and Concentration Plant, and also numerous boiler houses.

Provideniya is the biggest settlement inhabited by indigenous peoples in the CAO. The settlement has a seaport, a shipyard terminal, a tannery, and a meat-and-dairy plant. The indigenous population is involved in reindeer-breeding, fishing, the fur trade, and hunting. There are practically no industrial facilities in the settlements of Uelen and Kanchalan where the indigenous population is engaged in reindeer-breeding, hunting, and the fur trade. There are no major pollution sources except for solid household waste and pollution of coastal waters by petroleum products.

Data on air emissions from stationary sources in the CAO are presented in Figure 4.82. Although official statistics do not include data on PTS emissions, there is a well-defined general trend of decreasing emissions. It may be assumed that PTS emissions in this region are also decreasing, in accordance with this general trend. Official statistics on air emissions in the CAO from motor vehicles do not include private vehicles. Based on expert estimates, vehicles used for personal transport exceed the number of vehicles belonging to the state and to the various enterprises by about 50%. Data on air emissions from non-private motor vehicles are presented in Figure 4.83. Official statistics also exclude data on emissions of, for example, lead from the use of leaded gasoline by motor vehicles. This information, based on expert estimates, is provided below.

Official statistical data on pollutants in wastewater discharges in the CAO are presented in Table 4.30. Polluted wastewater is discharged from treatment facilities belonging to the various utilities in the cities of Anadyr and Pevek and the settlements of Bilibino and Iultin. Main areas of pollution were found around the city of Anadyr (affecting 185 km^2) and the settlement of Nagorny (affecting 60 km^2). Within the inventory area, wastewaters are discharged into natural water bodies without any form of treatment, with the exception of Kanchalan settlement, where effluents are collected from cesspits and transported to the settlement's dump for further partial treatment.

4.4.5.2. Main settlements in the inventory areas

Anadyr

Anadyr is the capital of CAO, and has the most developed infrastructure in the CAO. Emissions for the city of Anadyr, based on State statistical data, are presented in Table 4.31. The city has no wastewater treatment facilities. There are no enterprises registered as potential sources of PCB contamination in the area of Anadyr, and no information on users of PCB-containing equipment. Similarly, there are no industrial wastes in Anadyr which are likely to contain PCB, or hexachlorobenzene (HCB), as there are no activities connected with either their production, or use.

A potential source of brominated flame-retardant compounds (BFRs) is land occupied by municipal landfills, but there are no data currently available on their content due to a lack of information on types of solid household waste dumped at the landfill. In the opinion of experts from the municipal services, household and electronic apparatus that could represent a source of BFRs are seldom found among debris located at the landfills. The Anadyr municipal landfill and is located two kilometers from city. The amount of waste dumped annually in the landfill is 28000 m^3. It is important to

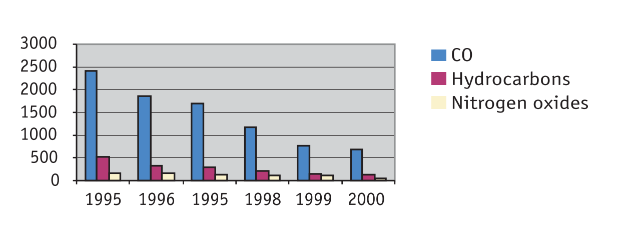


Figure 4.83. Atmospheric emissions from motor vehicles (excluding private cars) in the CAO, t/y.

Variable	1996	1997	1998	1999	2000	2001
Total	4.26	3.94	4.65	3.07	17.002	4.829
Dust	2.90	2.96	3.43	0.23	15.489	3.662
SO_2	0.53	0.51	0.56	1.51	0.463	0.509
CO	0.42	0.22	0.3	1	0.432	0.341
Nitrogen oxides	0.27	0.18	0.36	0.29	0.197	0.282

Table 4.31. Trend in air emissions of major pollutants in Anadyr, thousands of tonnes.

note that landfills in Chukotka are in a permanently frozen state and therefore among the safest landfills and, as certified by the communal services, has low potential for spontaneous combustion. and percolation from the landfill into groundwater.

Although no special studies have been undertaken, and there are no directly relevant data available, it is possible, on the basis of the information presented above, to infer the possible presence of dioxins and furans in the city. Furhtermore, there has been no work associated with organizing an inventory, collection, storage and treatment of mercury-containing luminescent lamps and such equipment.

Kanchalan

The settlement of Kanchalan is located in Anadyrsky District, on the bank of the river Kanchalan, part of the Anadyr river system. At present the settlement has no industry, and agriculture is represented only by reindeer-breeding farms, which only use the settlement as a base. The settlement's housing and municipal services operate a diesel electric power station and a coal-fired boiler-house, which uses coal from the Anadyr deposit.

There is no sewage system in the settlement, and collection is in cesspools, which are periodically cleaned, with the solid waste Being removed to the settlement landfill. According to environmental protection authorities, the level of air pollution in the settlement has never been investigated, and therefore available data is limited to potential sources of PTS only.

Provideniya

The settlement of Provideniya is located to the north of the Gulf of Anadyr, in the Emma Bay (Komsomolskaya). Ureliki village directly adjoins the settlement. Infrastructure in the settlement of Provideniya is similar to that of Anadyr city. The main enterprises are the sea trading port, the airport, a meat-and-milk complex, the 'Providensky kozhzavod' JSC, enterprises run by housing and municipal services, construction operations, and military infrastructure. The port is responsible for the water supply for the settlement. Water is taken from lake Istihet and the river Krasivyi. Effluent discharge amounts to 4.3 million m^3. There are no treatment facilities for industrial or domestic wastewater; and practically all waste water from the settlement and port is discharged into the bay of Komsomolskaya. The enterprises listed above are the main water pollution sources.

The following contaminants enter the bay with wastewater: suspended mineral substances (4.32 t), petroleum products (0.13 t), organic matter (24.84 t), chlorides (14.06 t), sulphates (8.33 t), total nitrogen (23 t), surfactants (0.012 t), and phosphorus (0.04 t). Of these pollutants, housing and municipal services release the following: mineral suspensions (3.82 t), organic chemicals (22.31 t), chlorides (12.96 t), sulphates (6.06 t), total nitrogen (2.13 t), and phosphorus (0.04 t).

Air pollution in the settlement of Provideniya and its nearest neighbours, originates from the burning of solid fuel (Beringov coal). In the mid-1990s, about 47500 t/yr were burned in boiler installations. Major pollutant sources include: the thermal power station at the seaport (coal consumption of 9728 t/y), boilers operated by housing and municipal service enterprises (8685 t/y), boilers in the village of Ureliki (7000 t/y), and boiler-houses run by the military infrastructure (7000 t/y).

More than 9600 t of black oil (Mazut) and diesel fuel are burned annually in the settlement. The major pollutant sources include boiler-houses belonging to the seaport and the communal service and diesel-fired power stations.

Annual emissions of pollutants to the atmosphere around Providenya are: 1390 t of dust, 500 t of sulphur dioxide, 750 t of carbon monoxide and 200 t of nitrogen oxides. Emissions from motor vehicles for the whole of Providensky District include: carbon dioxide (256 t), nitrogen dioxide (11 t), and methane (53 t). Mean atmospheric deposition of mineral salts in the areas of settlement for the last few years have been about 50 kg/ha/y, with wet deposition of sulphur at 4-6 kg/ha/yr and nitrogen at about 2 kg/ha/y.

An additional pollution source is solid household and industrial non-toxic debris, which is stored in planned landfills. In total, 33800 m^3 of solid waste are exported to landfills each year from all the enterprises within the settlements of Provideniya and Ureliki, and an additional 858 t/y from neighboring villages. There are no data currently available on PTS sources in the area.

Uelen

The settlement of Uelen is administered under Chukotsky District Uelen's infrastructure only includes enterprises belonging to the housing and municipal service departments: the Uelen workshop, farm, and social institutions (consisting of the school, medical station, and kindergarten).

Environmental pollution sources are as follows: the diesel-fired power station, coal-fired boiler, landfill for household debris, coal and ash waste repository, and household heating sources. Air emissions in the settlement in 2001 were: dust (939 t), carbon monoxide (1130 t), sulphur dioxide (668 t), and oxides of nitrogen (536 t).

According to information provided by the local authorities, chlorinated pesticides have not been used in the areas of the above settlements.

4.4.5.3. PTS mobilization from combustion of fossil fuels

As for other project pilot study areas, estimates of PTS emissions from the combustion of organic fuel are based on statistical data on fuel consumption and population distribution. About 30% of the population of the CAO reside in or around the city of Anadyr and the settlements of Kanchalan, Provideniya and Uelen. Due to a lack of data on fossil fuel consumption in the these areas, it was assumed that consumption therefore amounts to about 30% of the total fuel consumption in the CAO as a whole.

Estimates of total PTS emissions from the combustion of fossil fuel in the inventory area are presented in Table 4.32.

Contaminant	1993	1995	1997
Lead	1684.75	1160.70	1033.23
Mercury	3.61	3.30	3.23
Benzo[*a*]pyrene	10.22	6.94	5.61
Benzo[*b*]fluoranthene	11.46	7.20	5.37
Benzo[*k*]fluoranthene	9.31	6.13	5.09
Indeno[1,2,3-*c,d*]pyrene	23.55	18.49	17.42
Dioxins (mg TEQ)	1182.15	1034.29	1004.09

Table 4.32. Estimated emissions of selected PTS from the combustion of fossil fuels in Anadyr, Kanchalan, Provideniya, and Uelen, kg.

Due to the high consumption of local coal, lead emissions to air as a result of coal combustion are far greater than emissions from the use of leaded gasoline, even in the years when leaded gasoline was more widely used.

4.4.6. Conclusions

4.4.6.1. General conclusions

- An assessment of official statistics on the environmental release of pollutants, as well as data obtained by environmental protection authorities of the various administrative territories of the Russian Federation under the scope of the project, clearly indicates that existing environmental release control and reporting systems are not adequate for contemporary requirements. That is, a reporting system suitable for documenting the efficiency of actions taken by countries in connection with international measures to reduce environmental releases of PTS, and in particular the 'Stockholm Convention on Persistent Organic Pollutants'.
- The control and reporting systems of the environmental protection authorities do not adequately cover environmental releases from defence-related activities in the Arctic regions.
- The existing environmental monitoring systems, in almost all cases, do not cover secondary pollution sources; that is sources that are not directly linked to environmental pollution by industrial enterprises, although these may strongly influence the state of the environment, and ecosystems and human health. For example, monitoring of anthropogenic sources such as harbours and ports only covers petroleum hydrocarbons and few other contaminants, and not important PTS that can originate from shipping activities and associated wastes, and particularly from scrapping of ships.

4.4.6.2. Murmansk Oblast

Despite the fact that full, representative figures for releases to the environment are missing for some enterprises and that figures for some of the controlled variables have been obtained by calculation; based on the available information, it is possible to note the following:

- The main persistent pollutants emitted to the atmosphere of this area are copper and nickel, with emissions amounting to about 1000 tonnes per year. Compared to the emission of copper and nickel from industrial enterprises, fuel combustion makes a relatively small contribution to the total emissions of heavy metals in this region.
- Industrial enterprises located in the vicinity of the area where the Saami population is most dense, emit a significant proportion of the total industrial air emissions in Murmansk Oblast. Within the project study area, the most significant pollution source is the 'Severonikel' combined smelter in Monchegorsk. There are a number of other important pollution sources in the area, mainly with respect to heavy metals.
- Emissions of benzo[*a*]pyrene from industrial enterprises are approximately equal to those from the burning of organic fuels.
- According to official data, chlorinated pesticides have not been used and are not currently used in Murmansk Oblast.
- PCB-containing transformer fluids are used in only 13 transformers at 'Apatit' JSC. However, taking account of the high concentration of defence-related activities in Murmansk Oblast, it may be assumed that a considerable proportion of PCB-containing paints, varnishes, and lubricants produced in the former USSR have been used there.

- In general, there are a number of dioxin sources that might be relevant to the survey area. Some enterprises, such as the nickel combined smelter 'Severonickel' are considered potential dioxin pollution sources, but no information is available to confirm this assumption.
- Intentional mercury use in industrial production in Murmansk Oblast has not been documented. However, mercury-containing devices, in particular luminescent lamps, contribute to environmental contamination. The enterprise 'Ecord Ltd.' involved in handling of used luminescent lamps and located in the area has outdated equipment and itself contributes to mercury contamination of the environment.
- The 'Severonickel' combined smelter is considered to be a significant source of mercury contamination in the area due to mercury mobilisation during nickel and copper production. Annual mercury emissions from this enterprise are estimated to be about 0.2 tonnes. In addition, about 0.1 tonnes is accumulated annually in captured dust.
- Coal combustion is considered to be the major contributor to lead emissions that result from fossil fuel combustion. Total lead emissions from the combustion of fossil fuels in the Lovozero area have decreased in recent years, mainly due to a reduction in emissions from motor vehicles.
- Mercury contamination from local sources as a result of fossil fuel combustion is significantly less than that due to mercury mobilization from nickel and copper production at 'Severonickel' JSC However, given that domestic coal burning contributes to contamination of the indoor environment, the role of the latter in human intake may be much greater.
- Releases of PAHs from organic fuel combustion have gradually decreased, possibly, due to changes in the types of fuel used. However, after 1998, PAH emissions stabilized, presumably due to the recovery of the economy after the 1997 crisis.
- Industrial enterprises appear to be the main source of dioxin pollution from fossil fuel combustion in the Lovozero area. The role of municipal services, particularly local boilers used for non-centralized heating, in dioxin emissions has significantly increased in recent years. Although still much less than from industrial enterprises, the three-fold growth in emissions from municipal sources within 7 years should be a matter of concern.

4.4.6.3. The Nenets Autonomous Okrug (NAO)

- Main local pollution sources in the NAO are associated with oil and gas production and shipping.
- In spite of the fact that official statistical data do not document significant PTS pollution sources in the lower part of the Pechora basin, the assessment of PTS fluxes in the river flow indicate a possible input of some PTSs between Oksino and Andeg, i.e. in the vicinity of Naryan-Mar. Pollution levels in the Pechora delta tend to be elevated.
- Gas emissions during oil extraction are very high in the NAO, and methods of utilising the associated gas have not yet been developed or applied.
- The port at Nar'yan-Mar, located in a narrow channel connected to the Great Pechora river, is a source of pollution. The port has no treatment facility or storage tanks for liquid wastes and, therefore, wastewater is discharged directly into the river without treatment.
- The system of solid waste collection does not allow for separation of hazardous wastes, including those containing mercury. Disposal of such wastes at landfill sites results in environmental contamination by dangerous substances, which can include dioxins in the event of uncontrolled burning at the landfill site. Methods for handling of medical waste, rubber waste products, and ash and slag waste from boilerhouses has not been developed in the NAO
- Automotive vehicles are the main source of lead emissions in the NAO. The total amount of lead mobilized through fossil fuel combustion is relatively low. However, due to a significant increase in the number of motor vehicles in the area in recent years, an increase in lead emissions has been observed, despite greater use of unleaded gasoline.
- Coal consumption in the NAO is relatively low, since use of petroleum hydrocarbon-based fuels predominates in this region. However, use of firewood as a fuel is relatively common, particularly for domestic heating. As the result, this fuel contributes, for example, about three quarters of the total emissions of benzo[*a*]pyrene, and 80% of total dioxin emissions from the combustion of organic fuel.

4.4.6.4. The Taimyr Autonomous Okrug (TAO)

- The Norilsk Industrial Area, the largest producer of copper and nickel in the Arctic and in the Russian Federation, is acknowledged as the largest single source of environmental pollutants, not only in its immediate locality, but in the circumpolar Arctic. It emits a wide range of contaminants, including a number of heavy metals that fall within the scope of the project.
- Automotive vehicles are an important source of some PTS emissions. The Norilsk area in winter is characterized by numerous temperature inversions, and during these periods, pollution of the lower atmosphere by vehicle exhaust fumes often exceeds pollution from stationary combustion sources.
- About 10 million tonnes of toxic wastes containing over 50 different major pollutants, and more than 1 million tonnes of slag are stockpiled in the Norilsk area each year. Almost none of the waste-storage sites conforms fully to current legal and regulatory requirements.
- According to the results of the PCB inventory for the Russian Federation, significant amounts of PCB-containing fluids are used in electric equipment within the various enterprises of the Norilsk Industrial Area. According to estimates, the transformers used in this area discharge 3.33 tonnes of

PCB annually, and over the whole operating period of the transformers, more than 83 tonnes of PCB will have been released to the environment. In addition, an unknown amount of PCB may enter the environment as a result of releases from PCB-containing paints and varnishes, and compounds used in building construction, etc.

- In 2001, the production of non-ferrous metals in the Norilsk area was accompanied by the mobilization of 1.7–2.02 tonnes of mercury, which was emitted to the atmosphere. In addition, 0.65-0.99 tons of mercury were accumulated in captured dust.
- Dudinka port operates practically all year round. In spite of the fact that it is equipped with an adequate transport infrastructure and oil storage depots, large-scale loading activities, and washout of bulk copper-nickel concentrates causes contamination of the Yenisey river with a range of hazardous substances, in particular heavy metals.
- About 1 million m^3 of waste waters are discharged annually into the Khatanga river from the collector at the Khatanga settlement. There are no data available regarding the chemical composition of the wastewater discharged. The total volume of untreated wastewater discharged in the Khatanga area amounts to 6–8 million m^3 annually.
- The TAO, and the Norilsk Industrial Area in particular, is characterized by high coal consumption levels. Coal burning therefore plays a predominant role in PTS emissions associated with fossil fuel combustion, for example, mobilization of lead. It should be noted that the amount of lead mobilized annually from the combustion of coal in the TAO is greater than the amount emitted by the Norilsk combined smelter during the production of non-ferrous metals.
- Mercury mobilized from coal combustion at heat and power plants contributes up to 10% of atmospheric emissions, the remainder being due to mercury mobilization from ores used in the production of non-ferrous metals.
- Dioxin emissions from the combustion of petroleum hydrocarbon-based fuels in the entire TAO, including the Norilsk Industrial Area, are comparable to dioxin emissions from coal combustion in the TAO when the Norilsk Industrial Area is excluded.

4.4.6.5. The Chukchi Autonomous Okrug (CAO)

- Main local pollution sources in the CAO are related to the development of mineral resources including gold, tin, tungsten, mercury, and coal and lignite. Main pollution areas occur around the city of Anadyr (affecting 185 km^2) and the settlement of Nagorny (affecting 60 km^2).
- Coal dominates organic fuel consumption within the CAO, and, correspondingly, coal burning is responsible for emissions of a number of PTS.
- Sea ports in Anadyr, Lavrentiya and Provedeniya are considered to be local pollution sources.

4.5. Household and occupational sources of exposure

The knowledge accumulated over the last decade about effects of persistent organic pollutants on health indigenous people of the North has caused much public concern about their traditional food considered to be the major pathway of human exposures to highly toxic chlorinated organic compounds and metals. In the meantime other exposure sources and pathways of PTS were generally ignored.

To clarify potential indoor (household) and occupational sources and pathways of exposure, a targeted survey including human blood sampling among selected families and domestic and workplace matters were carried out. The targeted survey was designed as a case study involving 28 families from 3 selected native settlements. The selection of families was based on those measurements of cord blood concentrations of total PCBs derived from the basic survey of the project.

The work programme included re-interviewing and blood re-sampling of those women shown higher cord blood concentrations of total PCBs (over 500 ng/g lipids) at time of birth as well as interviewing and blood sampling of adult family members living together with target women. The referent group has been represented by families of those women found to have lower cord blood concentrations of total PCBs (below 500 ng/g lipids) living either in the same native community or in the closest vicinity of it. It has been proven that the sufficient number (at least 4) of families of “exposed” and “less exposed” newborns were available by the planning period only in:

- the settlement of Lorino, Chukotka coastal study area;
- the district of Khatanga, Taimyr Peninsula;
- and the settlement of Nelmin Nos, Pechora River Basin;

The invitation and interviewing procedures and blood sampling protocol were identical to the those applied for the general indigenous population in the 2001 survey but supplemented with the extended questionnaire focused on occupational and household sources of exposure to PTS since the treatment of animals against mosquito bites, protection of houses against rodents, bed-bugs and cockroaches are widely occurred in the northern communities The work programme thereof involved visiting the houses of selected families as well as work places and, where possible, sampling wash-outs and scrapes in home and occupational settings for further analyses for contaminants. Activities potentially associated with the human exposure to PTS are summarized in Table 4.33.

The impression on to what extent the indigenous population is at higher risk of exposure to PTS through the sources other than local foods can be illustrated by following information obtained from the questionnaire study :

Type of exposure	Site of exposure	Percent of pregnant women reported exposure	Per cent of general population reported exposure
Occupational	fishing/hunting, casting of pellets/plummets	0.9	7.3
	Reindeer herding, lather and fur handicrafts, animal treatment, maintenance female worker, veterinary	10.4	4.63
	Nurse, hospital worker	10.0	4.63
Vegetable gardening	Gardener	19.1	30.5
Use of toxic substances	Any place	41.3	34.1
	At home	39.6	30.96
	At work	5.2	2.3
	In vegetable garden	2.6	0.63
	Against rodents	6.1	3.74
Adverse habits	Smoking	35.2	54.1
	Alcohol abuse (including home-made hard liquors)	57.8	69.9

Table 4.33.
Activities associated with risk of PTS exposure (according to questionnaire).

- Casting of shot (plummet) and other hunting and fishing appliances can hardly be accounted as a source of significant lead exposure in surveyed populations. Only 7% indigenous people and below than 1% of pregnant indigenous women have reported activities potentially associated with contacting lead.
  Smoking is likely to remain one of the most significant source of cadmium intake in indigenous people, since 54% of adults of general population and 35% pregnant women have reported tobacco smoking habits.
- Household use of toxicants is reported by 34-41% of respondents. However, despite the fact that over 30% of surveyed population grow vegetables in garden plots or greenhouses, only few reported on the use of insecticides to protect cultivated plants.
- 70% respondents of general population and 58 % of pregnant women reported the frequent consuming alcohol. The significant number of respondents reported to consume homemade alcoholic drinks. A specific source of PTS contamination is that the indigenous people frequently use, for economical reasons, the wasted (second-hand) technical barrels and plastic containers to produce and store liquids including homemade alcohols.

Chemical analysis of some insecticides sampled as result of targeted survey shows that the most common household toxicants available in the market in Nenets, Taimyr and Chukchi AOs do not contain PCB, HCH, HCB, DDT in considerable concentrations (Table 4.34). The chemical named “Medifox super” produced by “Fox Company” (Russia) is the exception. According to its certificate the main constituent is the permitrin concentrate and “is used for pediculosis treatment and for disinfections of rooms against pediculosis and sarcoptoid ticks”. “Medifox” has been found to be used widely in Chukotka kindergartens, schools, health institutions, residential buildings for scabies treatment since early 1990’s.

“Mashen’ka” crayon imported from China and widely used in the North of Russia for cockroach combating does not appear to contain the POPs in question. However composition of this crayon as well as of other protectors may differ significantly from those used 10-20 years ago. Information about the insecticide composition used in the past, is not available.

The wash-outs were taken indoor (mainly from kitchen walls) whereas the scrapes were taken from surfaces of the kitchen furniture and appliances. Results of their POPs measurements are summarized in the Table 4.35. Judging by these results the indoor environment of indigenous residencies is likely to be one of the most common source of exposure to POPs.

The highest levels of DDT, PCB and HCH were found in the native communities of Chukotka. DDE/DDT ratios in wash-outs and scrapes amount to 10-70 % allow to suggest relatively recent contamination of the residencies by

Name	ΣPCB	HCB	ΣHCH	*4,4´*-DDE	*4,4´*-DDT	ΣDDT	ΣTox
“Mashen’ka” crayon	28.0	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Anti-cockroach compound	31.0	n.d.	n.d.	7.7	15.0	22.0	n.d.
Medifox (antilice compound)	234	406	n.d.	38.0	480	546	n.d.
Anti-insect compound	8.0	0.5	n.d.	n.d.	n.d.	0.3	n.d.
Anti-gadfly compound	0.3	0.1	n.d.	0.01	n.d.	0.01	n.d.
Anti –mosquito cream	n.d.	1.1	n.d.	n.d.	n.d.	n.d.	n.d.
Anti-mosquito cream	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Skin-tanning fluid	n.d.	n.d.	n.d.	n.d.	0.08	0.08	n.d.
Skin-tanning fluid	n.d.	n.d.	n.d.	n.d.	0.03	0.03	n.d.

Table 4.34.
POPs concentrations in insecticides and in skin-tanning fluids collected in Nenetz, Taimyr, and Chukotka regions in 2003, ng/g

Contaminants	Pechora River Basin	Taimyr	Chukotka	
	Wash-outs, µg / m²	Wash-outs, µg / m²	Wash-outs, µg / m²	Scrapes ng/g
	n=6	n=8	n=11	n=4
ΣPCBs	0.18	1.36	2.35	248.1
HCB	0.02	0.18	0.08	0.8
ΣHCH	0.27	0.28	0.49	67.4
***4,4`*-DDE**	0.28	0.57	0.90	126.3
ΣDDT	1.10	1.85	11.19	768.4

Table 4.35. POPs concentrations in wash-outs and scrapes collected inside the dwellings (geometric means)

DDT – containing chemicals. The intensive past use of household insecticides seems to be the major contributor to the persistent pesticide contamination of indoor environment. However, lack of awareness shown by interviewed indigenous people does not permit to specify the exact insecticide(s) which had been applied indoor. The chemical composition of retailed insecticides is generally unknown since these products had been supplied to the market mostly unlabelled.

The potential occupational exposure to POPs was most frequently reported as in form of the treatment of reindeer skin by various insecticides to protect the animals against mosquito bites. Blood-sucking insects, especially gadflies, can penetrate into animal's subcutaneous tissues as well as through naso-pharynx, impose a serious problem for animal health, and during the long-range running, the efficiency of insect combating may be a determinant of the deer herd livestock. The current variety of chemicals against mosquitoes and gadflies combating are different to those used in the past. Nowadays the most common are the synthetic piretroids which do not contain organo-chlorines, and they are not persistent and not capable of accumulating in the body at detectable levels. In the early 1970's organophosphines (chlorophos) with ammonium carbonate or with sodium hydroxide, hexamide with spindle oil and emulsifier, DDVP (dimethyldichlorvinylphosphate), etacide, trichlorometaphos-3, sulphur dioxide, smoke hexachlorane shells, cryoline-hexachlorane liniment and other hexachlorane compounds were widely used in reindeer collective farms. Among the above-mentioned chemicals only "hexachlorane" has been found to contain HCH at significant levels. Other currently used insecticides are generally free of POPs containing an array of organo-chlorine compounds, and are readily degradable in the nature.

Chapter 5

PTS levels in biota and biomagnification in food chains

5.1. Sampling strategy

Environmental sampling and analysis within the framework of Activity 4 'Biomagnification in Arctic food chains' had two objectives:

- determination of current PTS levels in main biota species, particularly those which are a utilised as part of the traditional diet of the indigenous populations in the pilot areas covered by the project;
- evaluation of the extent to which biomagnification occurs, i.e., the measurement of PTS accumulation in terrestrial, freshwater, and marine food chains, in which humans represent the uppermost trophic level.

These two aims place somewhat different requirements on sampling, sample treatment, and analysis. For the first objective, in order to estimate PTS intake with food, it is necessary to obtain as reliable and representative data as possible on PTS levels in those species and tissues that are widely used as traditional food. For the second objective, it is necessary to determine the average levels of contamination in species representing a range of trophic levels (and in specific tissues of organisms at higher trophic levels), and from this information, evaluate the degree to which PTS are being accumulated and biomagnified in the various food chains that form the basis for food items in the traditional diet.

Figure 5.1. Location of the environmental sampling area on the Kola peninsula.

Figure 5.2. Location of the environmental sampling area in the lower Pechora basin.

To these ends, environmental sampling was carried out in six areas within the four main project regions, these areas being located around settlements with the highest indigenous populations. Bearing in mind that hunting and fishing grounds can be located at some distance from the actual settlements, and that migration of reindeer herds depends upon the season and weather conditions, field sampling was based on prior consultations with local indigenous peoples involved in traditional activities. The environmental sampling areas that were defined following these consultations are shown in Figures 5.1–5.4.

It is also important to note that the optimal season for environmental sampling differed between locations. It depends, not only on availability of the specified species, but on the hunting seasons, which may vary between different regions. In addition, sampling of certain species of biota, particularly those species which are obtained by hunting or fishing, had to be arranged in close collaboration with local hunters and fishers. This was important, not only to ensure efficiency in sampling related to these activities, but also from a legal point of view, since licences for the hunting of some species and for marine mammals in particular, can only be obtained by indigenous communities.

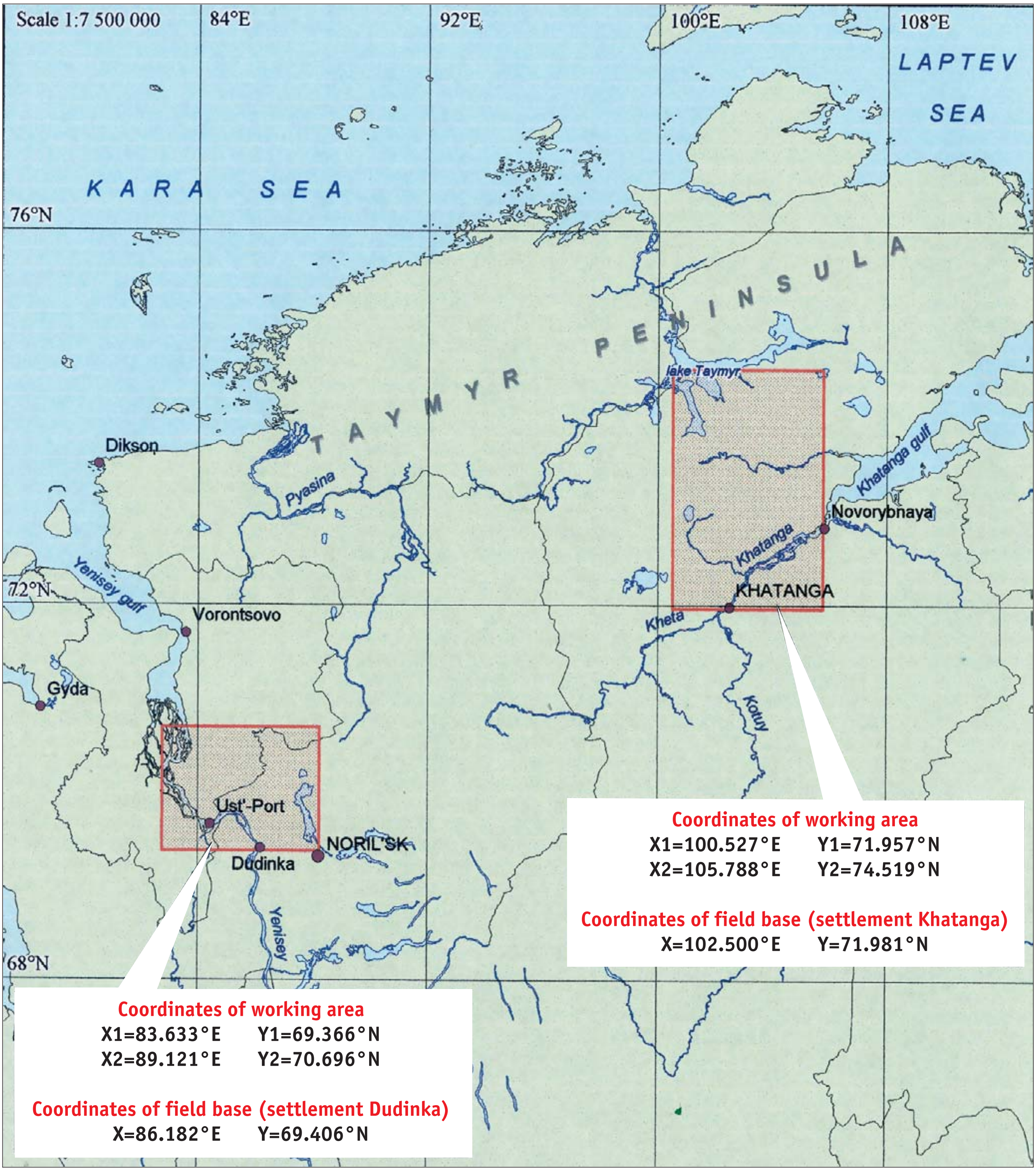


Figure 5.3. Location of the environmental sampling areas on the Taymir peninsula.

For these reasons, in addition to the main field sampling expeditions undertaken, additional field work in Chukotka was arranged in order to sample marine species (and particularly marine mammals) over the area shown in Figure 5.5.

The number and type of environmental samples were selected in accordance with the stated objectives of the activity. i.e., to study biomagnification in food chains and to measure PTS levels in traditional food sources of selected indigenous communities. Sampling of environmental media was designed to ensure that reliable data could be obtained for average concentrations of selected contaminants at the sample sites. For example, pooled water samples, which combined a number of replicated samples taken at different depths within the water column (e.g. sub-surface, middle and bottom), were utilized. A similar approach, i.e. using pooled samples, was employed for the lower trophic levels of food chains, and in particular for vegetation such as lichens, mosses, and mushrooms.

For biota species at higher trophic levels, specific organs and tissues known to be important with respect to PTS accumulation, were sampled. Tissue and organ

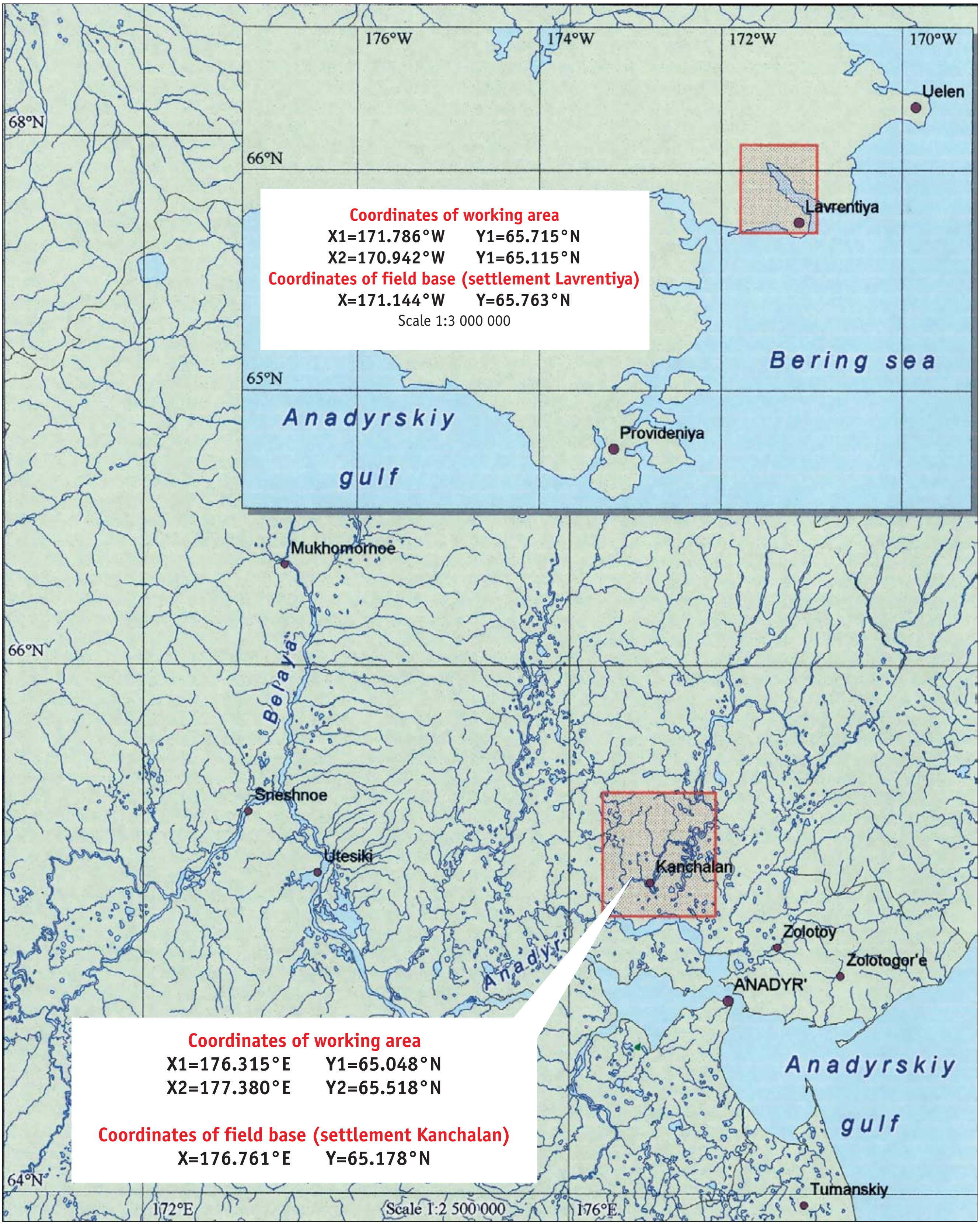


Figure 5.4. Location of the environmental sampling areas on the Chukotka peninsula.

samples from animals of the same sex and similar age groups were then pooled. An exception to this approach was made in the case of marine mammals, which feed at the top of (in some cases, long) marine food chains and can accumulate particularly high levels of lipophilic contaminants, including organochlorines, due to the high fat content in their bodies, and also high levels of methyl mercury. For these animals, samples were treated and analyzed individually and not pooled. All samples were frozen immediately after delivery to the field camp, and stored frozen until shipped to the laboratory. Samples pooling took place in the laboratory as a part of sample treatment prior to analysis.

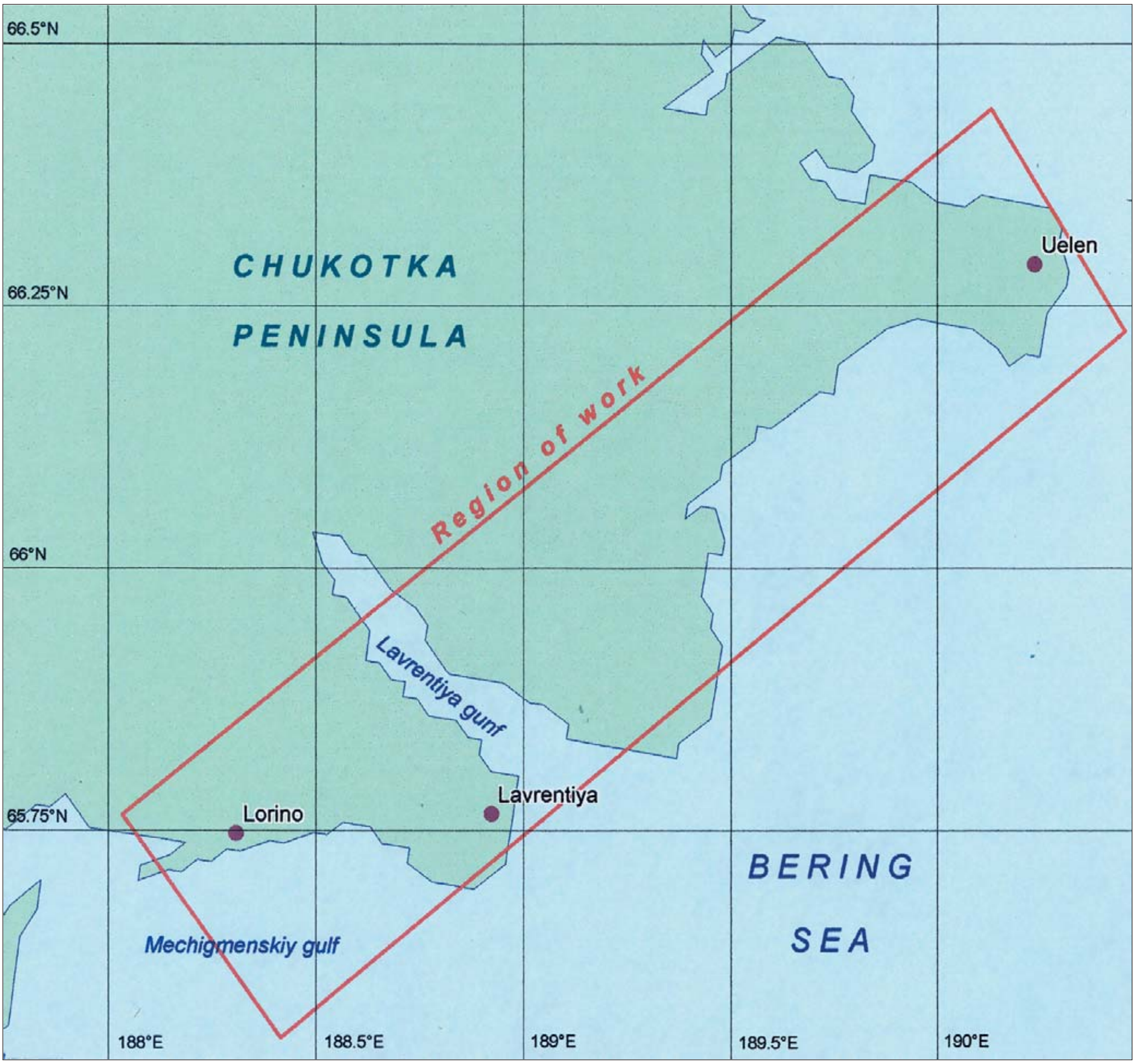


Figure 5.5. Location of the area in which marine food chain species were collected around the Chukotka peninsula.

Table 5.1 contains a list of environmental samples collected during field work, and a list of the pooled and individually analyzed samples of environmental media and biota is presented in Table 5.2.

5.2. Analytical methods and quality control

The analytical methods used for PTS determination in individual and pooled environmental and biotic samples were based on internationally recognized methodologies (ISO methods 8288:1986, 6468:1996, 5666:1983, 10382, 11048:1995, 10382, 19258, 14653-2; US EPA methods 200, 245.5, 245.6, 508, 525.1, 550, 608, 680, 8082, 8275a, 8290a, 8310a, PP-006; ASTM methods D 3534-85, D 3557-95, D 3559-96, D 5175-91, D 5412-93, D-5673-96, D5812-96; JAMP, 1999a and 1999b; NOAA, 1998; UNEP, 1993) also taking into account AMAP recommendations. Russian standard methodologies, as certified by the Russian State Standardization Committee (Gosstandart), were also used when appropriate (GOST 17.4.4.02-84, 26929-86, 26927-86, 26932-86, 26933-86, 7636-85, PND F 14.1:2:4.124-97, 14.2:4.74-96, 16.1.7-97, 16.1.4-97 14.2:4.70-96, RD 52.10.556-95, 52.18.180-89, 52.18.578-97, 52.44.590-97, 52.18.191-89, 52.44.592-97).

5.2.1. Quantitative determination of chlorinated and brominated organic compounds

Conventional extraction and clean-up procedures were utilised in the analytical treatment of samples. Extraction efficiency was checked by introducing internal standards (PCB-198 and dibromo-octafluorodiphenyl (DBOF)) prior to extraction.

Quantitative analysis of organochlorines (OC) was performed using gas chromatography (GC) with an electron capture detector (ECD). In addition, gas chromatography with mass spectroscopy (GC-MS) was employed for samples with an anomalous composition

Table 5.1.
List of environmental media and biotic samples obtained in the project study areas.

Environment	Sample (species)	Type (organ/ tissue)	Number of samples						
			Kola	Pechora	Taymir-Dudinka	Taymir-Khatanga	Chukotka-coastal/marine	Chukotka-Kanchalan	Total
Terrestrial	Soil	Upper layer	30	30	30	30	30	30	180
		Column	10	10	5	5	5	5	40
	Moss		20	20	20	20	20	20	120
	Lichen		20	20	20	20	20	20	120
	Berries	2 types	16 + 4	10 + 10	20 + 0	10 + 8 + 6	12 + 8	10	114
	Mushrooms	2 types	8 + 0	10 + 10	4 + 0	12 + 0	12 + 0	—	56
	Ptarmigan	Muscle	20	20	20	20	20	20	120
		Liver	20	20	20	20	20	20	120
	Water-fowl	Muscle	16	15	20	20	20	12	103
		Liver	16	15	20	20	20	12	103
	Hares	Muscle	10	15	15	14	—	15	69
		Liver	10	15	15	14	—	15	69
		Kidneys	10	15	15	14	—	15	69
	Reindeer	Muscle	10	15	10	10	10	10	65
		Liver	10	15	10	10	10	10	65
		Kidneys	10	15	10	10	10	10	65
Freshwater	Water		9	8	8	8	—	8	41
	Sediments		10	10	10	10	—	10	50
	Benthos		10	2	3	3	—	—	18
	Fish (3 species in each area)	Muscle	20 x 3	20 x 3	20 x 3	20 x 3	—	20 x 3	300
		Liver	20 x 3	20 x 3	20 x 3	20 x 3	—	20 x 3	300
Marine	Water		—	—	—	—	9	—	9
	Sediments		—	—	—	—	10	—	10
	Seaweed		—	—	—	—	20	—	20
	Fish (5 species)	Muscle	—	—	—	—	151	—	151
		Liver	—	—	—	—	151	—	151
	Ringed seal	Fat	—	—	—	—	14	—	14
		Muscle	—	—	—	—	14	—	14
		Liver	—	—	—	—	14	—	14
		Kidneys	—	—	—	—	14	—	14
	Other seal species	Fat	—	—	—	—	28	—	28
		Muscle	—	—	—	—	28	—	28
		Liver	—	—	—	—	28	—	28
		Kidneys	—	—	—	—	28	—	28
	Walrus	Fat	—	—	—	—	22	—	22
		Muscle	—	—	—	—	22	—	22
		Liver	—	—	—	—	22	—	22
		Kidneys	—	—	—	—	22	—	22
	Gray whale	Fat	—	—	—	—	8	—	8
		Muscle	—	—	—	—	8	—	8
		Liver	—	—	—	—	8	—	8
		Kidney	—	—	—	—	8	—	8
Total:			**389**	**420**	**395**	**404**	**846**	**362**	**2816**

or high concentrations of pollutants, to confirm the presence of the substances under consideration. Samples in which brominated biphenyls and brominated diphenyl ethers were detected in significant concentrations, were also subjected to additional GS-MS examination.

Quantitative determination was made using an absolute calibration method, using target components and the (DBOF) internal standard that was added to the sample before its analysis.

Routine analyses were performed using a measurement system consisting of a *Fisons Mega-2* chromatograph with *ECD800* detector, and a chromatographic data processing system consisting of a *Multichrome-1.4* and *Kristall-2000M* chromatograph with electron capture detector, an automated sampler, and the chromatographic data processing software, *Chromatec Analytic 1.21.*

Analysis of chlorinated compounds by mass-spectrometry was carried out using a *Fisons 8060* gas chromatograph and an *MD800* mass spectrometer operating in the electron shock mode (70 eV). For brominated compounds, the comparable system comprised a *Carlo-Erba 8060* gas chromatograph and *MD800* mass spectrometer as above. Operational control of the above systems, recording of mass-spectra, and their subsequent processing was undertaken using the *MassLab1.3* software package, and the National Institute of Science and Technology (NIST) library of organochlorine compounds.

A measurement system consisting of a *Carlo Erba 8035* chromatograph, and an *Autospec-Ultima (VG)* high resolution mass-spectrometer, operating in electron impact mode (36 eV) and with a resolution of ≥10.000, was used for isomer-specific analysis of polychlorinated dibenzo-p-dioxin and dibenzofurans (PCDD/Fs), brominated compounds and

Table 5.2.
List of pooled or individually analyzed samples of environmental media and biota.

Environmen t	Sample (species)	Type (organ/ tissue)	Number of samples: Kola	Pechora	Taymir-Dudinka	Taymir-Khatanga	Chukotka -coastal/ marine	Chukotka-Kanchala n	Total
Terrestrial	Soil		5	1	1	2	1	1	11
	Moss		3	1	2	2	1	2	11
	Lichen		4	1	2	2	1	2	12
	Berries	2 types	2	2	1	2	2	2	11
	Mushrooms	2 types	1	2	1	1	1	—	6
	Ptarmigan	Muscle	2	2	2	2	2	2	12
		Liver	2	2	2	2	2	2	12
	Water-fowl	Muscle	4	4	5	7	3	8	31
		Liver	4	4	5	7	3	8	31
	Hares	Muscle	2	2	2	2	—	2	10
		Liver	2	2	2	2	—	2	10
		Kidneys	2	2	2	2	—	2	10
	Reindeer	Muscle	6	6	5	4	2	2	25
		Liver	6	6	5	4	2	2	25
		Kidneys	6	6	5	4	2	2	25
Freshwater	Water		4	3	2	2	—	1	12
	Sediments		1	1	1	1	—	1	5
	Fish (3 species in each area)	Muscle	12	13	14	16	—	10	65
		Liver	12	13	14	16	—	10	65
Marine	Water		—	—	—	—	3	—	3
	Sediments		—	—	—	—	1	—	1
	Seaweed		—	—	—	—	2	—	2
	Fish (5 species)	Muscle	—	—	—	—	18	—	18
		Liver	—	—	—	—	18	—	18
	Ringed seal	Fat	—	—	—	—	14	—	14
		Muscle	—	—	—	—	14	—	14
		Liver	—	—	—	—	14	—	14
		Kidneys	—	—	—	—	14	—	14
	Other seal species	Fat	—	—	—	—	28	—	28
		Muscle	—	—	—	—	28	—	28
		Liver	—	—	—	—	28	—	28
		Kidneys	—	—	—	—	28	—	28
	Walrus	Fat	—	—	—	—	22	—	22
		Muscle	—	—	—	—	22	—	22
		Liver	—	—	—	—	22	—	22
		Kidneys	—	—	—	—	22	—	22
	Gray whale	Fat	—	—	—	—	8	—	8
		Muscle	—	—	—	—	8	—	8
		Liver	—	—	—	—	8	—	8
		Kidney	—	—	—	—	8	—	8
Total:			**80**	**73**	**73**	**80**	**352**	**61**	**719**

toxaphenes. Separation of isomers was carried out in a 60 m non-polar *DB-5MS J&W Scientific* column.

All standard solutions of organochlorine pesticides and PCBs used for calibration were produced by Ultra Scientific (USA) and certified by ISO9001. Standards for toxaphenes, brominated diphenyl ethers, and brominated biphenyls were produced by St. Petersburg University.

5.2.2. Quantitative determination of heavy metals

Measurements of mercury were carried out using a (Russian) *Kvant-Z.ETA* atomic absorption spectrophotometer (analogous to the Western *Varian AA-8000* system), operating with a *GRG-106* mercury generator in automatic mode, using Zeeman background correction.

Mercury in samples was reduced to its metal state using tin dichloride, and then transferred in an argon gas flow ('Cold Vapor' method) to a graphite furnace, the internal surface of which was covered with a fine palladium layer to ensure mercury retention in the furnace. The detection limit for mercury in the solutions under consideration was 0.001 μg/L, with a relative error of 20% at this level of concentration.

Measurements of lead and cadmium were carried out using a *Kvant-Z.ETA* atomic absorption spectrophotometer, with electrochemical atomization of the sample, using Zeeman background correction and a constant aliquot volume of 5 μL of sample solution. Prior to any measurements, a palladium modifier (at a concentration of 20 μg/L (Pd)) was added to the samples.

5.2.3. Quantitative determination of polyaromatic hydrocarbons (PAHs)

Determination of PAHs in all samples involved liquid extraction, followed by clean-up of extracts to remove substances that could cause interference during analysis. Octafluoronaphthalene (OFN) was introduced as an internal standard to check the extraction efficiency of PAHs.

PAH analytical determination was made using High Resolution Liquid Chromatography (HRLC), with target components registered by diode-matrix and fluorescent detectors connected in series. Quantification of PAH levels was made by absolute calibration, using standard solutions of target components and a control based on the internal standard (OFN) solution, which was added to the sample before its analysis. Analysis was performed using a measurement system consisting of an *HP1090M* chromatograph with a standard diode-matrix component, a *Spectraphysics* fluorescent detector with programmed excitation wavelength, and Hewlett-Packard hardware/software processing system for chromatographic data.

	Water	Bottom sediments	Soil	Vegetation	Reindeer	Hares	Birds	Fish	Marine mammals	Total
Heavy metals (HM)										
Analysis of blank samples	1	1	1	1	2	1	2	5	4	**18**
Analysis of replicate samples	1	1	3	1	2	1	2	5	4	**19**
Analysis of standard solutions	—	1	—	—						**1**
Analysis of samples with addition of target components					2	1	2	6	4	**15**
Polycyclic aromatic hydrocarbons (PAHs)										
Analysis of blank samples	1	1	1	1	2	1	2	5	4	**18**
Analysis of replicate samples	1	1	3	1	2	1	2	5	4	**19**
Analysis of standard solutions	—	1	—	—						**1**
Analysis of samples with addition of target components					2	1	2	6	4	**15**
Organochlorines: polychlorinated biphenyls (PCBs)										
Analysis of blank samples	1	1	1	1	2	1	2	5	4	**18**
Analysis of replicate samples	1	1	3	1	2	1	2	5	4	**19**
Analysis of standard solutions	—	1	—	—						**1**
Analysis of samples with addition of target components					2	1	2	6	4	**15**
Chlorobenzenes, polybrominated biphenyl and diphenyl ethers, polychlorinated camphenes (PCCs)										
Analysis of blank samples	1	1	1	1	2	1	2	5	4	**18**
Analysis of replicate samples	1	1	3	1	2	1	2	5	4	**19**
Analysis of standard solutions	—	1	—	—						**1**
Analysis of samples with addition of target components					2	1	2	6	4	**15**
Organochlorines: HCHs, DDTs, cyclodienes										
Analysis of blank samples	1	1	1	1	2	1	2	5	4	**18**
Analysis of replicate samples	1	1	3	1	2	1	2	5	4	**19**
Analysis of standard solutions	—	1	—	—						**1**
Analysis of samples with addition of target components					2	1	2	6	4	**15**
Chlorinated dibenzodioxins and dibenzofurans										
Analysis of blank samples					1		1		1	
Analysis of replicate samples					0		0		0	
Analysis of standard solutions										
Analysis of samples with addition of target components					1		1		1	

Table 5.3. Quality control analyses performed as part of the analysis of environmental and biotic samples.

Table 5.4.
Comparison of concentrations of brominated compounds in environmental and biotic samples obtained by routine GC, and by high resolution GC-MS methods. TeBD=tetra brominated diphenyl, PeBD=pentabrominated diphenyl, TeBDE=tetrabrominated diphenyl ether, PeBDE=pentabrominated diphenyl ether.

Samples	Routine GC method				High resolution GC-MS method			
	TeBD	PeBD	TeBDE	PeBDE	TeBD	PeBD	TeBDE	PeBDE
Bottom sediments, pg/g dw	< 200	< 200	< 200	< 200	< 2	< 2	3.1 - 24.1	1.0 - 3.0
Soil, pg/g dw	< 200	< 200	< 200	< 200	< 2	< 2	1.5 - 5.4	1.2 - 2.7
Mosses, pg/g dw	< 200	< 200	< 200	< 200	< 2	< 2	7.2 - 11.9	6.2 - 10.9
Lichens, pg/g dw	< 200	< 200	< 200	< 200	< 2	< 2	20.7 - 29.4	5.1 - 10.2
Berries, pg/g ww	< 200	< 200	< 200	< 200	< 2	< 2	3.2 - 21.8	1.0 - 9.5
Reindeer kidney, pg/g ww	< 200	< 200	< 200	< 200	< 2	< 2	136.2 - 233.3	5.1 - 7.1
Hare liver, pg/g ww	< 200	< 200	< 200	< 200	< 2	< 2	123.1 - 258.9	3.1 - 6.5
Fish liver, pg/g ww	< 200	< 200	420	< 200	6.7	< 2	620.2	8.9

All standard solutions for PAHs used for calibration were produced by Ultra Scientific (USA) and certified by ISO9001. The octafluoronaphthalene standard was produced by St. Petersburg University.

5.2.4. Quality control

Analytical quality control and quality assurance involved the execution of a full programme of work including analyses of blank samples, standard solutions, replicate samples, samples spiked with target components, and analysis of samples of different matrix compositions containing known levels of the determined components (Table 5.3). In addition, laboratories involved in the work participated in international intercalibration exercises within the framework of the 'QUASIMEME' Programme, and the AMAP Ring Test on analysis of POPs in human blood samples.

Under an arrangement made through the AMAP Secretariat, the laboratory responsible for analysis of environmental and biotic samples participated in the first stages of Rounds 22, 24 and 25 of the laboratory performance studies organized by 'QUASIMEME'. These concerned the analysis of bottom sediments and biota samples for levels of PAHs, OCs and HMs (Rounds 22 and 24), and the analysis of samples of sea and estuarine waters for OCs, HM and mercury (Round 25).

Calibration standards used were the Russian State Certified Standards and certified standards produced in other countries (by ULTRA Scientific, Wellington Laboratories, etc.). Previously analyzed samples, spiked with specific components at levels approximately 2-4 times greater than those detected during their original analysis, were employed as matrix samples containing known levels of the determined components. In addition, residual material from test samples distributed as part of the 'QUASIMEME' laboratory performance studies, with known composition and published 'assigned' concentration values, were also used as control samples.

As concentrations of toxaphenes, brominated diphenyl ethers and brominated biphenyls in most pooled samples were found to be very low (below the levels of reliable determination for these compounds using routine methods), 40 samples (6 bottom sediment, 6 soil, 6 lichen, 6 berry, 3 reindeer kidney, 4 hare liver, and 3 fish liver samples) were sent for control analysis using high resolution GC-MS (*Carlo Erba 8010/Autospec Ultima V6* system, described above) (Table 5.4). The control analyses confirmed the validity of the data obtained using the routine methods.

5.2.5. Processing and presentation of analytical results

Results of analyses were grouped according to sampling site and sample types. Concentrations of individual compounds within related groups of substances were summed to provide a total value for the group. For purposes of calculation, where results were below the detection limit, a value of half the detection limit was used if this did not contribute more than 20% of the summed value; otherwise no sum was calculated.

Sums were calculated for the following groups of substances:
ΣHCH: the sum of α-, β- and γ-isomers of HCH.
ΣDDT: the sum of *o,p'*- and *p,p'*-DDT, -DDE, -DDD.
ΣCHLOR: the sum of *cis*- and *trans*-chlordane and *cis*- and *trans*-nonachlor.
ΣPCB_{15}: the sum of 15 PCB congeners (#28, #31, #52, #99, #101, #105, #118, #128, #138, #153, #156, #170, #180, #183, and #187).
ΣPCB_7: the sum of 7 PCB congeners (#28, #52, #101, #118, #138, #153, and #180); calculated to allow comparison with data obtained in the Russian North in 1994/1995.
Toxaphene: the sum of Parlar-26, Parlar-50, and Parlar-62.
ΣPCDD/F: the sum of all 2,3,7,8-substituted congeners of dibenzo-*p*-dioxin and dibenzofuran.

Environmental contaminants commonly exhibit a log-normal frequency distribution in their concentration values (WHO, 1983). A log-normal distribution was therefore assumed to apply for concentrations of a particular contaminant (and concentration ratios) within any given sample type collected at a particular site. In most cases, therefore, data are reported as the geometric mean concentration (or ratio) and the associated standard deviation. Arithmetic mean concentrations and standard deviations were only calculated when concentration variability was low (i.e. where the standard deviation was less than 30% of the mean for most contaminants). This latter calculation, however, facilitated comparison with results from other studies, where PTS concentrations are commonly reported in terms of mean values and their standard deviations.

Sample type	Area	ΣPCB$_{15}$	ΣPCB$_7$	ΣHCB	ΣHCH
Lichens	Kola Peninsula, n=4	3.9±0.3	2.8±0.2	0.5 (0.1-0.9)[a]	0.53±0.17
	Pechora basin, n=1	3.2	2.3	1.25	0.74
	Taymir, west, n=2	3.5±0.3	2.5±0.2	0.5±0.1	1.4±0.5
	Taymir, east, n=2	3.5±0.6	2.5±0.4	1.0±0.2	1.6±0.4
	Chukotka, inland, n=2	3.4±0.5	2.2±0.2	0.4±0.1	0.89±0.08
	Chukotka, coast, n=1	3.9	2.5	0.15	0.76
Mosses	Kola Peninsula, n=3	12.6±0.1	9.1±0.1	0.2(0.1-0.45)[a]	0.8±0.2
	Pechora basin, n=1	7.7	6.2	0.95	1.4
	Taymir, west, n=2	11.8±1.8	9.0±1.2	1.0±0.3	2.3±0.5
	Taymir, east, n=2	10.3±0.5	7.7±0.1	0.7±0.1	1.9±0.2
	Chukotka, inland, n=2	13.1±1.0	9.6±0.5	0.5±0.2	0.69±0.04
	Chukotka, coast, n=1	13.1±1.0	10.5	0.24	0.5
Berries	Kola Peninsula, n=2	1.2 – 1.8[a]	1.1±0.2	0.18±0.04	0– 0.4[a]
	Pechora basin, n=2	1.4 – 1.8[a]	1.3±0.1	0.25±0.05	0.1 – 0.5[a]
	Taymir, west, n=1	4.4	3.25	0.21	0– 0.40[a]
	Taymir, east, n=2	1.5 – 3.0[a]	1.2±0.1	0.18±0.01	0– 0.5[a]
	Chukotka, inland, n=2	1.1 – 2.1[a]	1.1±0.1	0.19±0.08	0– 0.6[a]
	Chukotka, coast, n=2	1.0 – 1.5[a]	1.0±0.1	<0.1-0.15[a]	0– 0.40[a]
Mushrooms	Kola Peninsula, n=1	0.5 – 1.7[a]	0.4 – 0.9[a]	0.11	0– 0.4[a]
	Pechora basin, n=2	0.7 – 2.0[a]	1.0±0.2	0.20±0.05	0.1 – 0.5[a]
	Taymir, west, n=1	1.4 – 2.3[a]	1.2	0.14	0.1 – 0.4[a]
	Taymir, east, n=1	0.9 – 1.8[a]	0.88	0.14	0– 0.4[a]
	Chukotka, coast, n=1	0.5 – 1.7[a]	0.2 – 0.7[a]	0.05	0– 0.4[a]

Table 5.5a.
Concentrations (mean and standard deviation, or range; ng/g dw) of OCs in vegetation in the Russian Arctic in 2001.
[a] A range is given when the standard deviation is greater than 50% of the mean, or the concentration in one of the samples is below the detection limit. When lower and upper limits of the concentration interval were estimated for summed concentrations, any individual values that were below the detection limit were either set to zero or to the detection limit (see Section 5.2.5).
n = number of pooled samples analyzed.

5.3. Results – Terrestrial environment

5.3.1. PTSs in plants and mushrooms

The following species were collected and analysed for PTSs:
Lichens – *Cetraria cuculata, Cetraria islandica, Cladina rangiferina, Cladina alpica, Cladina stellaris, Cladina mitis*;
Bryophytes – *Polytrichum commune, Pleurozium schreberi*;
Mosses – *Dicranum sp., Sphagnum balticum, Hylocomium splendens*;
Berries – low-bush cranberry (*Vaccinium vitis-idaea*), cloudberry (*Rubus chamaemorus*), bilberry (*Vaccinium myrtillus*), blueberry (*Vaccinium uliginosum*), crowberry (*Empetrum nigrum*);
Mushrooms – orange-cap boletus (*Leccinum aurantiacum*), brown-cap boletus (*Leccinum scabrum*), mossiness mushroom (*Xerocomus sp.*).

The number of individual samples of each vegetation type collected at a given site and used in the preparation of a pooled sample was usually 10, but ranged between 4 and 20 (see Table 5.1). Vegetation was analysed for all PTS listed in Section 1.2.4.

Levels and trends

(a) Organochlorines

Concentrations of organochlorines (OCs) in vegetation that significantly exceeded detection limits are shown in Tables 5.5a and 5.5b. Data for those OCs which occurred at concentrations below the detection limit in most samples are not presented. The level of HCB was above the detection limit in all samples of plants and mushrooms. ΣPCB$_{15}$ and ΣPCB$_7$, ΣDDT and ΣHCH were detectable in all samples of lichens and mosses and ΣPCB$_7$ and ΣDDT also in most of the berry

Sample type	Area	*p,p'*-DDE	*p,p'*-DDT	ΣDDT	Mirex
Lichens	Kola Peninsula, n=4	0.24±0.07	0.4±0.1	1.0±0.3	<0.1
	Pechora basin, n=1	0.75	0.80	2.2	0.52
	Taymir, west, n=2	1.2±0.6	1.3±0.3	3.1±0.3	0.18±0.03
	Taymir, east, n=2	0.71±0.13	0.9±0.3	2.9±0.8	<0.1 – 0.3[a]
	Chukotka, inland, n=2	0.30±0.03	0.62±0.12	1.39±0.03	<0.1
	Chukotka, coast, n=1	0.24	0.67	1.2	<0.1
Mosses	Kola Peninsula, n=3	0.3±0.1	0.4±0.1	1.3±0.1	0.15±0.06
	Pechora basin, n=1	0.72	0.77	2.3	0.44
	Taymir, west, n=2	<0.05 – 1.1[a]	1.1±0.3	2.6±0.5	0.5±0.2
	Taymir, east, n=2	0.7±0.1	0.9±0.2	3.0±0.2	0.20±0.02
	Chukotka, inland, n=2	0.3±0.1	0.60±0.03	1.4±0.1	<0.1
	Chukotka, coast, n=1	0.20	0.39	1.0	<0.1
Berries	Kola Peninsula, n=2	<0.1-0.12	1.09±0.04	1.59±0.02	<0.1
	Pechora basin, n=2	<0.1	0.17±0.06	0.1-0.7[a]	<0.1
	Taymir, west, n=1	0.15	0.28	1.1	<0.1
	Taymir, east, n=2	<0.1-0.13	0.1-0.9[a]	0.1–1.5[a]	<0.1
	Chukotka, inland, n=2	0.13±0.03	0.13±0.03	0.1 –0.7[a]	<0.1
	Chukotka, coast, n=2	<0.1-0.1	<0.1-0.1	0.1 –0.6[a]	<0.1
Mushrooms	Kola Peninsula, n=1	0 – 0.12[a]	0.28	0.4 – 0.8[a]	<0.1
	Pechora basin, n=2	<0.1	<0.1	0– 0.6[a]	<0.1
	Taymir, west, n=1	0.1	0.18	0.5 – 0.8[a]	<0.1
	Taymir, east, n=1	<0.1	0.18	0.3 – 0.7[a]	<0.1
	Chukotka, coast, n=1	<0.1	<0.1	0– 0.6[a]	<0.1

Table 5.5b.
Concentrations (mean and standard deviation, or range; ng/g dw) of OCs in vegetation in the Russian Arctic in 2001.
[a] A range is given when the standard deviation is greater than 50% of the mean, or the concentration in one of the samples is below the detection limit. When lower and upper limits of the concentration interval were estimated for summed concentrations, any individual values that were below the detection limit were either set to zero or to the detection limit (see Section 5.2.5).
n = number of pooled samples analyzed.

and mushroom samples. The ΣPCB$_7$ value, when multiplied by two, can be used to provide an estimate of the total PCB concentration in mosses and, most likely, also in other plants (AMAP, 1998). Of the DDT group, only *p,p'*-DDT occurs in detectable concentration in all berry and most mushroom samples. ΣDDT concentration in berries and mushrooms were therefore estimated using the ratio of *p,p'*-DDT/ΣDDT found in lichens and mosses (0.39±0.07). This probably provides a conservative estimate as, at the three sites where ΣDDT in berries could be calculated directly, this ratio was equivalent to 0.5±0.2.

Concentrations of HCB, HCH, and DDT in mosses are comparable to those in lichens, while PCB levels are 2-4 times higher in mosses at all sites. Concentrations of these substances in berries and mushrooms are several times lower than those found in mosses and lichens.

Levels of HCB, HCH, and DDT follow a similar geographical trend, with highest levels found at the two locations on the Taymir Peninsula, and in the lower Pechora basin. In contrast, no geographical trend in PCB levels was observed. With only one exception (berries from Dudinka), all differences in PCB concentrations between the sites could be explained by analytical variability.

PCB levels in the Arctic have been found to be generally decreasing over time. Over the last few years, however, the rate of decrease has been small and levels have remained relatively constant (AMAP, 2002). In accordance with this tendency, mean ΣPCB$_7$ concentrations measured in 2001 in samples of lichens collected near Khatanga, in eastern Taymir (2.5 ng/g) and at Chukotka (2.2 and 2.5 ng/g) were slightly lower than those determined in these areas in 1995 (3.2 and 3.82 ng/g, respectively) (AMAP, 1998). In contrast, the ΣPCB$_7$ concentration for lichens from the Pechora basin in 1995 was below the detection limit, while 2.3 ng/g was found in 2001. An unexpected increase was also observed in the ΣPCB$_7$ concentration in mosses, which in 1994/1995 in the Russian North ranged from 0 to 3.6 ng/g (0–02.4 ng/g on the Taymir Peninsula; and below the detection limit in the Pechora basin). The ΣPCB$_7$ concentration in mosses in 2001 is significantly higher (10.3–013.9 ng/g).

The PCB congener patterns seen in lichens differ significantly from those occurring in most of the common technical mixtures used in Western countries. In Western products, PCB-138 and 153 dominate, while in the environment of Russian Arctic, PCB-28 makes the greatest contribution to the summed value in samples from all sites. However, relative levels of the congeners PCB-28, 52, 118, 138, 153 and 180 found in remote Arctic areas of North America also differ from those found in American technical mixtures (Wilcke and Amelung, 2000) and are close to those found in the Russian Arctic. Therefore, the PCB composition patterns provided in Figure 5.6 could also be a result of the fractionation of congeners during long-range transport.

Concentrations of ΣCBz (sum of HCB and pentachlorobenzene (PeCBz), not shown in tables) measured in plants in this study, in 2001, are distinctly higher than levels previously reported for the Russian North (see Figure 5.7). In August 1995, on the Taymir Peninsula, concentrations of 0.25 and 0.4 ng/g of ΣCBz were found in lichens and mosses, respectively (AMAP, 1998). Mean concentrations of ΣCBz in lichens and mosses obtained during the current study at two sites on the Taymir Peninsula, were 0.64±0.16 and 1.3±0.3 ng/g, and 0.9±0.1 and 1.4±0.2 ng/g, respectively. Concentration of ΣCBz in 3 samples of lichen collected near Khatanga in 1995 (AMAP, 1998) ranged from 0.16 to 0.66 ng/g, while concentrations of 1.2-1.5 ng/g ΣCBz were found at Khatanga in 2001 (see Figure 5.7). In the Pechora basin, mean ΣCBz concentrations in lichens and mosses in 1994/1995 ranged from 0 (i.e., below the detection limit) to 0.08 ng/g (AMAP, 1998), whilst in 2001 values of 0.2–1.0 ng/g were found. Thus, a comparison of the data obtained in 1994/1995 and in 2001, indicates that the concentration of chlorinated benzenes in lichens and mosses (and by inference in air) in the Russian North has shown a tendency to increase during recent years.

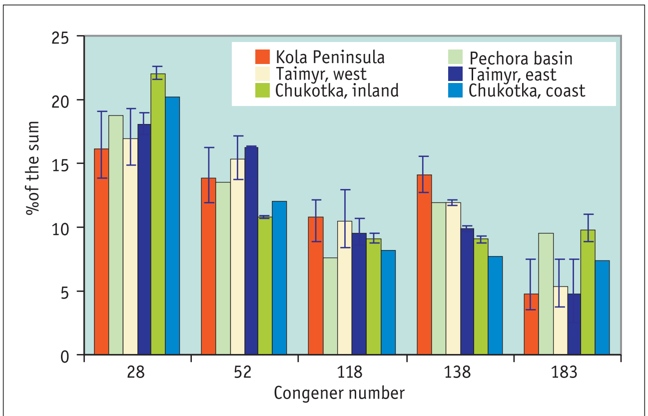


Figure 5.6. PCB congener contributions to ΣPCB$_{15}$ levels in lichen in the Russian Arctic in 2001. The congeners shown are the main contributors within each homologue group.

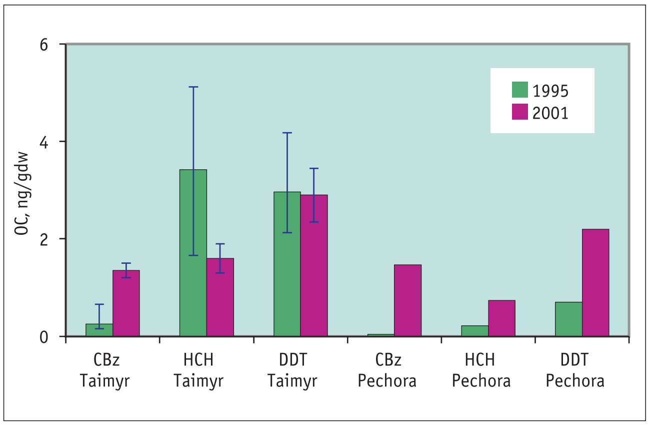


Figure 5.7. Mean values and ranges of OC concentrations measured in lichen in Eastern Taymir and the Pechora Basin in 1995 and in 2001. Values for Eastern Taymir were derived from the analysis of three samples in 1995, and two samples in 2001. CBz = sum of HCB and PeCBz, DDT=ΣDDT.

Sample type	Area	NAP	ACNLE	BIPN	NAP2M	FLE	ACNE	PA
Lichens	Kola Peninsula, n=4	179 (124-258)	1.3 (<0.5–7.9)	1.5 (<0.5–10)	45 (33-65)	12 (5.8-22)	1.2 (<0.5–5.7)	75 (33-142)
	Pechora basin, n=1	188	10.0	13.1	30	5.3	<0.5	237
	Taymir, west, n=2	177 (164-192)	8.5 (7.1-10.2)	7.4 (5.3-10.3)	29 (21-40)	9.8 (8.2-11.6)	<0.5	31 (26-38)
	Taymir, east, n=2	315 (262-378)	9.2 (6.8-12.5)	39 (33-45)	73 (59-91)	18 (15-21)	4.7 (3.5-6.3)	123 (105-144)
	Chukotka, inland, n=2	79 (63-100)	<0.5	<0.5	13 (11–14)	8.7 (6.8-11)	<0.5	65 (61-70)
	Chukotka, coast, n=1	505	7.9	<0.5	71	21	8.7	129
Mosses	Kola Peninsula, n=3	174 (86-432)	17 (13-21)	37 (28-50)	60 (48-78)	26 (20-35)	6 (4.2-9.8)	141 (110–166)
	Pechora basin, n=1	335	16	<0.5	91	13	<0.5	131
	Taymir, west, n=2	626 (512-765)	23 (16-35)	116 (102-132)	64 (54-75)	19 (19 –20)	6.5 (5.8-7.4)	66
	Taymir, east, n=2	275 (261-290)	11 (8.8-15)	35 (30-40)	208 (177-245)	13 (8.9-18)	<0.5	64
	Chukotka, inland, n=2	123 (112-134)	26 (24-28)	15 (13-17)	20 (19-21)	8.5 (7.8-9.2)	<0.5	61
	Chukotka, coast, n=1	144	<0.5	<0.5	28	27	5.0	136

Table 5.6a. Concentrations (geometric means and ranges; ng/g dw) of PAHs[a] in vegetation in the Russian Arctic in 2001.
[a] NAP = Naphthalene, ACNLE = Acenaphthylene, BIPN = Biphenyl, NAP2M = 2-Methylnaphthalene, FLE = Fluorene, ACNE = Acenaphthene, PA= Phenanthrene.

The mean ΣHCH concentration in 3 samples of lichens collected near Khatanga in 1995 (AMAP, 1998) was twice as high as those measured in the current study in the same area (3.42 and 1.6 ng/g, respectively). In contrast, ΣHCH concentrations in lichens and mosses in the Pechora basin in 1995 ranged from 0.17 to 0.38 ng/g, whilst concentrations of 0.74–1.4 ng/g were found in this area in 2001. Despite the difference in values, these results are unlikely to be indicative of a trend, as there is known to be a high degree of spatial variability in levels of contamination from HCH across the Russian North. In 1994/1995, the concentration of ΣHCH, as a function of sampling site, varied within two orders of magnitude, even for samples taken in the same area (AMAP, 1998).

No temporal trend in ΣDDT concentrations in lichens and mosses was evident in the Russian North. The mean concentration of ΣDDT in 3 samples of lichens collected near Khatanga in 1995 (AMAP, 1998) was almost the same as that found in 2001 (2.96 and 2.9 ng/g, respectively). The range of ΣDDT concentrations (0.7–3 ng/g) determined in lichens and mosses in five other areas in the Russian North in 1994/1995 (AMAP, 1998) is consistent with data obtained from the current study (1.0–3.1 ng/g). Concentrations of ΣDDT, ΣHCH, and ΣCBz found in lichens in the Russian Arctic in 2001 are all comparable with those found in the Canadian Arctic in 1993/4. PCB concentrations in Canada in 1993/4 were several times lower, while toxaphene levels were significantly higher, than those measured in Russia in 2001 (AMAP, 1998).

Mirex has not been used in the fSU/Russia. However, it does occur at detectable concentrations in some samples of lichens and mosses, presumably as a result of long-range atmospheric transport from remote sources. The geographical distribution pattern of Mirex is similar to that of ΣDDT, ΣHCH and HCB. In the most highly contaminated areas (the Pechora basin and the Taymir peninsula), Mirex concentration in lichens and mosses ranged from 0.2 to 0.5 ng/g. However, in the majority of samples collected in less contaminated areas (on the Kola peninsula, and Chukotka), Mirex concentrations were below the detection limit of 0.1 ng/g. The similarity between the spatial distribution observed for ΣDDT, ΣHCH, and HCB, and that of Mirex indicates that trans-boundary transport is at least an important source, and most likely the main source of contamination in the Russian Arctic for these compounds.

Samples of plants and mushrooms were also analyzed for other OCs listed in Section 1.2.4, with the exception of PCDD/Fs. Of these substances, only heptachlor was detected in some samples of lichen and mosses, in concentrations ranging from 0.1 to 0.3 ng/g. As all of these samples were collected in the Pechora basin and the Taymir peninsula, the spatial pattern of heptachlor distribution appears, at least qualitatively, similar to that of Mirex, ΣDDT, ΣHCH, and HCB.

Sample type	Area	ANT	FLU	PYR	BAA	CHR	BBF	BKF
Lichens	Kola Peninsula, n=4	2.0 (1.3-3.3)	41 (21-70)	18 (12-28)	1.2 (0.7-2.4)	16 (11-21)	14 (9.7-19)	3.7 (2.4-6.1)
	Pechora basin, n=1	2.3	14	2.7	1.0	18.2	4.0	1.6
	Taymir, west, n=2	1.6 (1.1-2.3)	7.6 (5.7-10.1)	6.2 (5.4-7.1)	0.7 (0.5-1.0)	12 (9.2-16)	2.5 (2.1-3.1)	1.0 (0.8 –1.2)
	Taymir, east, n=2	11 (9.0-12)	115 (85-152)	69 (54-88)	5.2 (3.6-7.3)	16 (12-20)	31 (27-35)	9.0 (6.6-12)
	Chukotka, inland, n=2	1.1 (0.8-1.4)	10 (8.8 –11)	7.4 (7.0-7.7)	0.6 (0.5-0.8)	3.8 (3.3-4.5)	2.6 (2.2-3.0)	1.1 (1.0-1.1)
	Chukotka, coast, n=1	2.8	27	13	1.5	9.6	2.3	2.2
Mosses	Kola Peninsula, n=3	1.3 (1.0-2.1)	18 (14-22)	15 (14-17)	2.8 (2.2-3.2)	12 (8.6-16)	6.8 (4.3-5.8)	4.8 (1.7-9.4)
	Pechora basin, n=1	1.7	13	10.4	1.3	17	6.1	3.1
	Taymir, west, n=2	3.9 (3.8-4.0)	12 (11-13)	18 (15-22)	1.0 (0.8-1.2)	6.2 (5.7-6.8)	2.3 (2.0-2.7)	1.2 (1.0-1.3)
	Taymir, east, n=2	9.3	45	47	6.5	21	20	11
	Chukotka, inland, n=2	0.7 (0.6-0.8)	9.2 (8.6-9.9)	5.6 (4.1-1.7)	0.5 (0.4-0.7)	12 (12-13)	3.0 (2.9-3.1)	1.0 (0.8-1.2)
	Chukotka, coast, n=1	2.4	12	16	1.1	17	10.4	4.3

Table 5.6b. Concentrations (geometric means and ranges; ng/g dw) of PAHs[a] in vegetation in the Russian Arctic in 2001.
[a] ANT= Anthracene, FLU = Fluoranthene, PYR = Pyrene, BAA = Benz[*a*]anthracene, CHR = Chrysene, BBF = Benzo[*b*]fluoranthene, BKF = Benzo[*k*]fluoranthene.

(b) PAHs

Geometric means and ranges of concentrations of PAHs in lichen and mosses are provided in Tables 5.6a and 5.6b. PAH composition is similar at all sites, with naphthalene, 2-methylnaphthalene and phenanthrene contributing 70-90% of the value of ΣPAH in both lichen and mosses. The highest concentrations, and especially those of heavier PAHs, are normally found near Khatanga. Lichens and mosses were also analyzed for benzo[*e*]pyrene, benzo[*a*]pyrene, perylene, dibenz[*ah*]anthracene, indeno[1,2,3-*cd*] pyrene and benzo[*ghi*] perylene. In the most cases, concentrations of these compounds were below the detection limit of 0.5 ng/g. Perylene, indeno[1,2,3-*cd*]pyrene and benzo[*ghi*] perylene were, however, found in concentrations which ranged from 1 to 10 ng/g in several samples, primarily from the Kola and Taymir peninsulas. A notable exception was the concentration of benzo[*ghi*]perylene found in mosses from Eastern Taymir, which was as high as 30 ng/g.

Naphthalene levels determined in berries and mushrooms are normally several times lower than those found in lichen and mosses. The difference in concentrations occurring between the two groups of plants increases with the molecular weight of the substance in question, and for the heaviest PAHs can be as much as two orders of magnitude. This may indicate that the greater efficiency of lichens and mosses for interception of gaseous and particulate PAHs from the air is partially offset by the ability of plants and mushrooms to take up PAHs with $\log K_{ow} < 4$ from the soil and translocate them to the aboveground parts of the plant (McLachlan, 1996).

(c) Brominated flame-retardants

Vegetation samples were analyzed for 2,2',4,4'-tetrabromodiphenyl; 2,2',4,4',5-pentabromodiphenyl; 2,2', 4,4'-tetrabromodiphenyl ether; and 2,2',4,4',5-pentabromodiphenyl ether. In all samples these substances were below the detection limit of 0.2 ng/g dw.

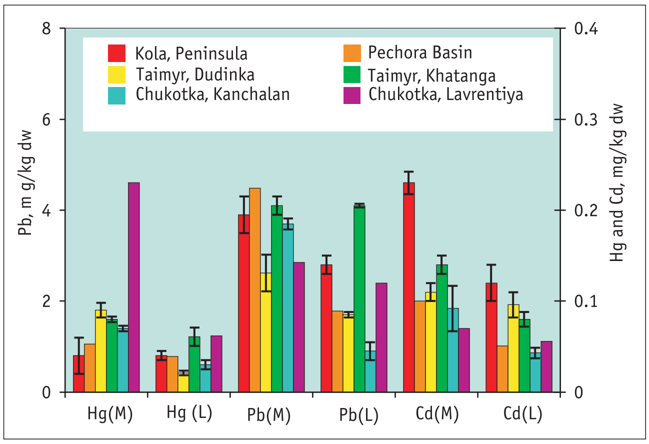


Figure 5.8. Concentrations of HMs in lichen (L) and mosses (M) in the Russian Arctic in 2001.

(d) Heavy metals

The heavy metals, mercury (Hg), lead (Pb) and cadmium (Cd) were detected in all samples of lichens, mosses and mushrooms (see Figure 5.8 and Table 5.7). In the majority of berry samples, Hg and Cd were below the detection limits (0.001 and 0.005 µg/g, respectively), while the Pb level was detectable in all samples. Pb concentrations ranged from 2.6 to 4.5 µg/g in mosses, from 0.9 to 4.1 µg/g in lichens, from 0.04 to 0.1 µg/g in mushrooms and from 0.01 to 0.05 µg/g in berries. Concentrations of Hg and Cd in samples of lichens and mosses ranged from 0.01 to 0.2 µg/g. No pronounced spatial trend was observed in HM contamination of lichens and mosses (see Figure 5.8). The relatively high Hg concentration in mosses collected at Chukotka is, very likely, due to a single anomalous sample, and was not confirmed by data for lichen from the same location. The only notable spatial tendency was a slight decreasing gradient in Cd concentrations from the Kola Peninsula towards Chukotka.

Table 5.7. Concentrations (mean and standard deviations; µg/g dw) of HMs in vegetation in the Russian Arctic in 2001.
[a] Range is given when the standard deviation is greater than 50% of the mean, or the concentration in one of samples is below the detection limit.
[b] Concentration detected in both samples.

Sample type	Area	Hg	Pb	Cd
Lichens	Kola Peninsula, n=4	0.04±0.01	2.80±0.25	0.12±0.02
	Pechora basin, n=1	0.039	1.78	0.051
	Taymir, west, n=2	0.021±0.003	1.7±0.2	0.096±0.014
	Taymir, east, n=2	0.061±0.002	4.1±0.2	0.080±0.008
	Chukotka, inland, n=2	0.03±0.01	0.9±0.5	0.043±0.006
	Chukotka, coast, n=1	0.062	2.4	0.056
Mosses	Kola Peninsula, n=3	0.04±0.02	3.9±0.1	0.23±0.02
	Pechora basin, n=1	0.053	4.5	0.10
	Taymir, west, n=2	0.089±0.008	2.62±0.05	0.11±0.02
	Taymir, east, n=2	0.089±0.008	4.1±0.2	0.14±0.01
	Chukotka, inland, n=2	0.071±0.003	3.70±0.06	0.092±0.006
	Chukotka, coast, n=1	0.23	2.8	0.069
Berries	Kola Peninsula, n=2	<0.001	0.018±0.001	<0.005
	Pechora basin, n=2	<0.001	0.016±0.003	<0.005
	Taymir, west, n=1	<0.001	0.012	<0.005
	Taymir, east, n=2	<0.001	0.025±0.005	<0.005
	Chukotka, inland, n=2	<0.001	0.029±0.011	<0.005
	Chukotka, coast, n=2	<0.001	0.008 - 0.050[a]	0.008[b]
Mushrooms	Kola Peninsula, n=1	0.018	0.041	0.082
	Pechora basin, n=2	0.010±0.001	0.022 - 0.058[a]	0.086±0.026
	Taymir, west, n=1	0.041	0.072	0.072
	Taymir, east, n=1	0.023	0.097	0.060
	Chukotka, coast, n=1	0.007	0.072	0.032

Comparison between data obtained in 1995 (AMAP, 1998) and 2001, indicates that an increase in the Hg deposition rate in Chukotka may have taken place during this period. Hg levels in lichens and mosses in 1995 (0.02 and 0.03 μg/g, respectively) were several times lower than those found in 2001 (0.06 and 0.15 μg/g, respectively). A similar temporal trend in Hg concentration in lichen is observed on the Taymir Peninsula (0.01 μg/g in 1995, and 0.06 μg/g in 2001).

For the other HMs and sample sites, changes over time are less significant, with the exception of a decrease by an order of magnitude (from 0.9 to 0.06 μg/g) in Cd concentration in lichen from Chukotka. However, over the same period, an increase in Cd levels in mosses was also observed in this area. Given the similar pathways for Cd uptake in mosses and lichen, these results suggest that the above-mentioned differences in HM concentrations occurring between 1995 and 2001 are most likely a reflection of normal intersample variability. Similar to the majority of OCs, HM concentrations measured in lichen and mosses in Russia in 2001 are consistent with concentration ranges obtained in the Canadian Arctic in 1993/4.

5.3.2. PTS in reindeer

Samples of reindeer (*Rangifer tarandus*) tissues were collected at all 6 sites in the four regions. The number of individual tissue/organ samples collected at a given site and combined in the preparation of pooled samples was 2-3 in most cases, but ranged from 1 to 6 (see Table 5.2). Pooled samples were prepared from tissue samples of animals of the same sex and with an age difference of less than 2 years. The ages of animals ranged from 1 to 8 years, and equal numbers of animals of each sex were sampled at all sites, except for Western Taymir, where tissue samples from 3 male and 2 female reindeer were collected. Samples were grouped according to sex, (female and male), age group (1-3 years and 4-8 years), and tissue type (liver, kidney, or muscle). Reindeer muscle, liver and kidney were analysed for all PTS listed in Section 1.2.4.

PTS concentration relationships with reindeer sex, age, and tissue type

(a) Organochlorines

Concentration dependence on animal sex, age, and tissue type was investigated for OCs that exhibited concentrations above detection limits in most cases (*p,p'*-DDT, *p,p'*-DDE, PCB-118, PCB-153 and HCB).

Ratios of (geometric mean) concentrations of various OCs between male and female reindeer were in the range 1.1 to 1.3, and were found to be independent of site, age group, and tissue type. The difference between these values and unity had very low statistical significance and therefore mean concentrations were calculated using data for both sexes.

Similarly, differences in OC concentrations between the two age groups, and between different tissue types were not statistically significant, the ratios for ‘old/young’ reindeer groups ranging from 0.8 to 1.3 (1.1–1.3 for *p,p'*-DDT, *p,p'*-DDE, PCB-118 and PCB-153 and 0.8 for HCB).

The geometric mean of the liver/muscle lipid concentration ratios, from the data collected in this study, was 1.5. Based on this value, somewhat higher concentrations of OCs might be expected in liver tissue when compared with muscle. However, the geometric means of both the liver/muscle and kidney/muscle concentration ratios for all of the OCs investigated were close to unity and independent of site.

From these results, it was decided to calculate mean concentrations based on data from both age groups; values for OCs in muscle tissue only are presented in Tables 5.8a and 5.8b.

Area	ΣPCB_{15}	HCB	ΣHCH
Kola Peninsula, n=6	1.7 (1.2-2.47)	0.27 (0.13-0.45)	0.47 (0.2-0.9)
Pechora basin, n=6	2.2 (1.7-2.7)	0.18 (0.14-0.35)	0.54 (0.28-2.49)
Taymir, west, n=5	1.4 (1.1-2.0)	0.09 (<0.05-0.30)	0.42 (0.24-0.91)
Taymir, east, n=4	1.3 (0.59-4.3)	0.12 (<0.05-0.29)	0.55 (0.31-0.91)
Chukotka, inland, n=2	2.8 (1.9-4.0)	0.24 (0.21-0.28)	0.47 (0.42-0.53)
Chukotka, coast, n=2	1.3 (1.2-1.3)	0.06 (0.06-0.06)	1.18 (1.16-1.20)

Table 5.8a. Concentrations (geometric mean and range; ng/g ww) of OCs in muscle of reindeer in the Russian Arctic in 2001.

Area	*p,p'*-DDE	*p,p'*-DDT	ΣDDT
Kola Peninsula, n=6	0.11(<0.05-0.24)	0.17(0.10-0.28)	0.49(0.25-0.63)
Pechora basin, n=6	0.11(<0.05-0.22)	0.28(0.13-1.1)	0.59(0.37-1.3)
Taymir, west, n=5	0.10(<0.05-0.17)	0.24(0.18-0.46)	0.51(0.28-0.69)
Taymir, east, n=4	0.10(<0.05-0.17)	0.21(0.12-0.33)	0.56(0.50-0.64)
Chukotka, inland, n=2	1.2(0.96-1.4)	0.88(0.51-1.5)	2.65(2.07-3.4)
Chukotka, coast, n=2	0.19(0.19-0.20)	0.13(0.13-0.13)	0.44(0.43-0.45)

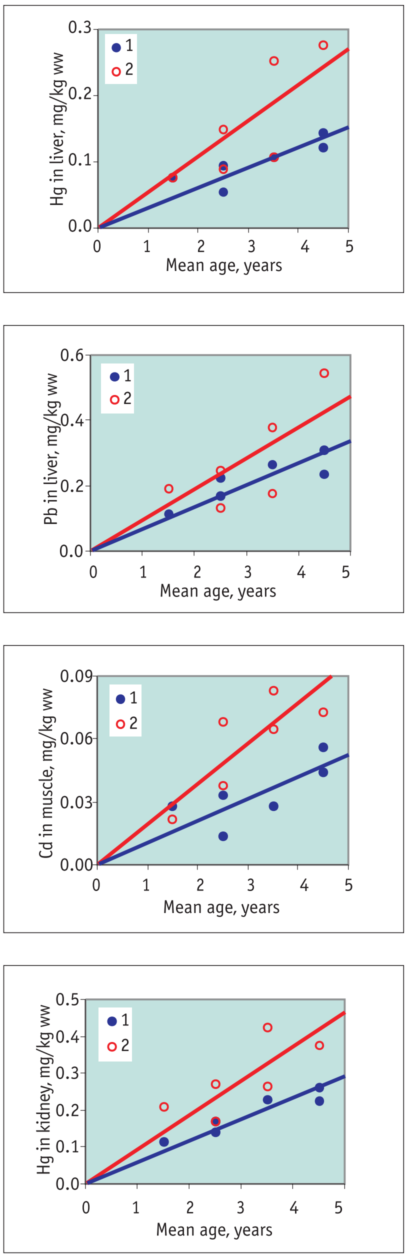
Table 5.8b. Concentrations (geometric mean and range; ng/g ww) of OCs in muscle of reindeer in the Russian Arctic in 2001.

(b) Heavy metals

As for OCs, the concentrations of HMs in reindeer tissues do not show any significant sex dependence. However, a slight, but consistent increase in concentrations does occur with increasing age of the animals sampled. Concentration ratios between the two age groups (3 years and under, and over 3 years) are similar for all HMs, sites, and tissue types; the geometric means of the age ratios, calculated for almost 30 samples, equal to 1.8, 1.7 and 1.9 for Hg, Pb, and Cd, respectively. Figure 5.9 shows examples of age dependency of HM concentrations in reindeer tissues for the two locations where samples included the greatest range of age groups. Similar relationships between concentrations and age are observed in samples from other sites. In all reindeer tissues, HM concentrations increase in direct proportion to the age of the animal sampled. This implies that the effective rate of HM accumulation in various tissues, expressed in µg/g per year, is independent of age, at least in the sampled mean age interval of 1.5–7.5 years. The only reasonably clear deviation from direct proportionality is the relatively low level of muscle contamination, primarily for Hg, seen in the youngest animals of 1.5–2.5 years of age. This possibly indicates that a steady state liver/kidney concentration ratio is established quite rapidly, whilst a steady state distribution of HM between the liver and muscle may require several years to develop.

The HM distribution between reindeer tissues, appears similar for both age groups and sexes. Only for Hg are liver/muscle and kidney/muscle ratios about

Figure 5.9.
Relationships between HM concentration in reindeer tissues and age, for the Kola peninsula (1) and the Pechora basin (2).



3 times higher for younger animals. Relative concentrations of HMs in the muscle, liver and kidney appear, respectively, in the ratios of 1:5:5 for Pb, 1:11:33 for Cd and 1:11:42 for Hg in reindeer over 3 years of age, and 1:31:136 for Hg in younger reindeer (figures are based on the geometric means of the ratios for pooled samples). The degree of variability between liver/muscle and liver/kidney concentration ratios for HMs within a herd is greatest for Hg. The level of variability between reindeer herds is similar. The liver/muscle concentration ratios are slightly lower than those calculated for Swedish herds, but the difference was not statistically significant (see Figure 5.10). As the distribution of HMs between tissues is herd specific, the age concentration ratios for HMs are relatively constant, and concentration variability within a herd is quite low, mean concentrations of Hg, Pb and Cd were calculated separately for all three tissue types and are shown only for the oldest age group. The calculation of separate mean concentrations for each age group does not significantly improve the representativeness of the results, because the variability found in concentrations of HMs within a herd is low.

Levels and trends

(a) Organochlorines

Concentrations of OCs reliably detected in reindeer muscle are given in Tables 5.8a and 5.8b. Levels of PCB, HCB, HCH and DDT vary within fairly narrow ranges and do not follow any pronounced spatial trend, although somewhat higher levels of PCB, HCB, and DDT are found in inland Chukotka (see Figure 5.11).

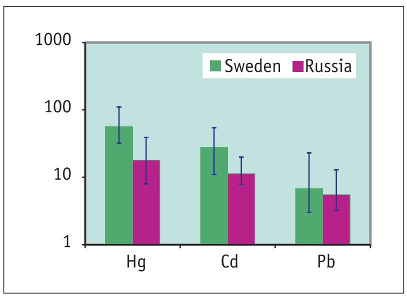


Figure 5.10.
Geometric means and ranges of HM liver/muscle concentration ratios in Swedish and Russian reindeers.
The Swedish data were for 10 herds (AMAP, 1998) and the Russian data for 6 herds.

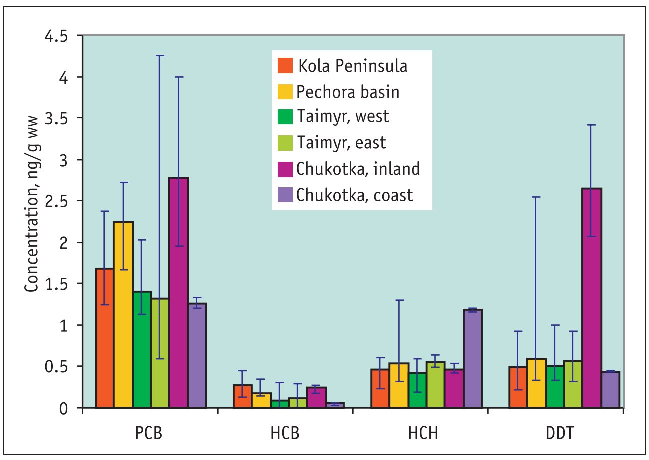


Figure 5.11. Geometric means and ranges of OC concentrations in reindeer muscle in the Russian Arctic in 2001. PCB= ΣPCB_{15}, HCH=ΣHCH, DDT=ΣDDT.

OCs in reindeer show no correlation with the spatial trends found for OC contamination in lichen. All concentrations are far below the maximum permissible concentrations (MPC) for OCs in meat, established by the Russian Ministry of Health; the MPC of 0.1 mg/kg for ΣHCH and ΣDDT, given in Chapter 3, is equivalent to 100 ng/g. Concentrations for all OCs measured in reindeer liver in 2001 coincide with the lower end of corresponding ranges obtained for the Russian North in 1994/1995 (AMAP, 1998) Values are also in reasonably good agreement with data on reindeer muscle OC contamination reported from Canada and Norway (AMAP, 1998). For example, the following concentrations of OCs were found in muscle samples from two Canadian reindeer herds: 1 ng/g for ΣHCH, 1-2 ng/g for ΣDDT and 2-10 ng/g for ΣPCB. The ranges of the geometric means for OC concentrations determined in Russia in 2001 were 0.4-1.2 ng/g for ΣHCH; 0.4 - 2.6 ng/g for ΣDDT; and 1.3-2.8 ng/g for ΣPCB. The Canadian data for summed PCB concentrations included more PCB congeners than did the Russian 2001 data. The agreement between the Canadian and Russian reindeer data is similar to that seen in the data concerning OCs measured in lichen and mosses in Russia in 2001, and in Canada in 1994.

Area	pg WHO-TEQ/g ww	pg WHO-TEQ/g lipids	pg WHO-TEQ/pg*
Muscle			
Kola Peninsula	0.98	20	0.20
Pechora basin	0.10	2.2	0.13
Taymir, west	0.031	1.3	0.11
Taymir, east	0.083	0.75	0.17
Chukotka, inland	0.066	4.3	0.10
Chukotka, coast	0.053	2.6	0.059
Liver			
Kola Peninsula	6.5	105	0.22
Pechora basin	2.4	38	0.20
Taymir, west	0.71	18.2	0.24
Taymir, east	0.49	8.0	0.23
Chukotka, inland	0.22	5.1	0.12
Chukotka, coast	0.24	4.2	0.21

Table 5.9. Concentrations (expressed as TEQ) of PCDD/Fs in reindeer tissues the Russian Arctic in 2001.
* – ratio of PCDD/F concentration in pg WHO-TEQ/g to that in pg/g

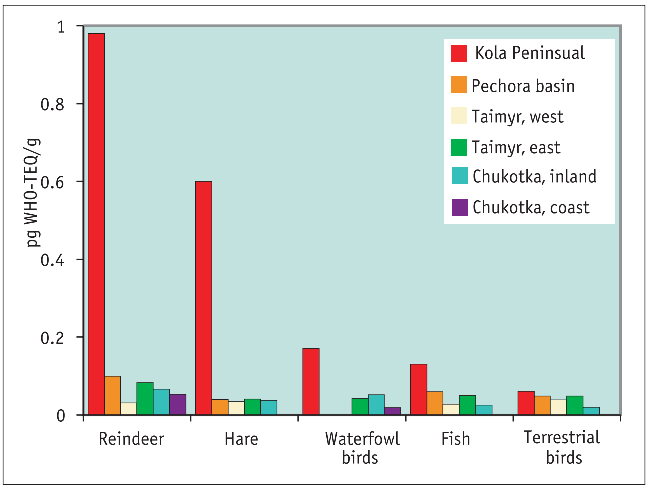


Figure 5.12. Levels of PCDD/Fs in muscle of reindeer, hare, waterfowl (molluscivores), fish (whitefish species), and terrestrial birds (browsers) in the Russian Arctic in 2001.

Samples of reindeer tissue were also analyzed for the other OCs listed in Section 1.2.4. In the majority of samples, all of these additional OCs exhibited levels below the detection limit. Only Mirex and some of the cyclodienes were found in concentrations close to the detection limit (about 0.1 ng/g), and then only in a few samples. This is again consistent with results of previous studies carried out in Canada and in the Russian North in 1995 (AMAP, 1998).

(b) PCDD/Fs

Concentrations of 2,3,7,8-substituted PCDD/Fs were analyzed using pooled samples of reindeer tissue. The results are presented in Table 5.9.

PCDD/F levels in reindeer in the Russian Arctic follow a distinct spatial distribution, that is reflected in other terrestrial mammals, birds, and fish (see Figure 5.12). The highest PCDD/F levels are found at the Kola Peninsula, where they are an order of magnitude greater than those found at other sites. After correction for tissue lipid content, residual differences still remain in PCDD/F concentrations between the various tissues types. In contrast to other OCs, PCDD/F levels occurring in the liver of reindeer are, on average, 7 times higher than those in the muscle. Maximum contamination levels were found in liver tissue from the Kola Peninsula (6.5 pg WHO-TEQ/g) and from the Pechora basin (2.4 pg WHO-TEQ/g). The liver concentrations associated with these TEQ values, and also those in muscle of reindeer from the Kola Peninsula, exceed the maximum permissible level for meat, established by the Russian Ministry of Health, which is 0.9 ng/g. All other concentrations measured were below this level.

Three congeners (2,3,7,8-TeCDD, 1,2,3,7,8-PeCDD, and 2,3,4,7,8-PeCDF) contribute more than half (and up to 85%) of the total WHO-TEQ in the majority of samples. The average contribution of 2,3,4,7,8-PeCDF, and the most toxic of the dioxins to the total TEQs are similar in waterfowl, terrestrial birds, fish and marine mammals (4.4% and 4.7%, respectively). In terrestrial animals, the average contribution of 2,3,4,7,8-PeCDF is significantly higher, whilst the contribution from the most toxic dioxins is almost the same (13% and 4.2%, respectively). For this reason, the ratio of concentration in pg WHO-TEQ to weight concentration for terrestrial animals is also higher.

(c) PAH

Reindeer tissue was analyzed for the same PAH set as vegetation. The geometric means and ranges of PAH concentrations determined in reindeer muscle in the Russian Arctic in 2001 are shown in Tables 5.10a and 5.10b. Results obtained from two sites in Chukotka were treated as one data set, due to the similarity of contamination levels and the small number of samples analyzed. PAH concentrations in liver were, on average, 3-5 times higher than those in muscle, while concentrations found in kidney and muscle are comparable.

Area	NAP	NAP2M	FLE	PA
Kola Peninsula, n=6	21(12-32)	3.5(<2-11)	<0.5-5.1	16(3.6-83)
Pechora basin, n=6	14(2.1-29)	3.2(<2-6.7)	2.1(<0.5-8.5)	13(1.6-36)
Taymir, west, n=5	19(12-28)	5.5(3.1-13)	<0.5-9.8	19(8.7-77)
Taymir, east, n=5	8.1(<2-30)	5.5(2.1-14)	<0.5-6.6	12(2.9-49)
Chukotka, n=4	21(6.8-40)	18(11-23)	6.8(4.5-13)	11(8.6-13)

Table 5.10a. Concentrations (geometric mean and range; ng/g ww) of PAHs[a] in reindeer muscle in the Russian Arctic in 2001.
[a] NAP = Naphthalene, NAP2M = 2-Methylnaphthalene, FLE = Fluorene, PA = Phenanthrene.

Area	ANT	FLU	PYR	BAA
Kola Peninsula, n=6	<0.5-1.4	<0.5-1.1	2.2(<0.5-8.8)	0.6(<0.5-2.6)
Pechora basin, n=6	<0.5-2.3	<0.5-1.6	2.5(<0.5-14)	1.0(<0.3-4.2)
Taymir, west, n=5	<0.5-2.2	1.0(<0.5-5.7)	2.8(<0.5-15)	<0.5-2.1
Taymir, east, n=5	<0.5-2.8	<0.5-1.3	<0.5-8.6	<0.3-1.7
Chukotka, n=4	0.8(0.6-1.3)	2.9(1.7-4.0)	0.7(<0.5-1)	<0.3

Table 5.10b. Concentrations (geometric mean and range; ng/g ww) of PAHs[a] in reindeer muscle in the Russian Arctic in 2001.
[a] ANT = Anthracene, FLU = Fluoranthene, PYR = Pyrene, CHR = Chrysene

As for OCs, no trend in spatial distribution was found. The PAH composition pattern in reindeer tissues reflects that found in lichen. Naphthalene, 2-methylnaphthalene and phenanthrene contribute well over half of the ΣPAH value. Reindeer tissues were also analyzed for the other PAH listed in Section 5.3.1.(b). In the majority of samples these PAHs were below the corresponding detection limits (0.5–2 ng/g) or, in a few samples of liver tissue, were only slightly above detection limits.

(d) Brominated flame-retardants

Samples of reindeer tissues were analyzed for 2,2', 4,4'-tetrabromodiphenyl, 2,2', 4,4',5-pentabromodiphenyl, 2,2', 4,4'-tetrabromodiphenyl ether, and 2,2', 4,4',5-pentabromodiphenyl ether. In all samples these occurred at levels below the detection limit of 0.2 ng/g ww.

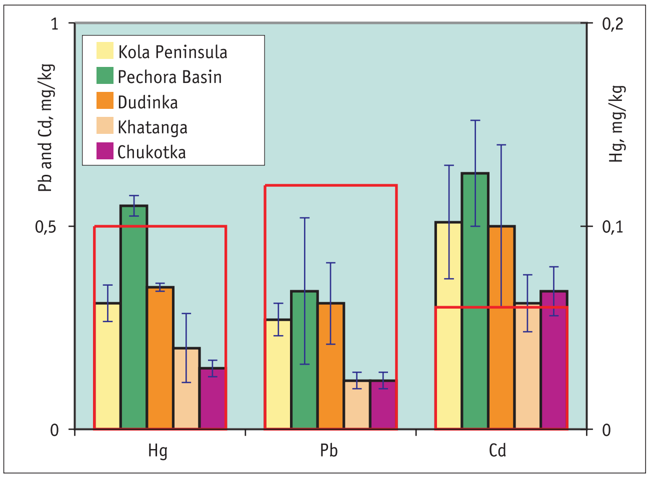


Figure 5.13. Means and ranges of HM concentrations in reindeer liver (wet weight) in the Russian Arctic in 2001. Red lines indicate the maximum permissible concentrations allowed by food safety standards.

(e) Heavy metals

Concentrations of HMs in reindeer tissues are shown in Table 5.11 and Figure 5.13. Levels of Pb are below the corresponding MPCs in all tissues, although the difference in the case of liver is quite small. Cadmium and Hg levels in all tissues, and at all sites, except for Hg in tissues from Chukotka, are either close to or exceed corresponding MPCs. The greatest disparity between observed levels of the metals under the scope and MPCs occurred in kidney tissue from the Pechora basin, which exceeded the MPC by two and a half times.

The spatial distribution of HM concentrations in reindeer liver tissue is shown in Figure. 5.13. HM levels in other tissues follow a similar pattern. As for OCs, there is no pronounced correlation with the spatial distribution of HMs in lichen. For all HMs, however, the least contaminated areas are inland Chukotka and the east Taymir (Khatanga) regions. As mentioned above, the HM concentration relationship with reindeer age is almost directly proportional, at least for the first few years of the animals' life. The coefficients for this rela-

Table 5.11. Concentrations (mean and standard deviation; g/g ww) of HMs in tissues of reindeer (>3 years of age) in the Russian Arctic in 2001.
[a] Hg level in one sample was close to the detection limit (0.001 ng/g ww), and below the detection limit in another.
[b] Hg level in both samples was close to the detection limit.
[c] Concentration range.

Tissue	Area	Hg	Pb	Cd
Muscle	Kola Peninsula, n=3	0.010±0.002	0.05±0.02	0.043±0.014
	Pechora basin, n=3	0.015±0.005	0.09±0.02	0.074±0.009
	Taymir, west, n=2	0.014±0.002	0.09±0.01	0.061±0.01
	Taymir, east, n=2	0.0005-0.001[a, c]	0.012-0.035[c]	0.016±0.002
	Chukotka, inland, n=2	0.001[b]	0.013±0.002	0.026±0.005
Liver	Kola Peninsula, n=3	0.062±0.009	0.27±0.04	0.51±0.14
	Pechora basin, n=3	0.11±0.05	0.37±0.18	0.63±0.13
	Taymir, west, n=2	0.07±0.02	0.33±0.10	0.50±0.20
	Taymir, east, n=2	0.039±0.017	0.14±0.02	0.31±0.07
	Chukotka, inland, n=2	0.030±0.004	0.16±0.02	0.34±0.06
Kidney	Kola Peninsula, n=3	0.24±0.02	0.21±0.05	2.0±0.9
	Pechora basin, n=3	0.36±0.08	0.34±0.16	2.5±0.9
	Taymir, west, n=2	0.33±0.06	0.31±0.15	2.1±1.3
	Taymir, east, n=2	0.12±0.01	0.12±0.02	2.1±1.3
	Chukotka, inland, n=2	0.15±0.03	0.12±0.02	0.78±0.07

Area	Muscle	Liver	Kindey
		Hg	
Kola Peninsula, n=6	0.0018 (0.0010-0.0033)	0.016 (0.012-0.021)	0.062 (0.056-0.068)
Pechora basin, n=6	0.0035 (0.0024-0.051)	0.035 (0.019-0.033)	0.096 (0.075-0.12)
Taymir, west, n=5	0.0015 (0.0006-0.0036)	0.012 (0.011-0.015)	0.058 (0.039-0.086)
Taymir, east, n=4	—	0.0089 (0.0054-0.015)	0.033 (0.018-0.062)
Chukotka, coast, n=2	—	0.020 (0.008-0.051)	0.11 (0.047-0.23)
		Pb	
Kola Peninsula, n=6	0.013 (0.009-0.021)	0.071 (0.060-0.083)	0.057 (0.045-0.070)
Pechora basin, n=6	0.021 (0.018-0.026)	0.088 (0.062-0.12)	0.076 (0.059-0.098)
Taymir, west, n=5	0.017 (0.013-0.021)	0.056 (0.033-0.093)	0.048 (0.030-0.079)
Taymir, east, n=4	0.0052 (0.0029-0.010)	0.034 (0.021-0.051)	0.034 (0.019-0.060)
Chukotka, coast, n=2	0.0059 (0.0033-0.011)	0.095 (0.054-0.017)	0.067 (0.044-0.10)
		Cd	
Kola Peninsula, n=6	0.011 (0.0073-0.015)	0.13 (0.12-0.15)	0.40 (0.28-0.56)
Pechora basin, n=6	0.019 (0.015-0.023)	0.16 (0.14-0.18)	0.52 (0.37-0.73)
Taymir, west, n=5	0.011 (0.0078-0.016)	0.093 (0.050-0.17)	0.28 (0.18-0.043)
Taymir, east, n=4	0.0043 (0.0022-0.0083)	0.081 (0.043-0.015)	0.24 (0.14-0.42)
Chukotka, coast, n=2	0.014 (0.0083-0.024)	0.20 (0.14-0.28)	0.43 (0.22-0.82)

Table 5.12. Geometric means and 95% confidence interval of effective rates of accumulation of heavy metals in reindeer tissues (µg/g ww per year).

tionship are given in Table 5.12, and these can be considered as the effective rates of accumulation of metals in reindeer tissues. The lowest values normally occur in the Taymir Peninsula, however, the values do not differ by more than a factor of 3 and the differences are therefore of no great significance.

Concentrations of Cd and Hg in muscle tissue sampled in 2001 are very close to those found in 1994/1995 in the Russian North (AMAP, 1998), while levels of Pb in muscle are an order of magnitude lower than those reported earlier. In comparison with 1995 values, liver/muscle concentration ratios calculated in 2001 are significantly higher for all HMs, and are similar to those measured in other regions of the Arctic (AMAP, 1998). Levels of all HMs are similar to, or slightly lower than those determined in the Canadian Arctic in 1998-2001 (CACAR, 2003). However, as concentrations of HM in Canadian reindeer are reported on a dry weight basis, direct comparison is not possible; on a dry wt basis, absolute values are typically up to an order of magnitude greater.

5.3.3. PTS in the Arctic hare

Tissues of Arctic hare (*Lepidus timidus*) were sampled at all sites, except for coastal Chukotka. The number of single samples of each tissue, collected at a given site and used in the preparation of pooled samples, ranged from 4 to 10 (see Table 5.1). Equal numbers of male and female animals, all younger than 3 years, were sampled at each site. The muscle, liver and kidney of hare were analyzed for all PTS listed in Section 1.2.4.

PTS concentration relationships with hare sex and tissue type

(a) Organochlorines

Only a few OCs (HCB, *p,p'*-DDT, *p,p'*-DDE, PCB-118, PCB-138 and PCB-153) were detectable at all sites and in the majority of samples. No significant concentration relationship to either sex or tissue type was identified for these OCs in hare.

(b) Heavy metals

HMs occur in detectable concentrations in all samples, except for Hg in muscle tissue. Calculated male/female concentration ratios for Hg, Pb, and Cd do not differ significantly from unity and are neither site nor tissue specific. Mean concentrations for HMs were, therefore, calculated using data for both sexes. The distribution of the three HMs between tissues is similar for both sexes, and approximates that found in reindeer. Relative levels of contaminants in muscle, liver and kidney are in the ratio of 1:11:5 for Pb and 1:26:160 for Cd (based on geometric means of ratios for pooled samples).

Levels and trends

(a) Organochlorines

The levels of OCs that were generally above detection limits in tissues of hare (HCB, *p,p'*-DDT, *p,p'*-DDE, PCB-118 and PCB-153) did not follow any geographical trend. Geometric means of OC concentrations range from 0.06 ng/g ww (*p,p'*-DDT, *p,p'*-DDE) to 0.12 ng/g ww (HCB). Concentrations of PCB-138, PCB-180, as well as α- and γ- HCH occur at similar levels at several sites. In a few samples, some of the other OCs (PCBs, Mirex, and cyclodienes) were found in concentrations close to the detection limit. Concentrations of all detectable OCs in hare tissues are 2-4 times lower than those in reindeer, and are far below the limit values for these substances established in Russia.

Area	pg WHO-TEQ/g ww	pg WHO-TEQ/g lipids	pg WHO-TEQ/pg*
	Muscle		
Kola Peninsula	0.60	29	0.18
Pechora basin	0.043	2.7	0.15
Taymir, west	0.034	1.4	0.084
Taymir, east	0.041	3.5	0.18
Chukotka, inland	0.037	1.8	0.14
	Liver		
Chukotka, inland	0.10	2.5	0.082

Table 5.13. Concentrations (expressed as TEQ) of PCDD/Fs in hares in the Russian Arctic in 2001.
* – ratio of PCDD/F concentration in pg WHO-TEQ/g to that in pg/g

(b) PCDD/Fs
Concentrations of 2,3,7,8-substituted PCDD/Fs were analyzed in pooled samples of hare tissues collected at each site. Results are presented in Table 5.13 and Figure 5.12. PCDDFs in hare tissues follow the same spatioal distribution pattern as for reindeer. All concentrations are at levels below the (maximum) permissible level for meat.

(c) PAH
Hare tissues were analyzed for the same PAH set as were reindeer tissues. In contrast to OCs, most PAH concentration levels in hare are either comparable with those in reindeer or are higher. Only phenanthrene concentrations in hare muscle are, for most sites, found to be several time lower than those in reindeer.

(d) Brominated flame-retardants
Samples of hare tissue were analysed for 2,2',4,4'-tetrabromodiphenyl, 2,2',4,4',5-pentabromodiphenyl, 2,2',4,4'-tetrabromodiphenyl ether and 2,2',4,4',5-pentabromodiphenyl ether. In all samples, concentrations of these substances were below the detection limit of 0.2 ng/g ww.

(e) Heavy metals
HM concentrations measured in hare tissues are given in Table 5.14. Concentrations are usually several times lower than those found in reindeer, with the exception of Cd in kidney tissue, for which levels in hare and reindeer are comparable. Spatial distribution patterns observed for all three HMs are similar to those for reindeer. The lowest concentrations occur in Chukotka and eastern Taymir. Concentrations of HMs in hare tissues measured in this study are similar to those reported for hares in Finland in 1995 (AMAP, 1998). Differences in levels between the data from Finland in 1995 and Russia in 2001 are relatively small (within a factor of two), with the exception of Pb in muscle, which is 4.4 times higher in the Russian North.

5.3.4. PTS in birds

Waterfowl and terrestrial game birds harvested by indigenous peoples in the Russian Arctic for the project, were analyzed for all contaminants listed in Section 1.2.4. Samples tissues of the following groups of birds were collected:

- Grazers (geese that graze mainly on aquatic and terrestrial vegetation): bean goose (*Anser fabalis*), white-fronted goose (*Anser albifrons*), goldeneye duck (*Bucephala clangula*) and ptarmigan (*Lagopus sp.*);
- Omnivores (surface-feeding ducks with a varied diet consisting mainly of aquatic vegetation): pintail (*Anas acuta*), wigeon (*Anas penelope*), and teal (*Anas crecca*);
- Molluscivores (diving ducks feeding mainly on invertebrates): eider (*Somateria mollissima*), and long-tailed duck or oldsquaw (*Clangula hyemalis*);
- Piscivores (diving ducks feeding mainly on fish): scaup (*Aythya marila*), merganser (*Mergus sp.*), scoter (*Melanitta sp*).

For most sites, equal numbers of male and female birds of each groupwere harvested. Exceptions were: omnivores (1 male pintail) and piscivores (1 female scoter) in eastern Taymir; grazers (1 female goose) at inland Chukotka; and molluscivores (1 male eider) at coastal Chukotka.

PTS concentration relationships with bird sex
No significant concentration dependence on sex was identified for any of the detectable OCs, for Hg and Cd in all bird groups, and for Pb in waterfowl. Pb concentrations in the muscle tissue of male browsers were consistently about twice as high as those measured in females at all six sites; the male/female ratios ranging from 1.7 to 2.6, with a geometric mean of 2.1 for the six values. Since the male/female ratios for Pb in browsers are not particularly high, the ratio is independent of site, and the same sample pattern for sexes was followed at all sites (50% male and 50% female), all geometric means, including those for Pb concentrations in browsers, were calculated using data for both sexes

Levels and trends

(a) Organochlorines
Concentrations of OCs in birds are shown in Tables 5.15a and 5.15b and Figures 5.14 and 5.15. The lowest contamination levels are found in the muscle tissue of browsers. The only OC that was repeatedly detected in these birds was *p,p'*-DDE. Levels of ΣPCB_{15} in browsers

Table 5.14.
Concentrations (mean and standard deviation; µg/g ww, n=2) of HMs in tissues of the Arctic hare (< 3 years of age) in the Russian Arctic in 2001.
[a] The range (in brackets) is given where the standard deviation is larger than 50% of the mean.

Tissue	Area	Hg	Pb	Cd
Muscle	Kola Peninsula	<0.001	0.005 (<0.001–0.008)[a]	0.010±0.002
	Pechora basin	<0.001	0.012±0.001	0.016±0.004
	Taymir, west	<0.001	0.012±0.004	0.014±0.003
	Taymir, east	<0.001	0.022 (<0.001-0.042)[a]	0.007±0.001
	Chukotka, inland	<0.001	0.031 (<0.001-0.059)[a]	0.007±0.001
Liver	Kola Peninsula	0.007 (0.002-0.017)[a]	0.12±0.02	0.29±0.11
	Pechora basin	0.020±0.002	0.19±0.03	0.36 (0.20-0.52)[a]
	Taymir, west	0.021±0.002	0.18±0.04	0.40±0.11
	Taymir, east	0.010±0.004	0.10±0.03	0.19±0.06
	Chukotka, inland	0.020±0.006	0.087±0.013	0.21±0.06
Kindey	Kola Peninsula	0.066±0.008	0.048±0.013	2.0±0.9
	Pechora basin	0.11±0.02	0.072±0.023	2.5±1.1
	Taymir, west	0.098±0.021	0.078±0.022	2.2±0.9
	Taymir, east	0.053±0.008	0.038±0.008	1.0±0.3
	Chukotka, inland	0.051±0.004	0.045±0.019	1.04±0.08

Bird group	Area	ΣPCB$_{15}$	HCB	ΣHCH	ΣCHLOR
Browsers	Kola Peninsula, n=2	1.52 (1.49-1.56)	0.10 (0.05-0.20)	0-0.46[a]	0-0.21[a]
	Pechora basin, n=2	0.6-2.0[a]	<0.05	<0.20	<0.20
	Taymir, west, n=2	0.6-1.1[b]	<0.05-0.20	0.07-0.41[a]	<0.20
	Taymir, east, n=2	0.6-1.1[b]	<0.05-0.14	0.19 (0.14-0.27)	0-0.21[a]
	Chukotka, inland, n=2	1.46 (1.20-1.77)	<0.05-0.35	<0.20	0-0.24[a]
	Chukotka, coast, n=2	0.6-1.1[b]	<0.05-0.34	0.10-0.23[a]	<0.20
Grazers	Taymir, west, n=2	2.81 (2.07-3.82)	0.06 (0.05-0.08)	0.18-0.28[a]	<0.20
	Taymir, east, n=2	2.87 (2.58-3.21)	0.10 (0.07-0.15)	0.12-0. 28[a]	<0.20
	Chukotka, inland, n=1	1.14	0.17	<0.20	<0.20
Omnivores	Pechora basin, n=4	2.30 (1.62-3.34)	0.16 (0.07-0.37)	0-0.89[a]	0-0.57[a]
	Taymir, west, n=3	2.88 (2.32-3.45)	0.22 (0.13-0.36)	0-0.43[a]	0.08-0.39[a]
	Taymir, east, n=2	3.44 (2.54-4.66)	0.36 (0.17-0.76)	0.50 (0.26 - 0.97)	0.16 (0.11-0.23)
	Chukotka, inland, n=3	3.20 (2.23-4.47)	0.28 (0.15-0.54)	0.41 (0.24-0.76)	0.10-0.50
Molluscivores	Kola Peninsula, n=2	3.88 (2.57 –5.86)	0.39 (0.25-0.62)	0.52 (0.39 –0.71)	0.33 (0.28-0.40)
	Taymir, east, n=2	13.6 (10.7-17.2)	1.36 (1.22-1.50)	2.21 (1.78-2.64)	2.67 (2.01-3.55)
	Chukotka, inland, n=2	4.09 (3.32-5.04)	0.43 (0.29-0.56)	1.71 (1.28-2.13)	0.64 (0.52-1.00)
	Chukotka, coast, n=3	3.47 (2.81-4.01)	0.32 (0.15-0.36)	0.60 (0.40-0.80)[b]	0.47 (0.37-0.61)[b]
Piscivores	Kola Peninsula, n=2	4.07 (3.63-4.65)	0.42 (0.32-0.55)	<0.20	0-0.21[a]
	Taymir, east, n=1	3.88	0.12	0.32	0.31
	Chukotka, inland, n=2	1.71 (1.68-1.74)	0.23 (0.18-0.30)	<0.20	<0.20

Table 5.15a. Concentrations (geometric mean and range; ng/g ww) of OCs in the muscle of birds in the Russian Arctic in 2001.

[a] In at least one sample, more than half of the concentrations were below the detection limit. Concentrations below the detection limit were set to zero or to the detection limit when determining lower and upper limits of concentration ranges.

[b] The range is given only for oldsquaw (n=2). Concentrations in eider were below the detection limit.

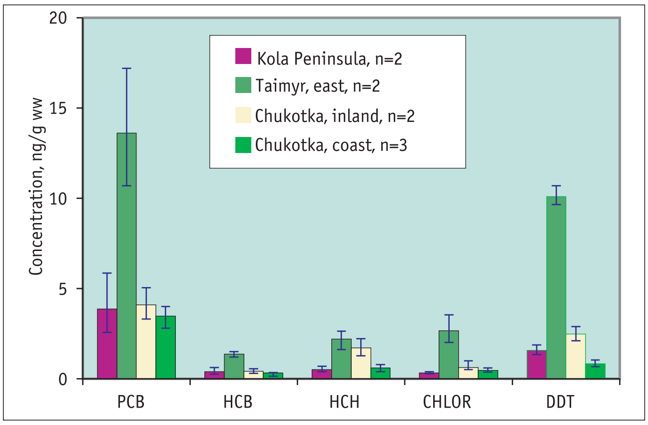


Figure 5.14. Geometric means and ranges of OC concentrations in molluscivores. PCB=ΣPCB$_{15}$, HCH=ΣHCH, CHLOR=ΣCHLOR, and DDT=ΣDDT.

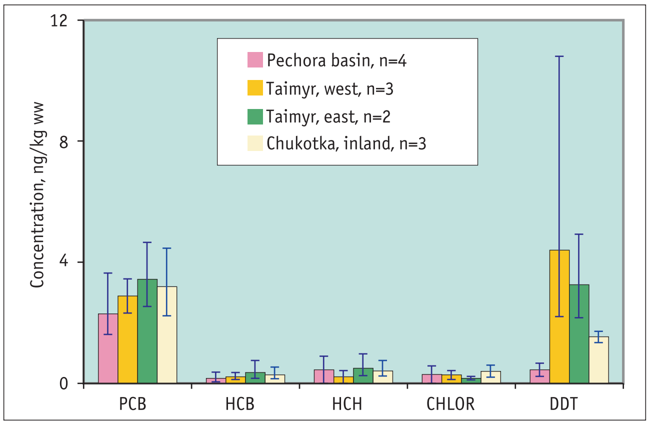


Figure 5.15. Geometric means and ranges of OC concentrations in omnivores. PCB=ΣPCB$_{15}$, HCH=ΣHCH, CHLOR=ΣCHLOR, and DDT=ΣDDT.

Bird group	Area	*p,p'*-DDE	*p,p'*-DDT	ΣDDT	Mirex
Browsers	Kola Peninsula, n=2	0.23 (0.22-0.25)	<0.05-0.56	0.48-0.91[a]	<0.05
	Pechora basin, n=2	0.24 (0.16-0.36)	<0.05-0.26	0.42-0.65[a]	<0.05
	Taymir, west, n=2	0.19 (0.16-0.23)	<0.05-0.30	0.29-0.68[a]	<0.05
	Taymir, east, n=2	0.24 (0.20-0.29)	<0.05-0.25	0.45-0.95[a]	<0.05
	Chukotka, inland, n=2	0.18 (0.14-0.18)	<0.05-0.24	0.14-0.62[a]	<0.05
	Chukotka, coast, n=2	<0.05-0.05	0.22 (0.19-0.26)	0.31-0.52[a]	<0.05
Grazers	Taymir, west, n=2	3.88 (3.25-4.63)	<0.05	3.45-5.09[a]	0.09 (0.06-0.15)
	Taymir, east, n=2	5.09 (4.52-5.74)	<0.05 - 0.07	5.67-6.12[a]	0.12 (0.07-0.21)
	Chukotka, inland, n=1	0.35	<0.05	0.56	<0.05
Omnivores	Pechora basin, n=4	0.34 (0.23-0.41)	<0.05	0.23-0.67[a]	0.14 (0.13-0.16)[c]
	Taymir, west, n=3	3.47 (1.29-10.1)	0.26 (0.21-0.40)	4.40 (2.11-10.8)	<0.05-0.09
	Taymir, east, n=2	2.43 (1.31-4.50)	0.18 (0.08-0.42)	3.26 (2.17-4.92)	<0.05
	Chukotka, inland, n=3	0.51 (0.26-1.16)	0.29 (0.14-0.49)	1.54 (1.35-1.72)	<0.05
Molluscivores	Kola Peninsula, n=2	1.21 (0.94-1.55)	0.14 (0.11-0.18)	1.59 (1.34-1.89)	<0.05
	Taymir, east, n=2	9.09 (8.56-9.56)	0.25 (0.24-0.26)	10.1 (9.66-10.7)	0.08 (0.08-0.09)
	Chukotka, inland, n=2	1.04 (0.79-1.36)	0.30 (0.23-0.38)	2.47 (2.12-2.90)	<0.05
	Chukotka, coast, n=3	0.35 (0.26-0.50)	0.23 (0.21-0.26)	0.83 (0.67-1.04)[b]	<0.05
Piscivores	Kola Peninsula, n=2	1.26 (1.19-1.33)	0.05 - 0.11	1.25-1.59[a]	0.11 (0.10-0.11)
	Taymir, east, n=1	0.92	0.22	1.44	<0.05
	Chukotka, inland, n=2	0.30 (0.22-0.40)	<0.05	0.31-0.74[a]	0.06 (0.05-0.08)

Table 5.15b. Concentrations (geometric mean and range; ng/g ww) of OCs in the muscle of birds in the Russian Arctic in 2001.

[a] In at least one sample, more than half of the concentrations were below the detection limit. Concentrations below the detection limit were set to zero or to the detection limit when determining lower and upper limits of concentration ranges.

[b] The range is given only for oldsquaw (n = 2). Concentrations in eider were below the detection limit.

[c] The geometric mean and range is given only for pintail (n = 2). Concentrations in mallard are below the detection limit.

were about 1 ng/g ww, about 2-3 times higher than ΣDDT at all sites. Other OCs occurred at concentrations below or close to the detection limit in all samples. As for OCs in reindeer, there was no evident geographical trend for OCs in terrestrial birds.

OC levels in waterfowl are up to an order of magnitude greater that those in browsers. Clear maximum concentrations of all OCs in molluscivores are found in eastern Taymir, near Khatanga. In other bird groups, OC levels at this site are comparable to those found at other sites. Maximum concentrations range from 0.08 ng/g ww for Mirex, and 1-3 ng/g ww for HCB, ΣCHLOR, and ΣHCH, to about 10 ng/g ww for ΣDDT and ΣPCB_{15}. Similar patterns of OC concentrations are seen in other waterfowl at all sites. Concentrations of *p,p'*-DDE found at all sites, are significantly higher than those found in reindeer muscle, while concentrations of other OCs are comparable with those in reindeer. The lowest concentrations occur, as a rule, at sites in Chukotka. Contamination levels in most cases, decrease in the following order: molluscivores > omnivores > piscivores > grazers. All OC concentrations in birds are far below the (maximum) permissible levels for bird meat established in Russia.

(b) PCDD/Fs

Concentrations of 2,3,7,8-substituted PCDD/Fs were analyzed in pooled samples of bird muscle tissue collected from each site. Results are presented in Table 5.16 and Figure 5.12. PCDD/F concentrations in birds follow the same geographic distribution pattern as they do in reindeer, although the spatial differences are less pronounced in birds. All concentrations occur at levels which are far below the maximum permissible levels for these substances in meat.

(c) PAH

Bird tissues were analyzed for the same PAH set as reindeer. Geometric means and ranges of PAH concentrations found in bird muscles in the Russian Arctic in 2001 are given in Table 5.17. Concentrations of 2-methylnaphthalene and fluorene in waterfowl are several times higher, whilst concentrations of phenanthrene and pyrene are several times lower than those found in browsers. Naphthalene and fluoranthene occur in the two bird groups in comparable concentrations. Those PAHs not included in Table 5.17, were found in concentrations close to their detection limits, and then only in few samples of waterfowl. In contrast, chrysene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*ghi*]perylene, and biphenyl were detectable in most of the browser muscle samples in concentrations

Species	Area	pg WHO-TEQ/g ww	pg WHO-TEQ/g lipids	pg WHO-TEQ/pg*
Browsers				
Lagopus sp.	Kola Peninsula	0.061	3.1	0.095
	Pechora basin	0.049	2.8	0.130
	Taymir, west	0.038	1.8	0.100
	Taymir, east	0.049	2.2	0.079
	Chukotka, inland	0.020	0.87	0.13
	Chukotka, coast	0.018	1.2	0.16
Molluscivores				
Bucephala clangula	Kola Peninsula	0.17	5.3	0.17
Clangula hyemalis	Taymir, east	0.042	1.9	0.13
	Chukotka, inland	0.052	1.9	0.24
	Chukotka, coast	0.019	0.53	0.078
Omnivores				
Anas acuta	Pechora basin	0.026	1.0	0.093
	Taymir, west	0.11	4.6	0.14

Table 5.16. Concentrations (expressed as TEQ) of PCDD/Fs in bird muscles in the Russian Arctic in 2001.
* – ratio of PCDD/F concentration in pg WHO-TEQ/g to that in pg/g

Bird group	Area	NAP	NAP2M	FLE	PA	FLU	PYR
Browsers	Kola Peninsula, n=2	31 22-43)	7.9 (7.1-8.7)	0.61(0.58-0.65)	21 (18-25)	1.4 (1.2-1.6)	4.3 (3.1-6.1)
	Pechora basin, n=2	35 (19-62)	8.1 (5.2-13)	0.83(0.78-0.88)	25 (16-38)	1.6 (1.3-1.9)	5.2 (5.0-5.6)
	Taymir, west, n=2	28 (23-33)	6.6 (3.5-13)	<0.5-0.89	25 (17-38)	1.5 (1.1-2.0)	4.5 (4.5-4.6)
	Taymir, east, n=2	20 (16-24)	6.2 (2.5-15)	<0.5-1.3	26 (13-52)	1.0 (0.5-1.7)	4.3 (4.1-4.6)
	Chukotka, inland, n=2	35 (30-41)	5.8 (4.2-7.9)	<0.5	37 (16-86)	1.3 (0.84-1.9)	6.1 (4.8-7.8)
	Chukotka, coast, n=2	25 (16-38)	4.7 (3.5-6.2)	<0.5	22 (22-22)	0.75 (0.54-1.0)	5.3 (4.5-6.3)
Grazers	Taymir, west, n=2	6.7 (6.7-7.3)	14 (12-16)	3.7 (3.1-4.5)	5.8 (5.4-6.3)	1.0 (1.0-1.0)	<0.5
	Taymir, east, n=2	9.3 (3.5-25)	21 (19-22)	3.1 (2.8-3.5)	8.3 (6.9-10)	<0.5-0.6	<0.5
	Chukotka, inland, n=1	36	27	4.6	9.2	1.0	<0.5
Omnivores	Pechora basin, n=4	28 (22-40)	14 (4.4-45)	<0.5-5.2	6.8 (4.2-10)	1.2 (1.0-1.4)	<0.5-1.2
	Taymir, west, n=3	12 (5.1-36)	19 (11-25)	2.6 (2.2-3.4)	8.9 (4.4-17)	1.1 (1.0-1.2)	<0.5-1.1
	Taymir, east, n=2	44 (26-73)	22 (15-32)	<0.5-2.0	5.6 (4.5-6.8)	1.4 (1.2-1.6)	<0.5-1.0
	Chukotka, inland, n=3	25 (20-37)	6.7 (4.1-8.9)	2.7 (2.1 –3.5)	5.2 (4.6-6.2)	2.3 (1.9-2.6)	<0.5-1.4
Molluscivores	Kola Peninsula, n=2	24 (22-26)	10 (6.4-16)	1.6 (1.3-2.0)	5.5 (5.3-5.7)	1.9 (1.8-2.1)	1.1 (1.0-1.2)
	Taymir, east, n=2	25 (21-31)	24 (21–28)	3.4 (2.4 – 4.9)	7.3 (7.1-7.6)	<0.5-1.1	<0.5
	Chukotka, inland, n=2	17 (16-18)	7.0 (5.3-9.3)	<0.5 – 1.2	3.7 (3.0-4.7)	1.3 (0.93-1.7)	<0.5
	Chukotka, coast, n=3	7.0 (2.0-14)	11 (7.1-20)	2.8 (2.2 –3.8)	4.3 (2.4-8.4)	1.1 (<0.5-2.7)	1.0 (<0.5-2.2)
Piscivores	Kola Peninsula, n=2	20 (13-31)	19 (14-27)	4.9 (4.3-5.5)	7.7 (6.1-9.6)	0.90 (0.81-1.0)	<0.5
	Taymir, east, n=1	28	14	3.4	6.0	2.3	1.1
	Chukotka, inland, n=2	29 (25-34)	38 (29-50)	4.5 (4.5-4.5)	8.1 (7.5-8.7)	0.79 (0.63-1.0)	<0.5

Table 5.17. Concentrations (geometric mean and range; ng/g ww) of PAHs a in muscle of birds in the Russian Arctic in 2001.
a NAP = Naphthalene, NAP2M = 2-Methylnaphthalene, FLE = Fluorene, PA= Phenanthrene, FLU = Fluoranthene, PYR = Pyrene

Bird group	Area	Hg	Pb	Cd
Browsers	Kola Peninsula, n=2	<0.001	0.14 (0.10-0.22)	0.056 (0.042-0.074)
	Pechora basin, n=2	<0.001	0.20 (0.14-0.29)	0.067 (0.063-0.072)
	Taymir, west, n=2	<0.001	0.24 (0.16-0.37)	0.091 (0.061-0.13)
	Taymir, east, n=2	<0.001	0.11 (0.07-0.18)	0.049 (0.045-0.053)
	Chukotka, inland, n=2	<0.001	0.09 (0.07-0.12)	0.047 (0.036-0.061)
	Chukotka, coast, n=2	<0.001	0.11 (0.08-0.18)	0.050 (0.038-0.066)
Grazers	Taymir, west, n=2	0.012 (0.011-0.013)	0.057 (0.054-0.060)	0.006 (0.004-0.008)
	Taymir, east, n=2	0.006 (0.006-0.006)	0.09 (0.07-0.11)	0.010 (0.005-0.021)
	Chukotka, inland, n=1	0.010	-[a]	0.028
Omnivores	Pechora basin, n=4	0.062 (0.035-0.12)	0.13 (0.11-0.17)[a]	0.012 (0.005-0.036)
	Taymir, west, n=3	0.037 (0.019-0.10)	0.31 (0.27-0.35)	0.034 (0.031-0.037)
	Taymir, east, n=2	0.065 (0.059-0.071)	0.067 (0.047-0.095)	0.004 (0.003-0.005)
	Chukotka, inland, n=3	0.019 (0.012-0.043)	0.43 (0.15-1.2)	0.013 (0.008-0.019)
Molluscivores	Kola Peninsula, n=2	0.10 (0.10-0.11)	0.52[a]	0.030 (0.011-0.085)
	Taymir, east, n=2	0.073 (0.063-0.085)	0.35 (0.22-0.57)	0.069 (0.050-0.096)
	Chukotka, inland, n=2	0.027 (0.026-0.029)	0.23 (0.22-0.24)	0.015 (0.013-0.018)
	Chukotka, coast, n=3	0.055 (0.050-0.064)	0.12 (0.08-0.18)	0.020 (0.017-0.032)
Piscivores	Kola Peninsula, n=2	0.064 (0.046-0.090)	0.11 (0.10-0.12)	0.020 (0.019-0.021)
	Taymir, east, n=1	0.034	0.21	0.003
	Chukotka, inland, n=2	0.080 (0.073-0.086)	0.21[a]	0.012 (0.011-0.013)

Table 5.18. Concentrations (geometric mean and range; µg/g ww) of HMs in muscle of birds in the Russian Arctic in 2001.
[a] Data for one sample which was contaminated by lead shot was discarded. Pb concentrations in contaminated samples range from 0.5 to 11 µg/g wet weight.

from 0.5 to 5 ng/g ww. Levels of all PAHs in browsers, with the exception of fluorene, were about twice as high as those found in reindeer. No noticeable geographic trend was observed for any of the PAHs. For these substances, the variability between samples was always comparable with the variability between sites.

(d) Brominated flame-retardants

Samples of bird tissues were analyzed for 2,2',4,4'-tetrabromodiphenyl, 2,2',4,4',5-pentabromodiphenyl, 2,2',4,4'-tetrabromodiphenyl ether, and 2,2',4,4',5-pentabromodiphenyl ether. In all samples, these substances were found at concentrations below the detection limit of 0.2 ng/g ww.

(e) Heavy metals

In most of the waterfowl samples, levels of Hg exceeded the MPC for this metal, and only in browsers were Hg concentrations below the detection limit at all sites (see Figure 5.16). Levels of Pb and Cd in terrestrial birds and waterfowl are comparable (see Table 5.18). No pronounced geographic trend was observed for any of the HMs in any bird group. Concentration differences occurring between any two sites, for a given HM and bird group, were not statistically significant, despite inter-sample variability being quite low at almost all sites. The only notable exception to this, was the concentration of Cd measured in omnivores and piscivores in eastern Taymir, which was found to be significantly lower than at other sites. Concentrations of Pb and Cd in birds were normally below maximum permissible levels for these metals (0.5 and 0.05 mg/kg, respectively), and only in few samples were concentrations found to be higher (up to twice the MPC level).

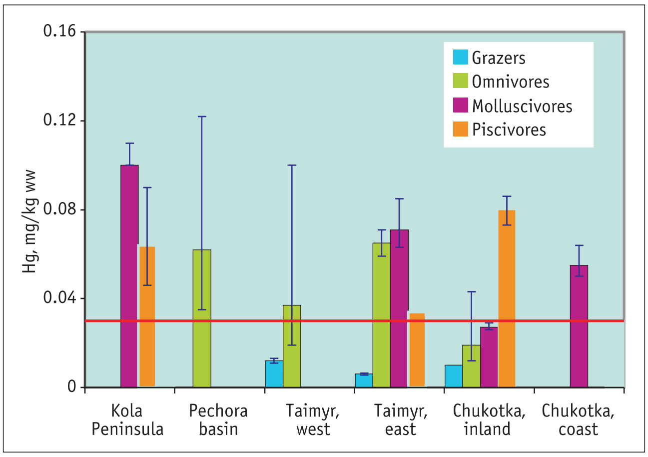


Figure 5.16. Geometric means and ranges of Hg concentrations in muscle of waterfowl in the Russian Arctic in 2001. The red line indicate the maximum permissible concentrations of Hg allowed by food safety standards. The number of values used for calculating means varied between 1 and 4.

5.3.5. PTS transfer in the terrestrial food chain

For the estimation of soil-to-lichen and water-to-fish transfer coefficients, pooled samples of soil were collected at all 6 sites. The number of pooled samples ranged from 1 to 5, and the number of single samples used in the preparation of pooled samples ranged from 3 to 9 (see Table 5.1). Most of the soils sampled were of peat litter.

(a) Organochlorines

It is well known that POPs that are present in abiotic media (soil, water and air) can be taken up by living organisms, and subsequently transferred within food chains. In most cases, intake via the diet is the major pathway for human POP exposure. In a steady state system, POPs are distributed throughout the environment according to the fugacity capacities of the various environmental compartments. For POPs, fugacity capacities are proportional to the lipid concentration in a given biological compartment (Sharpe and Mackay, 2000; McLachlan, 1996). In this section, the partitioning of OCs between abiotic media and the tissues of terrestrial organisms in the Russian Arctic is considered, mainly using data on *p,p'*-DDT and *p,p'*-DDE levels. These two OCs, are convenient reference compounds, being detectable in most biotic and abiotic samples collected. In addition, the ratio of *p,p'*-DDE to *p,p'*-DDT levels in soil is widely used to estimate the age of the contamination and can, therefore, serve as an indicator of the relative rate of *p,p'*-DDT metabolic transformation in organisms. Most other OCs follow similar patterns of uptake and transport in food chains that have been studied.

The soil-lichen-reindeer food chain is one of the most important in the Arctic. An example of levels of *p,p'*-DDT and *p,p'*-DDE in this chain are given for Khatanga in eastern Taymir in Figure 5.17. Geometric means of soil-to-lichen transfer factors (concentration ratios) for both *p,p'*-DDT and *p,p'*-DDE are equal to 2.9 ranging from 0.7 (for *p,p'*-DDT on the Kola Peninsula) to 15 (for *p,p'*-DDE in western Taymir). The soil-to-lichen transfer factors for other OCs show a similar degree of variability and similar geometric means (1.1 for PCB-28 and PCB-153, 1.9 for HCB, and 2.5 for HCH isomers). High levels of within site variability in the ratios are most probably explained by a relatively high variability of *p,p'*-DDT and *p,p'*-DDE concentrations in soils. Variability in OC concentrations at a particular site is significantly less in lichens and mosses than soils. Lichens and mosses uptake pollutants primarily from the air, which, in the absence of local sources of pollutants, has relatively uniform contamination levels.

Even though lichens do not take up OCs directly from the soil, soil-to-lichen transfer coefficients can still be calculated, is based on the fact that, in the air of remote areas, OC levels are proportional to those in soil, especially surface soil. Proportionality of OC levels between soils and lichens can, therefore, also be expected. Uptake from the air is the main route by which POPs contaminate, not only mosses and lichens, but also other plants; as POPs are highly lipophilic compounds and, once adsorbed on the root surfaces, they tend not to be translocated to the aboveground parts of plants (McLachlan, 1996). Concentrations of OCs in air were not measured in the current study, therefore, only relative air-to-plant transfer factors (based on interspecies concentration ratios) could be calculated. Using such ratios, once the OC concentration has been measured in one particular plant species at a given site, the concentration in any other species can be estimated using the corresponding species/ species concentration ratio.

This approach relies on the similarity of the uptake mechanism for POPs in different plant species. The predominant pathway for uptake of POPs by plants is dry gaseous deposition from the atmosphere (Paterson *et al.*, 1994; McLachlan, 1996). The POP concentration in plants (C_P) can be related to that in air (C_A) by the following equation:

$$C_P = L \cdot K_{OA} \cdot C_A \qquad (5.1)$$

where:

L is the lipid fraction in the plant tissue (volume/volume);

K_{OA} – is the octanol-air partition coefficient (the ratio of volume concentrations when at equilibrium).

Taking into account of the relatively low variability in lipid content in plant tissues, Equation 5.1 indicates that POP concentration ratios between two species can be considered as being independent of site. If the kinetic limitations of uptake and depuration are ignored, it could also be expected that the same ratio value would apply for all POPs. A comparison of the concentrations of all OCs (excluding PCB) in lichens and mosses supports these assumptions (see Figure 5.18). From Figure 5.18, it is evident that OC concentrations in lichens show a clear relationship to those in mosses. The best correlation is seen for DDT metabolites, probably because these contaminants are present at higher concentrations and there is a lower detection error. The lichen/moss concentration ratio for POPs, obtained using linear regression analysis, is equal to 0.97. In other words, POPs concentrations in lichen can be used as a direct estimate of the POP concentrations in mosses in the study area, and vice versa.

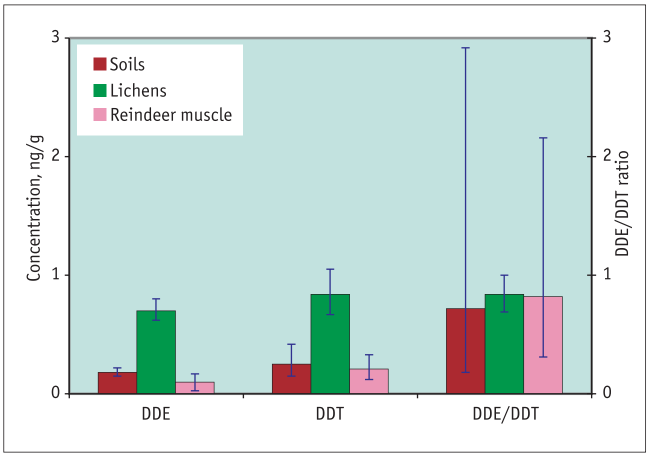


Figure 5.17. Absolute and relative levels of *p,p'*-DDE and *p,p'*-DDT for the soil-lichen-reindeer food chain in the Khatanga area. Geometric means and ranges of DDE and DDT levels in soil and lichen are provided on a dry weight basis, while levels in reindeer muscle are on a wet weight basis; 95% confidence limits are shown for ratios.

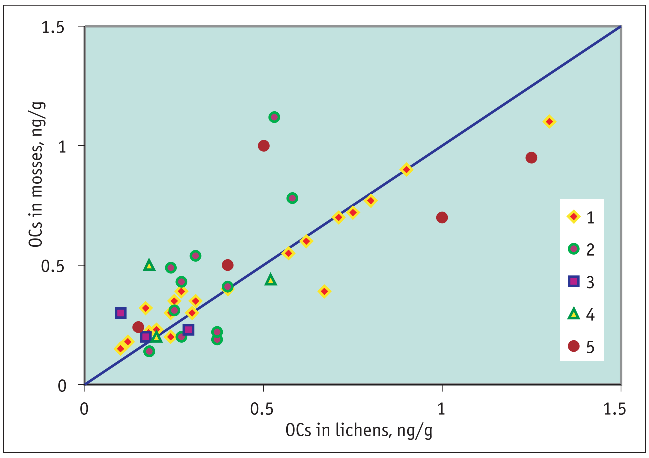


Figure 5.18. The relationship between OC concentrations in mosses and lichen (dry weight) in the northern Russia. 1 – DDT and its metabolites, 2 – HCH isomers, 3 – Heptachlor, 4 – Mirex, 5 – HCB.

Berries and mushrooms are both components of the human diet in the Russian North. Assessment of their contribution to human OC exposure in the Arctic requires data on contamination levels. As the available data set for berry and mushroom contamination in the Arctic is much more limited than that for lichen and mosses, the calculated lichen/berry and lichen/mushroom concentration ratios are useful. Sufficiently reliable data for calculation of the berry/lichen concentration ratio were obtained only for *p,p'*-DDT and HCB (although data for the Kola Peninsula site where an anomalously high *p,p'*-DDT level was measured were excluded). The berry/lichen concentration ratio for *p,p'*-DDT was found to be practically the same as that for HCB. The geometric mean of the nine ratios calculated, using data on both *p,p'*-DDT and HCB, is equal to 0.27.

Lichen-to-reindeer transfer factors (TF_{LR}) were also of the same value (0.3, based on wet wt. and dry wt. concentrations, respectively) for both *p,p'*-DDT and *p,p'*-DDE. They ranged from 0.1 (for *p,p'*-DDE in western Taymir) to 1.8 (for *p,p'*-DDE in Chukotka). In the Canadian Arctic, in 1993, this factor was found to range from one to values in the tens (based on lipid wt. and dry wt. concentrations, respectively) for different OCs (CACAR, 1997). The geometric mean of lipid content measured in reindeer muscle in the current study was about 5%. Using this value to convert the transfer factors based on wet wt. concentrations to their lipid wt. equivalents yields values that are close to those reported for Canada. TF_{LR}s for other OCs that were found at concentrations above detection limits in the current study are of similar values to those determined for *p,p'*-DDT and *p,p'*-DDE (0.2 for PCB-28, 0.8 for PCB-153, 0.5 for α- and γ-HCH, and 0.3 for HCB, based on wet wt. and dry wt. concentrations, respectively).

All transfer factors obtained for *p,p'*-DDT and *p,p'*-DDE in the soil-lichen-reindeer chain agree reasonably well with the values expected on the basis of corresponding concentration ratios for lipids. This result is reasonable since POP concentrations in the soil surface and in plants will generally be at close to equilibrium with POP concentrations in the air, and will reflect the lipid contents of the soil and plants (McLachlan, 1996). Relatively large deviations from equilibrium are observed only for concentrations of POPs which have a very high molecular weight, but even then, these deviations are similar in both plants and soils. POP absorption and depuration by mammals is significantly slower than that by plants. For example, the depuration half-life for PCDD in the human body can be as long as several years (Masuda, 2001). However, given relatively stable levels of air contamination, POP concentrations in mammal tissues and in vegetation used for food should, in general, be comparable, after correction for lipid content (McLachlan, 1996). For example, cow milk/fodder fugacity quotients measured in Germany were, with a few exceptions, close to unity for HCB, PCBs, and PCDD/Fs (McLachlan, 1996). This indicates that a steady state partitioning of OCs between feed and cow tissues takes place. Data obtained in the current study indicated that OC distribution between soil, lichen, and reindeer tissues was also close to a steady state. The observed lack of dependence of OC concentrations in reindeer tissues on animal age, and also the similarity of values calculated for OC concentration and lipid content ratios for reindeer/hare and reindeer/birds also support this conclusion (see Figure 5.19). All differences found between reindeer/hare and reindeer/bird concentration ratios for lipids and any of the OCs were small and within a factor of two, and OC ratio ranges agreed closely with those for lipids.

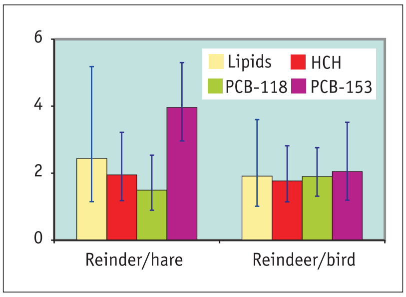


Figure 5.19. Concentration ratios (geometric mean and 95% confidence limits) for OCs and lipid content in reindeer/hare and reindeer/birds, for all sample sites.

The DDE/DDT ratio in soils immediately following application of DDT pesticide is normally about 0.1 or less (Harner *et al.*, 1999). As a result of the microbiological transformation of *p,p'*-DDT into *p,p'*-DDE, and other metabolites, this ratio increases with time. In temperate zones, the DDE/DDT ratio in soils 30 years after the last pesticide application ranges from 0.7 to 2 (Harner *et al.*, 1999). Ratios in the Russian Arctic are, as a rule, at the lower end of this range (see Table 5.19a). This may indicate that fresh use of DDT is still contributing to contamination of the Russian Arctic. However, lower ratio values can be also explained by the slower rate of metabolic processes which occur in Arctic soils.

Metabolic transformation of *p,p'*-DDT also takes place in higher organisms (WHO, 1982) and the DDE/DDT ratio in their tissues can serve as an indicator of the relative rate of *p,p'*-DDT transformation in different species. DDE/DDT ratios in terrestrial food chains in the Russian Arctic are provided in Figure 5.17 and Tables 5.19a and 5.19b. No statistically significant differences were observed between the ratio values, either in soils, lichens, or reindeer tissues, or, between the 6 sites (see Table 5.19a and 5.19b). This indicates that the *p,p'*-DDT transformation rate in reindeer tissues is comparable with that in soils and lichens. The ratio values for terrestrial birds are, as a rule, somewhat higher than in reindeer (see Table 5.19a), probably due to a faster rate of metabolic *p,p'*-DDT transformation in birds.

(b) Heavy metals

Some HMs, such as copper (Cu) and zinc (Zn) are essential elements for both plants and animals and as such, their levels in tissues are under homeostatic control (Yagodin *et al.*, 1989; Speidel and Agnew, 1982).

Table 5.19a.
DDE/DDT ratios (geometric means and 95% confidence interval) in terrestrial food chains.
n. d. – not detected

Site	Soil	Lichens	Browsers	
			Muscle	Liver
Kola Peninsula	0.35 (0.26-0.49)	0.60 (0.49-0.73)	0.39	4.2 (0.84-21)
Pechora basin	0.53 (0.4-0.69)	0.28	3 (0.14-65)	2.2 (0.69-3.2)
Taymir, west	0.54 (0.46-0.63)	0.87 (0.28-2.78)	0.77	1.4 (1.30-1.6)
Taymir, east	0.72 (0.18-2.9)	0.84 (0.69-1.0)	3.1 (0.22-41)	2.1 (0.63-7.4)
Chukotka inland	2.4	0.49 (0.33-0.74)	0.75	0.76 (0.76-0.77)
Chukotka, coast	0.48	0.44	0.19	n.d.
All sites	0.52 (0.48-0.71)	0.64 (0.54-0.74)	1.2 (0.14-10)	1.9 (0.6-5.7)

Non-essential elements, such as Hg and Cd, do not appear to be well-regulated by living organisms. Thus, tissue concentrations of Hg and Cd proportional to environmental (or food) contamination levels can be expected. The use of transfer factors is based on this assumption. However, deviations from direct proportionality do occur, and quite often are more pronounced at higher levels of exposure, especially for Pb (WHO 1989a, 1989b, 1991, 1992, 1995). A possible explanation for this is that HMs in high concentrations are toxic for all organisms and their transfer through cell membranes may be limited when tissue contamination exceeds some critical level. In addition, Pb content in tissue is probably under at least some degree of homeostatic regulation, since it belongs to a group of so-called 'conditionally essential elements' (Yagodin *et al.*, 1989; Speidel and Agnew, 1982). As a result, the HM transfer coefficient for a particular link in a food chain depends not only upon environmental conditions, but also upon the HM concentration in abiotic media (or food). It follows that use of HM transfer coefficient values obtained at low exposure levels, for tissue concentration assessment at high exposure levels, can lead to an overestimation of the concentration of that HM.

Another important condition for the applicability of the transfer factor approach, is the absence of kinetic limitations. The biological half-life of HMs in mammals is difficult to estimate (WHO 1989a, 1989b, 1991, 1992, 1995). The biological half-life of Hg and Pb in blood and the soft tissues of mammals normally ranges from several weeks to several months. However, significantly slower Hg and Pb elimination rates have also been reported. For example, the half-life of Hg in brain tissue and of Pb in bone ranges from years to decades, and for a mammal to eliminate 50% of absorbed Cd can take as long time as 30 years. Based on these elimination rates, HM food-to-mammal transfer factors can be expected to show a significant degree of dependence on mammal age.

As for OCs, the soil-lichen-reindeer food chain is one of the most important pathways for human exposure to HMs in the Arctic. Lichen is able to assimilate mineral substances from any material to which it adheres. However, the similar pattern of HM concentration ratios in lichens, mosses and soils (Hg: Cd: Pb in the ratio of 2:3:95) indicates that mosses, as well as lichen, take up most of their HM burden from the air, apparently from windblown soil and dust. Geometric mean values of lichen/moss concentration ratios ranged from 0.5 to 0.6 for all three HMs. This ratio can be considered indicative of the greater ability of mosses to intercept particles. The geometric mean for the lichen/moss concentration ratio, calculated using the pooled set of data for all three metals was equal to 0.56.

An example of HM concentration patterns for the soil-lichen-reindeer food chain is given in Figure 5.20.

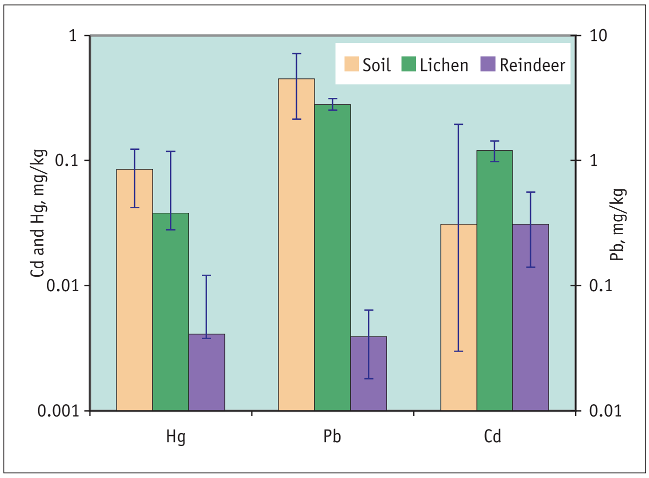


Figure 5.20. HM distribution patterns in the soil-lichen-reindeer food chain on the Kola Peninsula in 2001. Concentrations of HMs in soil and lichen and their ranges are given on the dry weight basis, while those for reindeer muscle are provided on the wet weight basis.

Table 5.19b.
DDE/DDT ratios (geometric means and 95% confidence interval) in terrestrial food chains.
n. d. – not detected

Site	Reindeer		
	Muscle	Liver	Kidney
Kola Peninsula	0.63 (0.38-1.1)	1.3 (0.67-2.4)	0.93 (0.54-1.6)
Pechora basin	0.39 (0.21-0.73)	1.2 (0.75-1.8)	0.83 (0.53-1.3)
Taymir, west	0.55 (0.35-0.85)	0.47 (0.23-0.96)	0.72 (0.58-0.88)
Taymir, east	0.82 (0.31-2.16)	0.38 (0.12-1.2)	0.41 (0.13-1.3)
Chukotka inland	1.33 (0.67-2.6)	0.5	n.d.
Chukotka, coast	1.5 (1.43-1.58)	0.49 (0.46-0.51)	n.d.
All sites	0.65 (0.48-0.89)	0.76 (0.54-1.1)	0.73 (0.55-0.96)

Soil-to-lichen transfer coefficients for Hg and Pb are similar (the geometric mean equal to 0.6, ranging from 0.3 to 1.3 based on dry wt. concentrations). The geometric mean for Cd was about twice as high (1.3), but the difference is of low statistical significance. Soil-to-lichen transfer factors for HMs are several times lower than those for OCs. This is consistent with the hypothesis that soil dust interception is the main pathway of HM uptake by lichens, whilst organic chemicals, in addition to this mechanism, are also absorbed through dry gaseous deposition. Uptake of HMs from soil by mushrooms is more strongly affected by the chemical state of the metal. Geometric mean values of soil-to-mushroom transfer factors (based on dry weight concentrations) ranged from 0.12 and 0.25 for Pb and Hg, respectively, to 1.5 for Cd. The geometric mean of the soil-to-berry transfer factor for Pb (0.006) is two orders of magnitude lower than that calculated for lichens.

Significant differences between Pb and Hg and Cd also occur in the transfer of HMs from lichen to reindeer tissues. Geometric means of lichen-to-reindeer transfer factors for Hg and Cd are similar (0.4 and 0.5, respectively) and an order of magnitude higher than that calculated for Pb (0.03). All transfer factors as a function of herd, vary within an order of magnitude. This variability can be partially explained by differences in the mean age of animals sampled. The age dependence of a pollutant concentration in an animal tissues can be described by the following simple model:

$$\frac{dC}{dt} = r_i - k_e C \qquad (5.2)$$

Where:

C is the pollutant concentration in the animal, ng/g ww;
r_i is the pollutant accumulation rate, ng/g ww per year;
k_e is the pollutant elimination rate constant, per year;
t is the animal age, years.

Assuming that the intake rate is constant, this can be expressed as:

$$C = \frac{r_i}{k_e}(1 - e^{-kt}) \qquad (5.3)$$

When $k_e t$ is small (i.e., elimination is slow), equation 5.4 can be simplified and the concentration dependence on age becomes directly proportional:

$$C = r_i t \qquad (5.4)$$

As was shown in section 5.3.2, HM levels in reindeer are directly proportional to age. This means that the elimination rate is quite slow ($k_e t$ is small) during at least the first few years of life, and effective rates of HM accumulation in reindeer tissue (see Table 5.12) provide an estimate of r_i. Values for the elimination rate (k_e) can be estimated by applying equation 5.3 to experimental data. Because of the small number of age groups and narrow age intervals recorded, the accuracy of such estimates using data obtained in this study is low. However, it is clear that the elimination half-life for all three HMs is at least several years, and could be in the order of 10 years.

Using a typical rate of lichen consumption by reindeer (i.e. 40 g dw/kg live weight per day; White *et al.*, 1999) and HM concentrations from Table 5.7, the total annual uptake of HMs from lichen by reindeer can be calculated. Based on geometric means, this yields values of 0.51, 29, and 1.0 mg/kg live weight per year for uptake of Hg, Pb and Cd, respectively. Comparison of these values with effective deposition rates from Table 5.12 indicate that less than 0.1% of Pb from consumed lichens is transferred into the muscle, while the effectiveness of Hg and Cd transfer to muscle is up to an order of magnitude greater, with values of 0.4% and 1.0%, respectively.

5.4. Freshwater environment

5.4.1. PTS in fish

Fish were obtained from Lake Lovozero (Kola Peninsula), the Pechora River, the Yenisey River (western Taymir), the Khatanga River (eastern Taymir), and the Kanchalan River (inland Chukotka). Fish age ranged from 5 to 14 years. The number of individual samples of tissue collected at a given location for use in the preparation of pooled samples ranged from 1 to 13 (see Table 5.1). The following fish species were sampled:

- pike (*Esox lucius*)
- burbot (*Lota lota*)
- perch (*Perca fluviatilis*)
- ide (*Leuciscus idus*)
- whitefish (*Coregonus lavaretus*)
- Arctic cisco (*Coregonus autumnalis*)
- broad whitefish (*Cerogonus nasus*)
- Arctic char (*Salvelinus alpinus*)
- inconnu (*Stenodus leucichthys nelma*)
- grayling (*Thymallus thymallus*)

Fish muscle and liver tissues were analyzed for all PTS listed in Section 1.2.4. Results of analysis were divided into groups according to sex (male or female), age (either two or three classes), and tissue type (muscle or liver). Age differences within groups ranged from 1 to 2 years. The difference between the mean ages of fish in the oldest and youngest groups was always less than a factor of two.

PTS concentration relationships to fish sex, age and tissue type

(a) Organochlorines

Male/female concentration ratios of OCs that could be reliably quantified (*p,p'*-DDT, *p,p'*-DDE, PCB-138, PCB-153, and HCB) were calculated using data from fish of the same age groups. No statistically significant difference was found between the geometric mean of the ratios and unity, for any OCs or any species. Calculated age ratios (for middle/young and old/young age groups) are, with a few exceptions, slightly higher than unity and range from 0.8 to 2.8. However, in all cases, the standard deviation was comparable to, or larger than the mean ratio value. Taking into account the relatively small number of values included in the average, this implies that the statistical significance of any observed age dependency is very low, and that data for all age groups can be combined in the calculation of geometric mean OC concentrations. The geometric means of OC liver/muscle concentration ratios are close to unity for salmon species and range from 2 to 5 for pike, perch and ide. The highest absolute and relative concentrations of all OCs from all sites were found in burbot liver samples. In the liver of both male and female burbot, fished from Yenisey River, OC concentrations were as high as 580 ng/g for ΣPCB_{15}, 470 ng/g for ΣDDT, and 39 ng/g for ΣCHLOR. Levels of OCs in the liver of other fish species were much lower. In contrast, OC concentrations in burbot muscle were very close to those in other species. The liver/muscle concentration ratio for burbot varied from site to site within two orders of magnitude. The geometric mean for detected OCs in burbot ranges from 50 to 160. These observations are explained by the fact that the lipid content of burbot liver is significantly higher than that of the other species studied, whilst lipid levels in the muscle

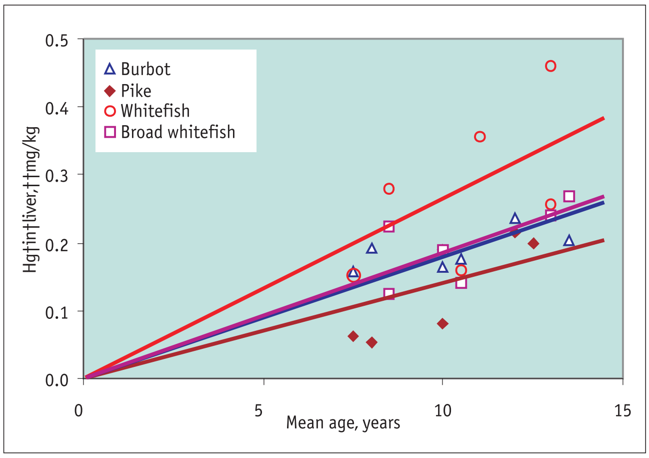


Figure 5.21. Hg concentration in fish liver as a function of the fish age in northern Russia in 2001.

Table 5.20.
Geometric means and 95% confidence interval of effective rates of accumulation of heavy metals in fish tissues (μg/g ww per year).

Fish	Area	Muscle	Liver
		Hg	
Burbot	Kola Peninsula, n=4	0.018 (0.013-0.024)	0.043 (0.037-0.049)
	Taymir, west, n=6	0.011 (0.0088-0.013)	0.019 (0.016-0.021)
	Taymir, east, n=4	0.010 (0.072-0.14)	0.020 (0.014-0.029)
Pike	Kola Peninsula, n=4	0.017 (0.013-0.023)	0.035 (0.031-0.039)
	Chukotka, inland, n=6	0.0058 (0.0039-0.088)	0.012 (0.0080-0.017)
Perch	Pechora basin, n=3	0.012 (0.011-0.013)	0.025 (0.020-0.031)
Ide	Pechora basin, n=5	0.0069 (0.0053-0.089)	0.013 (0.011-0.016)
Whitefish	Kola Peninsula, n=4	0.014 (0.013-0.015)	0.043 (0.034-0.054)
	Pechora basin, n=5	0.0053 (0.0046-0.0060)	0.013 (0.011-0.014)
	Taymir, west, n=4	0.0069 (0.0048-0.010)	0.017 (0.014-0.020)
	Taymir, east, n=6	0.014 (0.0066-0.030)	0.025 (0.019-0.033)
Arctic cisco	Taymir, west, n=4	0.0039 (0.0030-0.0052)	0.011 (0.010-0.013)
Broad Whitefish	Taymir, east, n=6	0.0075 (0.0066-0.086)	0.018 (0.015-0.022)
Inconnu	Chukotka, inland, n=2	0.0031 (0.0028-0.0036)	0.014 (0.089-0.022)
		Pb	
Burbot	Kola Peninsula, n=4	0.0051 (0.0040-0.0064)	0.019 (0.014-0.0025)
	Taymir, west, n=6	0.015 (0.011-0.022)	0.025 (0.021-0.030)
	Taymir, east, n=4	0.0037 0.0017-0.0081)	0.010 (0.0054-0.017)
Pike	Kola Peninsula, n=4	0.012 (0.0099-0.015)	0.046 (0.040-0.052)
	Chukotka, inland, n=6	0.018 (0.016-0.021)	0.044 (0.037-0.052)
Perch	Pechora basin, n=3	0.020 (0.016-0.026)	0.057 (0.044-0.074)
Ide	Pechora basin, n=5	0.0031 (0.0027-0.0036)	0.013 (0.011-0.016)
Whitefish	Kola Peninsula, n=4	0.0014 (0.0010-0.0019)	0.013 (0.012-0.015)
	Pechora basin, n=5	0.0014 (0.0012-0.0017)	0.016 (0.013-0.020)
	Taymir, west, n=4	0.0033 (0.0028-0.038)	0.022 (0.018-0.028)
	Taymir, east, n=6	0.0016 (0.0009-0.0030)	0.021 (0.018-0.025)
Arctic cisco	Taymir, west, n=4	0.0021 (0.0020-0.0023)	0.012 (0.0081-0.017)
Broad Whitefish	Taymir, east, n=6	0.00083 (0.0006-0.0011)	0.021 (0.018-0.025)
Inconnu	Chukotka, inland, n=2	0.0089 90.0067-0.012)	0.028 (0.021-0.38)
		Cd	
Burbot	Kola Peninsula, n=4	0.0037 (0.0029-0.0045)	0.024 (0.019-0.030)
	Taymir, west, n=6	0.0032 (0.0022-0.0045)	0.019 (0.015-0.026)
	Taymir, east, n=4	0.0052 (0.0026-0.010)	0.011 (0.010-0.0014)
Pike	Kola Peninsula, n=4	0.037 (0.0032-0.0042)	0.021 (0.015-0.028)
	Chukotka, inland, n=6	0.0028 (0.022-0.0036)	0.0084 (0.0075-0.0095)
Perch	Pechora basin, n=3	0.0043 (0.0034-0.0053)	0.018 (0.015-0.022)
Ide	Pechora basin, n=5	0.0026 (0.0020-0.0032)	0.023 (0.020-0.028)
Whitefish	Kola Peninsula, n=4	0.0032 (0.0027-0.0038)	0.024 (0.021-0.028)
	Pechora basin, n=5	0.0020 (0.0015-0.0025)	0.015 (0.012-0.019)
	Taymir, west, n=4	0.0019 (0.0014-0.0027)	0.0080 (0.0073-0.0088)
	Taymir, east, n=6	0.0018 (0.0012-0.0027)	0.017 (0.013-0.023)

Fish	Area	ΣPCB 15	HCB	ΣHCH	ΣCHLOR
Freshwater species					
Burbot	Kola Peninsula, n=4	3.7 (2.4-5.7)	0.04 (<0.05-0.080)	0.18 (<0.05-0.36)	0-0.27[a]
	Taymir, west, n=6	4.8 (3.6-5.7)	0.095 (<0.05-0.18)	0.05-0.16[a]	<0.25
	Taymir, east, n=4	2.1 (1.8-2.3)	0.082 (<0.05-0.14)	0.05-0.25[a]	<0.25
Pike	Kola Peninsula, n=4	1.4 (1.2-1.7)	0.079 (0.070-0.10)	0.20 (0.13-0.21)	0-0.29[a]
	Chukotka, inland, n=6	2.3 (1.2-3.9)	0.072 (<0.05-0.25)	0.05-0.22[a]	<0.25
Perch	Pechora basin, n=3	0.6-1.6[a]	0.071 (0.050-0.090)	0.37 (0.19-0.66)	<0.25
Ide	Pechora basin, n=5	1.8 (1.4-2.1)	0.26 (0.18-0.38)	0.59 (0.51-0.74)	0.06-0.53[a]
Salmon species					
Whitefish	Kola Peninsula, n=4	2.3 (2.0-2.5)	0.074 (0.050-0.11)	0.42 (0.37-0.48)	0.14-0.32[a]
	Pechora basin, n=5	2.0 (1.6-2.5)	0.15 (<0.05-0.27)	0.20 (0.10-0.36)	0-0.63[a]
	Taymir, west, n=4	3.2 (2.3-6.2)	0.25 (0.20-0.32)	0.05-0.33[a]	0.23-0.58[a]
	Taymir, east, n=6	3.1 (2.1-3.7)	0.20 (0.15-0.25)	0.31 (0.21-0.37)	1.4 (0.96-2.1)
Arctic cisco	Taymir, west, n=4	3.7 (3.0-4.6)	0.062 (<0.05-0.17)	0.34 (0.17-0.50)	0.81 (0.42-1.3)
Broad Whitefish	Taymir, east, n=6	2.7 (1.6-3.8)	0.11 (0.090-0.17)	0.05-0.35[a]	0.91 (0.39-2.0)
	Chukotka, inland, n=2	1.4 (1.3-1.5)	0.075 (0.070-0.080)	0.26 (0.23-0.30)	0-0.28[a]
Inconnu	Chukotka, inland, n=2	1.4 (1.3-1.5)	0.094 (0.080-0.11)	0.05-0.47[a]	0-0.31[a]
Arctic grayling	Chukotka, cost, n=2	2.1 (2.0-2.2)	0.16 (0.15-0.17)	0.22 (0.19-0.24)	0.60 (0.50-0.71)

Table 5.21a. Concentrations (geometric mean and range; ng/g wet weight) of OCs in fish muscle in the Russian Arctic in 2001.
[a] More than half of concentrations were below the detection limit in at least 50% of the samples. In such cases, when lower and upper limits of the concentration interval were estimated, concentrations below the detection limits was set to zero or to the detection limit, respectively.

of all species are comparable. The high lipid concentration of burbot liver makes it a popular component of the diet of indigenous peoples.

(b) Heavy metals

Concentrations of HMs are similar in male and female fish of each species. Concentrations measured in the oldest fish groups are, on average, twice as high as in the corresponding youngest age group, whereas the mid-age/young-age group ratio is equal to 1.2. These values are consistent with ratios of mean ages in the groups, i.e., even for relatively old fishes, HM contamination levels are close to being proportional to age. Examples of Hg concentration dependence on fish age for those sites with the maximum number of sample age groups are given in Figure 5.21. Effective rates of HM accumulation in fish species are given in Table 5.20. For Pb they are comparable with those found in reindeer tissues, whilst for Hg and particularly Cd, rates are lower.

Concentrations of HMs in the liver of all species is higher than that in the muscle. The liver/muscle concentration ratios are similar for all species within a fish group and show no significant relationship to site. Geometric means of the liver/muscle concentration ratios for Hg, Pb and Cd in freshwater species are equal to 2.0, 2.8 and 4.8, respectively. For salmon species these values are somewhat higher (2.4, 8.6 and 7.5, respectively).

Levels and trends

(a) Organochlorines

OC concentrations in fish muscle are shown in Tables 5.21a and 5.21b. Concentrations of all OCs that were found at detectable levels are broadly similar for both salmon and freshwater groups, although slightly higher concentrations were found in salmon species. No pronounced geographic trend was found for any OC. All concentrations in muscle were below the corresponding MPCs established in Russia for freshwater fish (0.03 mg/kg for ΣHCH, and 0.3 mg/kg for ΣDDT) as well as those for sea fish. Most OC levels are comparable with those detected in reindeer. The only exception to this concerned concentrations of ΣDDT, which are several times higher in fish. Mean OC con-

Fish	Area	*p,p'*-DDE	*p,p'*-DDT	ΣDDT	Mirex
Freshwater species					
Burbot	Kola Peninsula, n=4	0.34 (0.07-0.93)	<0.05-0.70	0.07-0.26	<0.05-0.13
	Taymir, west, n=6	0.62 (0.42-0.89)	0.071 (<0.05-0.13)	0.66-1.4a	0.07 (<0.05-0.15)
	Taymir, east, n=4	<0.05-0.10[a]	0.089 (<0.05-0.20)	0.14-0.65a	<0.05
Pike	Kola Peninsula, n=4	0.39 (0.22-0.61)	0.28 (0.16-0.34)	0.38-1.2a	<0.05
	Chukotka, inland, n=6	<0.05	<0.05-0.20	0-0.64a	<0.05
Perch	Pechora basin, n=3	0.32 (0.19-0.75)	0.39 (0.36-0.48)	0.28 (0.67-1.5)	<0.05
Ide	Pechora basin, n=5	0.58 (0.33-0.96)	0.14 (0.10-0.20)	1.3 (0.83-2.0)	<0.05
Salmon species					
Whitefish	Kola Peninsula, n=4	1.1 (0.85-1.25)	0.31 (0.25-0.40)	1.9 (1.6-2.0)	<0.05
	Pechora basin, n=5	0.43 (0.30-0.70)	0.54 (0.35-0.70)	1.6 (1.4-1.9)	<0.05
	Taymir, west, n=4	0.85 (0.59-1.1)	0.33 (0.25-0.47)	2.2 (2.0-2.5)	<0.05
	Taymir, east, n=6	0.61 (0.52-1.0)	1.5 (1.0-2.0)	2.5 (1.7-3.3)	<0.05
Arctic cisco	Taymir, west, n=4	1.0 (0.62-2.0)	0.53 (0.35-0.75)	1.9 (1.1-3.2)	<0.05
Broad Whitefish	Taymir, east, n=6	0.44 (0.25-0.60)	0.59 (0.41-0.96)	1.3 (0.77-2.0)	<0.05
	Chukotka, inland, n=2	0.31 (0.22-0.43)	0.23 (0.17-0.30)	0.72 (0.68-0.76)	<0.05
Inconnu	Chukotka, inland, n=2	0.38 (0.35-0.41)	0.24 (0.20-0.29)	1.0 (0.9-1.1)	<0.05
Arctic grayling	Chukotka, cost, n=2	1.8 (1.3-2.5)	1.4 (1.0-1.8)	4.2 (3.9-4.6)	<0.05

Table 5.21b Concentrations (geometric mean and range; ng/g wet weight) of OCs in fish muscle in the Russian Arctic in 2001.
[a] More than half of concentrations were below the detection limit in at least 50% of the samples. In such cases, when lower and upper limits of the concentration interval were estimated, concentrations below the detection limits was set to zero or to the detection limit, respectively.

centrations in muscle of whitefish species from three lakes in the Canadian Arctic in 1993–1999 ranged from 4.7 to 24.7 ng/g for ΣPCB (102 congeners), from 0.32 to 2.66 ng/g for ΣHCH, from 1.7 to 9.0 ng/g for ΣCHLOR, and from 1.9 to 24.6 ng/g for ΣDDT (all – in ww) (CACAR, 2003). In comparison with the Canadian data, Figure 5.22, the upper limit of concentration ranges for whitefish species in the Russian North in 2001 coincides with the lower limit of the concentration ranges calculated for whitefish in Canada. The upper limits of concentration ranges for all OCs from the Canadian studies are several times higher than those seen in the Russian Arctic. In comparison with results from studies in northern Scandinavia, however, contamination levels in Russia are reasonably similar to concentrations measured in lake whitefish at three Norwegian sites in 1994 (0.5–1.6 ng/g for the sum of 6 PCB congeners; 0.10–0.12 ng/g for ΣHCH; 0.03–0.23 ng/g for ΣCHLOR; and 0.15-0.63 ng/g for ΣDDT), and also with concentrations measured in Arctic char in Finland (AMAP, 1998).

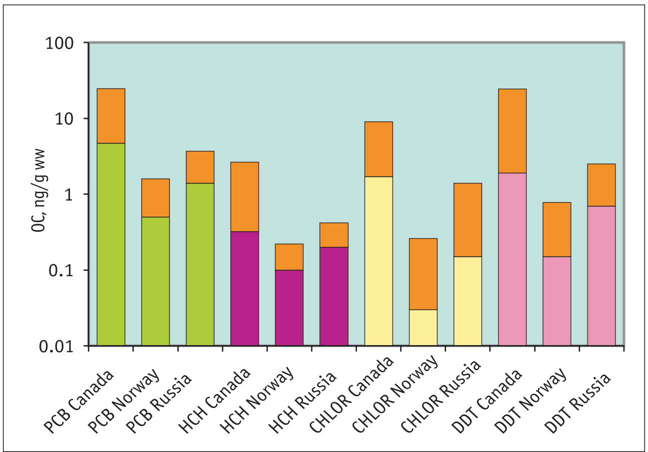


Figure 5.22 Comparison of mean OC concentrations in whitefish species in the Canadian Arctic (1993-1999), Norway (1994), and Russia (2001). The lower part of each column corresponds to the minimum mean concentration, and the total column height, to the maximum mean concentration. PCB=ΣPCB_{15}, HCH=ΣHCH, CHLOR=ΣCHLOR, DDT=ΣDDT

Samples of fish tissues were also analysed for other OCs, listed in Section 1.2.4. In the majority of samples, all other OCs were below detection limits. Only Heptaclor was found in few samples of burbot and whitefish liver and in broad whitefish muscle in concentrations close to the detection limit of 0.05 ng/g ww.

(b) PCDD/Fs

Concentrations of 2,3,7,8-substituted PCDD/Fs were analyzed in pooled fish muscle samples. Results are presented in Table 5.22 and Figure 5.12. PCDD/Fs in fish species follow a similar, but less pronounced, geographical distribution to that seen in reindeer. All concentrations are far below the maximum permissible levels associated with consumption of meat.

Levels of PCDD/Fs found in this study (0.03-0.2 WHO-TEQ/g) were of an order of magnitude lower than in fish muscle samples from the Grate Slave Lake in northern Canada in 1994/5 (0.6-1.1 WHO-TEQ/g; CACAR, 2003). PCDD/Fs concentrations in lake whitefish sampled in Norwegian lakes (1994) were even higher (5.3 ng I-TEQ/g). At four other sites in Scandinavian countries, however, PCDD/F levels in fish muscle were more comparable with those measured in the Russian North in 2001 (0.05-0.09 and 0.02-0.15 ng I-TEQ/g, respectively; AMAP, 1998).

Sample type	Area	pg WHO-TEQ/g ww	pg WHO-TEQ/g lipids	pg WHO-TEQ/pg*
		Freshwater species		
Pike	Kola Peninsula	0.089	14	0.12
Ide	Pechora basin	0.031	0.96	0.046
		Salmon species		
Whitefish	Kola Peninsula	0.13	13.8	0.120
	Pechora basin	0.060	1.5	0.077
	Taymir, west	0.027	1.6	0.063
	Taymir, east	0.050	2.4	0.130
Broad whitefish	Taymir, east	0.041	2.6	0.088
	Chukotka, inlanc	0.025	2.3	0.070

Table 5.22. Concentrations (expressed as TEQ) of PCDD/Fs in fish muscle the Russian Arctic in 2001.
* – ratio of PCDD/F concentration in pg WHO-TEQ/pg to that in pg/g

Fish	Area	NAP	NAP2M	FLE	PA	FLU
			Freshwater species			
Burbot	Kola Peninsula, n=4	105 (93-114)	25 (21-28)	5.5 (3.7-7.0)	14 (14-15)	4.2 (3.4-5.5)
	Taymir, west, n=6	77 (72-96)	37 (28-45)	5.1 (3.8-6.3)	11 (9.6-13)	3.1 (2.1-6.0)
	Taymir, east, n=4	67 (59-82)	53 (43-61)	5.4 (3.6-6.7)	14 (13-15)	4.9 (3.1-7.1)
Pike	Kola Peninsula, n=4	9.9 (8.1–12)	4.6 (4.0-6.6)	2.6 (2.1-3.8)	3.2 (1.6-4.9)	<0.5-1.2
	Chukotka, inland, n=6	52 (22-130)	24 (9.6-41)	4.3 (3.2-5.4)	10 (6.5-16)	3.3 (1.1-6.4)
Perch	Pechora basin, n=3	50 (28-67)	16 (12-16)	3.3 (2.0-4.5)	3.3 (1.2-5.6)	1.3 (1.1-1.5)
Ide	Pechora basin, n=5	37 (31-44)	6.2 (4.8-7.3)	2.0 (1.1-2.3)	2.7 (2.2-3.7)	0.95 (0.48-1.4)
			Salmon species			
Whitefish	Kola Peninsula, n=4	52 (42–61)	11 (8.6-15)	2.4 (1.9-3.0)	3.0 (2.4-3.9)	<0.5-1.3
	Pechora basin, n=5	55 (38-68)	18 (15-21)	<0.5-4.2	<0.5-5.6	<0.5-1.4
	Taymir, west, n=4	71 (69-73)	31 (22-41)	3.2 (2.6-4.4)	5.4 (4.5-6.1)	1.5 (1.3-1.9)
	Taymir, east, n=6	66 (43-80)	31 (21-39)	3.2 (1.8-5.4)	5.4 (3.6-7.8)	0.70 (<0.25-2.6)
Arctic cisco	Taymir, west, n=4	57 (45-66)	11 (7.5-16)	2.6 (1.2-4.5)	2.8 (1.8-4.2)	<0.5-1.1
Broad Whitefish	Taymir, east, n=6	26 (15-42)	16 (11-21)	4.8 (3.1-7.8)	3.0 (1.7-6.0)	<0.5-1.0
	Chukotka, inland, n=2	41 (37-48)	6.0 (4.8-7.4)	2.7 (2.5-2.9)	3.4 (3.0-3.9)	1.0 (1.0-1.0)
Inconnu	Chukotka, inland, n=2	39 (30-50)	17 (13-21)	4.1 (3.6-4.8)	4.0 (3.7-4.3)	1.0 (1.0-1.1)
Arctic grayling	Chukotka, cost, n=2	53 (44-64)	15 (12-18)	4.4 (4.3-4.5)	4.0 (3.6-4.5)	1.2 (1.0-1.4)

Table 5.23. Concentrations (geometric mean and range; ng/g ww) of PAHsa in muscle of fish species in the Russian Arctic.
[a] NAP = Naphthalene, NAP2M = 2-Methylnaphthalene, FLE = Fluorene, PA= Phenanthrene, FLU = Fluoranthene

(c) PAHs

The geometric means and ranges of PAH concentrations in the muscle of fish species in the Russian Arctic are given in Table 5.23. PAH levels in fish, in contrast to OCs, are higher than those in waterfowl, including the piscivores. The distribution of PAH between tissues is also very different from that of OCs. For example, the OC concentration in liver tissue in burbot can be several hundred times higher than that in muscle, while PAH levels in both of these tissues are comparable. No geographic trend in PAH levels in fish is apparent, although concentrations in pike from inland Chukotka are several times higher than those on the Kola Peninsula. However, for other fish species there are no noticeable differences between Chukotka and other regions.

(d) Brominated flame-retardants

Samples of fish tissues were analysed for 2,2',4,4'-tetrabromodiphenyl, 2,2',4,4',5-pentabromodiphenyl, 2,2',4,4'-tetrabromodiphenyl ether and 2,2',4,4',5-pentabromodiphenyl ether. In the majority of samples, concentrations were below the detection limit of 0.2 ng/g ww. Only 2,2',4,4'-tetrabromodiphenyl ether was found at higher levels in a few samples of fish liver (see Table 5.24).

(e) Heavy metals

No pronounced geographic trends are apparent in the levels of HMs in fish (see Table 5.25), although Hg concentrations measured on the Kola Peninsula are consistently higher than at other sites. Hg and Cd concentrations are generally comparable in all species at all sites, apart from relatively low Cd levels occurring in Arctic grayling. Pb levels are, as a rule, somewhat higher in freshwater species. All concentrations, with one exception, are significantly below the relevant MPCs (of 0.6 mg/kg for Hg, 0.2 mg/kg for Cd, and 1.0 mg/kg for Pb), established in Russia for predatory fish. The exception is Hg in whitefish from the Khatanga River, the concentration of which exceeds permissible limits by a factor of 1.5.

No significant difference was observed in Cd and Pb levels in caregonids in the Russian North between 1995 and 2001. Levels of Hg in these species in the Yenisey and Khatanga Rivers were higher in 2001 than in 1995, while Hg levels reported for whitefish caught in the Pechora River in 1995 (AMAP, 1998) are comparable with those measured in 2001. Hg levels in species in the Russian North are also consistent with results from the Canadian Arctic. Mean concentrations of Hg in whitefish species in Canadian lakes in 1996-2000 ranged from 0.03 to 0.35 µg/g (CARCAR, 2003), and those in Russian lakes and rivers in 2001 from 0.055 to 0.15 µg/g. These concentrations are also similar to those found in fish in northern Norway in 1995 (AMAP, 1998).

Area	Species	Number of samples analyzed	Number of samples with detectable levels	Concentration
Kola Peninsula	Whitefish	4	1	0.28
Kola Peninsula	Pike	4	2	0.23-0.31
Pechora basin	Perch	3	1	0.3
Pechora basin	Ide	4	1	0.23
Chukotka, inland	Pike	6	4	0.22-0.27
Chukotka, inland	Inconnu	2	2	0.34-0.42

Table 5.24. Concentrations (ng/g ww) of 2,2',4,4'-tetrabromodiphenyl ether in liver of fish in the Russian Arctic in 2001.

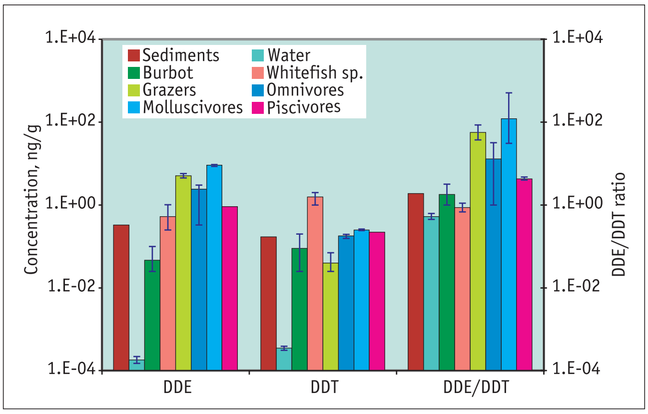


Figure 5.23. Absolute and relative levels of *p,p'*-DDE and *p,p'*-DDT in aquatic food chains in the Khatanga area. Geometric means and ranges of DDE and DDT levels in sediments are given on a dry weight basis, while levels in the muscle of birds and fish are on a wet weight basis. Ratios are shown with 95% confidence limits.

Fish	Area	Hg	Pb	Cd
Burbot	Kola Peninsula, n=4	0.16 (0.12-0.18)	0.045 (0.037-0.063)	0.032 (0.022-0.045)
	Taymir, west, n=6	0.11 (0.10-0.13)	0.15 (0.10-0.27)	0.032 (0.016-0.061)
	Taymir, east, n=4	0.089 (0.07-0.11)	0.033 (0.010-0.081)	0.046 (0.030-0.115)
Pike	Kola Peninsula, n=4	0.16 (0.13-0.18)	0.11 (0.09-0.14)	0.034 (0.028-0.039)
	Chukotka, inland, n=6	0.057 (0.024-0.12)	0.18 (0.12-0.25)	0.028 (0.015-0.029)
Perch	Pechora basin, n=3	0.096 (0.072-0.13)	0.16 (0.15-0.17)	0.034 (0.030-0.041)
Ide	Pechora basin, n=5	0.067 (0.054-0.082)	0.031 (0.027-0.034)	0.024 (0.018-0.031)
Whitefish	Kola Peninsula, n=4	0.15 (0.12-0.18)	0.037 (0.029-0.052)	0.035 (0.029-0.047)
	Pechora basin, n=5	0.055 (0.051-0.059)	0.015 (0.012-0.018)	0.020 (0.016-0.037)
	Taymir, west, n=4	0.078 (0.061-0.099)	0.037 (0.029-0.052)	0.022 (0.013-0.026)
	Taymir, east, n=6	0.15 (0.07-0.95)	0.017 (0.005-0.042)	0.014 (0.010-0.021)
Arctic cisco	Taymir, west, n=4	0.039 (0.025-0.052)	0.021 (0.018-0.024)	0.014 (0.011-0.016)
Broad Whitefish	Taymir, east, n=6	0.079 (0.055-0.12)	0.0087 (0.0047-0.015)	0.019 (0.006-0.058)
	Chukotka, inland, n=2	0.11 (0.07-0.14)	0.013 (0.010-0.018)	0.018 (0.010-0.032)
Inconnu	Chukotka, inland, n=2	0.032 (0.025-0.042)	0.092 (0.088-0.096)	0.11 (0.10-0.11)
Arctic grayling	Chukotka, cost, n=2	0.077 (0.065-0.090)	0.017 (0.013-0.021)	0.0035 (0.0030-0.0041)

Table 5.25. Concentrations (geometric mean and range; µg/g ww) concentrations of HMs in the freshwater fish muscle in the Russian Arctic in 2001.

5.4.2. PTS transfer in the freshwater food chain

(a) Organochlorines

The major link in the contamination of many aquatic food chains by OCs, is their transfer from water to fish. As an example of *p,p'*-DDT and *p,p'*-DDE uptake patterns in freshwater aquatic food chains, Figure 5.23 shows levels of these contaminants in fish muscle and waterfowl from the Khatanga area of eastern Taymir, (the only site where all fish and bird groups were sampled).

The characteristic time for hexachlorobiphenyl (PCB-155) absorption/depuration, as determined by laboratory experiments on adult rainbow trout, is about 1 month (Gobas *et al.*, 1999). This indicates that steady state OC concentrations in fish are established within a period of months, even for OCs with a $\log K_{OW}$ value as high as 7. As shown, OC distribution between water and fish tissues can be quite accurately described by a simple adsorption/desorption model, with the water-to-fish transfer factor (TF_{WF}, mL/g ww of muscle) calculated as follows (Verhaar *et al.*, 1999):

$$TF_{WF} = (V_{LM}K_{OW}^{a1} + V_{WM})/(V_{LW}K_{OW}^{a2} + V_{WW}) \qquad (5.5)$$

Where:

V_{LM} and V_{LW} are lipid fractions in the muscle of fish and in water, respectively;
V_{WM} and V_{WW} are water fractions in the muscle of fish and water, as a physical body respectively;
a1 and a2 are Collander coefficients, which compare the similarity of the lipid in a given compartment with octanol.

A typical value for dissolved organic matter (DOM) concentration in surface freshwater is about 10 mg/L whilst the normal lipid concentration in the muscle of fish is several percent. A typical value for the Collander coefficient for the organic matter of soil and sediments (a1) is 0.8 (Schwarzenbach *et al.*, 1993). A significantly smaller coefficient a2 might be expected, however, when experimental data are applied to equation 5.5 a similar value is obtained for both coefficients (Verhaar *et al.*, 1999). Therefore, for the purposes of this study, a value of 0.8 was used for both a1 and a2. Using these input parameters, equation 5.5 predicts almost constant transfer factors (TF_{WF} 1000 mL/g ww) for all hydrophobic substances with $\log K_{OW} > 6$. This is consistent with previously reported experimental TF_{WF} - K_{OW} dependences (Verhaar *et al.*, 1999). K_{OW} values selected by Pantolillo and Eganhouse (2001) were used for *p,p'*-DDT ($\log K_{OW} = 6.6$, the geometric mean of two selected K_{OW} values), and for *p,p'*-DDE ($\log K_{OW}$ 7.0), while the K_{OW} values of other OC's were taken from the publication by Mackay *et al.* (1992). For fish species harvested in Lake Lovozero, and from rivers in the study, most TF_{WF} values calculated for *p,p'*-DDT and *p,p'*-DDE, as well as for other OCs with detected levels and with $\log K_{OW} \geq 6$ are about 1000 mL/g ww, or somewhat higher.

The TF_{WF} values predicted for *p,p'*-DDE, with only one exception, overestimate experimental values, while those for *p,p'*-DDT underestimate values in most cases. This is unlikely to be the result of poor choice of K_{OW} values, because according to equation 5.5, when K_{OW} is sufficiently large, the accuracy of its value is not critical for freshwater, and the relative concentrations of all highly hydrophobic contaminants in fish and water are expected to be similar. However, the measured DDE/DDT ratio in fish is several times higher (see Figure 5.23 and Table 5.26a and 5.26b), probably indicating a faster rate of *p,p'*-DDT metabolism in fish tissues than predicted. In any event, the assumption seems reasonable for waterfowl, in which the DDE/DDT ratio is 1-2 orders of magnitudes higher than in water, sediments and fish. As the chemical and physical properties of *p,p'*-DDE and *p,p'*-DDT are quite similar, it is unrealistic to expect that the dramatic difference in their relative concentrations could have a non-metabolic explanation. Comparison with whitefish species provides further evidence of an enhanced rate of metabolic transformation of *p,p'*-DDT into *p,p'*-DDE in birds and/or in their food. Levels of *p,p'*-DDT and *p,p'*-DDE in whitefish are, respectively, higher and lower than in birds, whilst levels of the sum of *p,p'*-DDT and *p,p'*-DDE are comparable and consistent with the corresponding lipid concentrations. Despite feeding at the highest trophic level, piscivore tissues do not contain the highest levels of *p,p'*-DDT and *p,p'*-DDE, nor do they have the highest DDE/DDT ratio. Only DDE concentration is consistently higher in piscivore bird species than in fish, while other OC levels (such as *p,p'*-DDT) are comparable or even lower. From this it can be inferred that the fish-to-birds transfer factor is close to unity for OCs which do not undergo significant metabolic transformation in bird tissues.

Site	Water	Freshwater fish	Salmonid sp.
Kola Peninsula	0.23 (0.16-0.32)	2.6 (1.7-3.9)	3.40 (2.6-4.5)
Pechora basin	0.67 (0.45-1.0)	2.2 (1.4-3.4)	1.1 (0.74-1.6)
Taymir, west	2.4	4.1 (3.5-4.8)	3.4 (2.5-4.5)
Taymir, east	0.52 (0.45-0.62)	1.8 (1.0-3.2)	0.87 (0.68-1.1)
Chukotka inland	-	4.1 (3.9-4.3)	2.2 (1.4-3.2)

Table 5.26a. DDE/DDT ratios (geometric means and 95% confidence interval) in freshwater food chains.

Table 5.26b. DDE/DDT ratios (geometric means and 95% confidence interval) in freshwater food chains.

Site	Grazers	Omnivores	Molluscivores	Piscivores
Kola Peninsula	-	-	24 (6.9-80)	12.0
Pechora basin	-	2.1	-	1.7 (1.1-2.7)
Taymir, west	100 (59-180)	13 (5.1-34)	-	-
Taymir, east	56 (37-85)	13 (3.8-41)	120 (31-510)	4.3 (4.0-4.7)
Chukotka inland	4.2	1.2 (0.33-4.2)	3.2 (2.2-4.7)	-

Contaminants in water also constitute the basis for the most important food chain pathways that give rise to contaminants in waterfowl. All other conditions (such as forage composition, DOM concentration etc.) being equal, OC levels in birds are directly proportional to the level of contamination in water. This being so, it is possible for water-to-bird transfer factors to be calculated. These are comparable for all bird groups at all sites and equal 5700 and 980 mL/g ww for *p,p'*-DDE, and *p,p'*-DDT, respectively. Transfer factors for HCB and PCBs range from 460 mL/g ww (HCB, water- to- piscivores in eastern Taymir) to 67000 mL/g ww (PCB-153, water-to-molluscivores in western Taymir). The geometric means of transfer factors are in a good agreement with those predicted using equation 5.5 and equal 1200 mL/g ww for HCB, 1800 mL/g ww for PCB-153 and 4100 mL/g ww for PCB-28. The lower value obtained for PCB-153 when compared with that of PCB-28 may be due to the kinetic limitation of highly hydrophobic compound levels in bird tissues. Higher transfer factors for waterfowl when compared to fish are consistent with the bird/fish concentration ratio for PCDD/F of ~ 2.2, and with the approximately two times greater lipid concentration in the muscle of birds. All differences between waterfowl /fish concentration ratios for lipids and OCs are within a small (factor of two) variance, and there is close correlation between the ranges for OC ratios and those of lipids (see Figure 5.24).

(b) Heavy metals

Equillibrium levels of Hg, Pb and Cd in fish in laboratory experiments can normally be established in several weeks or months (WHO 1989a, 1989b, 1991, 1992, 1995). This indicates that, in the absence of sudden temporal or spatial changes in HM concentrations in environmental media or in the food supply, contamination levels in fish tissues would be expected to be relatively constant and in equilibrium with levels found in the environment.

Figure 5.24.
Concentration ratios (geometric mean and 95% confidence limits) for OCs and lipid content in waterfowl/fish, for all sample sites.

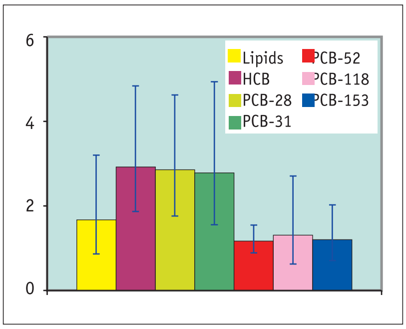
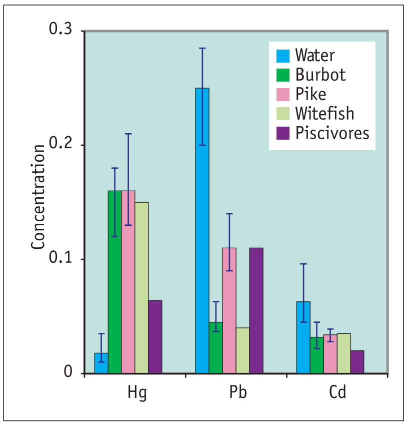


Figure 5.25.
The HM distribution pattern in water-fish-bird food chains on the Kola Peninsula in 2001. HM concentrations and their ranges in bird and fish muscle are in µg/g ww, while those in water are in µg/L.



An example of HM distribution patterns in an aquatic food chain are presented in Figure 5.25. Despite occupying a higher trophic level, HM contamination levels in piscivorous birds are comparable with those of fish. Water-to-fish and water-to-bird transfer factors for HMs vary within an order of magnitude. Values of water-to-fish transfer factors for Hg and Cd are similar for salmon species and for freshwater fish, while the water-to-fish transfer factor for Pb is several times higher for freshwater species. Geometric means of Hg and Cd TFWFs, calculated using pooled sets of data, are equal to 3300 and 570 mL/g ww, respectively. Geometric means of Pb TFWFs are equal to 280 mL/g ww for freshwater species and 60 mL/g ww for salmon species. Default values for Hg and Pb biomagnification in fish edible parts provided in the IAEA Handbook (IAEA, 1994) are consistent with values obtained in this study.

As shown in section 5.3.4, HM contamination levels are close to being directly proportional to fish age, even for relatively old fish. This indicates that HM elimination rates are low and that the biological half-lives for the 3 HMs considered are about 10 years. The elimination rates determined in this study are significantly slower than those measured in laboratory experiments, in which a state of equilibrium was normally reached within several weeks or months (WHO 1989a, 1989b, 1991, 1992, 1995). A possible explanation for this discrepancy is the relatively short duration of laboratory experiments. If this is the case, HMs could have accumulated primarily in tissues and organs that are capable of fast absorption and elimination of HMs. This hypothesis is supported by observations from laboratory experiments that the elimination rate decreases with time. The biological half-life of the remaining HM fraction may, therefore, be many years. This is the slowest stage of HM elimination and is, quite possibly, the controlling rate under natural conditions.

5.5. Marine environment

5.5.1. PTSs in marine fish

Among marine fish species, only yellowfin sole flounder (*Limanda aspera*), harvested in the Bering Sea was sampled and analysed for PTSs content. However, for this analysis, some anadromous fish species such as smelt (*Osmerus eperlanus*), chum salmon (*Oncorhynchus keta*) and sea-run Arctic char (*Salvelinus alpinus*) were included in the group of sea fish, since they inhabit sea waters for a major part of year, migrating into river mouths only in the fall season for spawning.

(a) Organochlorines

As it is shown in Tables 5.27a and 5.27b, concentrations of OCs in muscle tissue of yellowfin sole are within the range of OC levels for anadromous fish. For concen-

Fish	Area, number of pooled samples (number of individual fish pooled)	ΣPCB15	HCB	ΣHCH	ΣCHLOR
Chum salmon	Chukotka, coast, 4 (43)	2.3 (1.3-3.8)	0.26 (0.12-0.21)	0.62 (0.61 –0.63)	0.67 (0.55– 0.80)
Arctic char	Chukotka, coast, 8 (47)	6.5 (3.6–26.1)	0.31 (0.27-0.36)	0.27 (0.26-0.29)	1.3 (0.69–2.3)
Yellowfin sole	Chukotka, coast, 2 (20)	2.5 (2.45-2.55)	0.11 (0.11-0.12)	0.42 (0.39 - 0.46)	0.18 (<0.05-0.23)
Smelt	Chukotka, coast, 2 (25)	1.5 (1.0-2.5)	0.06 (<0.05-0.10)	0.16 (<0.05-0.22)	0.15 (0.14-0.16)

Table 5.27a. Concentrations (geometric mean and range; ng/g wet weight) of OCs in muscle tissue of marine and anadromous fish in the Russian Arctic in 2001.

Fish	Area, number of pooled samples (number of individual fish pooled)	*p,p'*-DDE	*p,p'*-DDT	ΣDDT	Mirex
Chum salmon	Chukotka, coast, 4 (43)	0.68 (0.62-0.74)	0.53 (0.45-0.63)	1.9 (1.5-2.2)	<0.05
Arctic char	Chukotka, coast, 8 (47)	1.9 (0.84-4.1)	0.39 (0.19-0.79)	3.3 (1.6-6.5)	0.28 (0.23-0.33)
Yellowfin sole	Chukotka, coast, (20)	0.19 (0.16-0.23)	<0.05	0.41 (0.38– 0.45)	<0.05
Smelt	Chukotka, coast, 2 (25)	0.25 (0.23-0.26)	0.11 (0.10-0.13)	0.66 (0.59-0.75)	<0.05

Table 5.27b. Concentrations (geometric mean and range; ng/g wet weight) of OCs in muscle tissue of marine and anadromous fish in the Russian Arctic in 2001.

trations of OCs found above detection limits, such as ΣPCB_{15}, ΣHCB, ΣHCH and ΣCHLOR, yellowfin sole muscle is approximately in the middle of the range of values for anadromous fish, although it had the lowest levels of DDT and its metabolites.

(b) Heavy metals

From Table 5.28, it can be seen that levels of Hg and Cd in yellowfin sole were, as for OCs, within the range of values for Hg and Cd found in anadromous fish, however, Pb concentrations in its flesh were higher than those in the anadromous fish group. Concentrations of all HM tested were well below guidelines concerning permissible levels of Hg, Pb and Cd in marine fish (0.4, 1.0 and 0.2 µg/g ww, respectively).

5.5.2. PTSs in marine mammals

5.5.2.1. Seal species

The seal family (*Phoca sp.*) in this study is represented by the ringed seal (*Phoca hispida*), the bearded seal (*Erignatus barbatus*) and the larga, or spotted seal (*Phoca largha*). Seals are the most abundant and widely distributed of the resident Arctic pinnipeds. Their diet consists of fish and crustaceans. Ringed seals have a broad circumpolar distribution and prefer annual, land-fast ice, but are also found near multiyear ice. Adults are believed to be relatively sedentary, but subadults can disperse over long distances. Ringed seals are a key component of the diet of the Inuit in northern Canada and Greenland, and of the Yupik and coastal Chukchi on the Chukotka Peninsula of Arctic Russia.

14 samples of ringed seal liver, kidney, muscle and blubber, together with 5 samples of bearded seal, and 22 samples of larga seal were collected from various communities located on the shores of Lavrentiya Bay in the Bering Sea, during the summer and fall periods of 2000 and 2002.

PTS concentration relationships to seal sex, age, and tissue type

As the age range of sampled animals among the seal species was very low (from 0.5 to 3.5 years), it was considered that neither age nor sex difference was likely to be particularly important in explaining variations in contaminant levels. Consequently, averages were calculated based on values obtained from both sexes and all ages.

Table 5.28. Concentrations (geometric mean and range; g/g wet weight) of HMs in muscle tissue of marine and anadromous fish in the Russian Arctic in 2001.

Fish	Area, number of pooled samples (number of individual fish pooled)	Hg	Pb	Cd
Chum salmon	Chukotka, coast, 4 (43)	0.17 (0.15-0.18)	0.078 (0.070-0.086)	0.17 (0.14-0.20)
Arctic char	Chukotka, coast, 0 8 (47)	0.21 (0.15-0.28)	0.069 (0.067-0.072)	0.14 (0.12-0.15)
Yellowfin sole	Chukotka, coast, 0 2 (20)	0.053 (0.049-0.057)	0.132 (0.110-0.154)	0.032 (0.023-0.041)
Smelt	Chukotka, coast, 0 2 (25)	0.088 (0.078-0.098)	0.016 (0.014-0.018)	0.017 (0.015-0.020)

Table 5.29. Concentrations (mean ± S.D. ng/g ww) of OCs in blubber of male and female seals harvested in the Russian Arctic (Chukotka), compared with data from northern Canada (CACAR, 1997).

OCs	Chukotka (coastal area)				Canada	
	Ringed seal		Larga seal		Ringed seal	
	male	female	male	female	male	female
ΣHCH	158±77	120.8±24.2	191.0±44.8	190±61	210±36.9	179±21.8
ΣDDT	86±33	72.0±28.4	232.3±95.7	208±72	703±890	359±166
ΣCHLOR	112±18	122±91	272.3±81.7	237±66	470±324	322±129
ΣCBz	15.0±2.7	16.2±2.7	37.1±14.3	23.6±8.6	36.1±7.1	37.6±9.4
Toxaphene	3.57±1.35	3.58±1.64	35.5±19.3	26.5±7.1	180±83.9	175±65.8
ΣPCBs	242±87	270±79	445±187	362±70	675±597	467±195

Seal species, number of samples	Organ or tissue	ΣPCB$_{15}$	HCB	ΣHCH	ΣCHLOR
Ringed Seal, (n=14)	Muscles	2.3 (1.5-2.9)	0.08 (<0.05-0.17)	0.94 (0.49-1.8)	0.38-1.2[a]
	Liver	2.5 (1.5-3.1)	0.09 (<0.05-0.22)	1.2 (0.8-1.5)	0.12-1.1[a]
	Kidney	2.2 (1.2-3.5)	<0.05-0.12a	0.81 (0.44-1.1)	0.36-1.1[a]
	Blubber	100 (70-154)	6.0 (4.2-9.4)	55 (36-74)	44 (21-92)
Larga Seal, (n=23)	Muscles	7.5 (5.7-10)	0.18 (0.05-0.48)	2.6 (1.4-4.2)	1.7 (0.87-3.9)
	Liver	2.9 (1.6-4.7)	0.22 (0.13-0.37)	1.3 (0.53-1.8)	0.69 (0.36-1.2)
	Kidney	1.8 (1.4-2.2)	0.18 (0.08-0.29)	0.69 (0.21-1.1)	0.46 (0.24-0.77)
	Blubber	123 (101-162)	9.5 (7.6-13)	52 (19-88)	35 (21-63)
Bearded Seal, (n=5)	Muscles	2.3 (2.2-2.4)	<0.05	<0.20	0.05-0.51[a]
	Liver	3.7 (3.4-4.0)	0.05 (0.06-0.09)	0.38 (0.32-0.44)	0.39-0.89[a]
	Kidney	4.9 (4.6-5.2)	0.09 (<0.05-0.13)	0.59 (0.51-0.68)	1.7 (1.6-1.8)
	Blubber	87 (79-95)	1.7 (1.0-2.6)	8.7 (7.0-11)	32 (30-35)

Table 5.30a. Concentrations (geometric mean and range; ng/g ww) of OCs in organ and tissues of seal species in the Russian Arctic.
[a] More than a half of concentrations measured were below the detection limit in at least one of the pooled samples.

In the ringed seal samples, PCBs, HCH, chlordanes, and DDT were the most prominent contaminants, while chlorobenzenes and toxaphene were present at lower concentrations. Average concentrations of PCB and chlordanes in females were higher than those in males, while mean levels of ΣHCH and ΣDDT in males exceeded those in females (Table 5.29). Mean concentrations of the sum of chlorobenzenes (ΣCBz) and toxaphene were very similar in both males and females.

In larga seals, PCBs, ΣCHLOR, ΣDDT, and ΣHCH were the main contaminants found, and average concentrations of all OCs tested were higher in males than in females.

Comparison of OC levels in the blubber of ringed seal harvested in the Canadian and Russian Arctic have shown that for all OCs under consideration, except for HCH, concentrations in the blubber of ringed seal from the Canadian Arctic, exceeded those in ringed seal from the Bering Sea. The most probable explanation for this is the difference in age between the two groups of seals, since seals hunted in the Bering Sea were no older than 3.5 years of age, whereas ringed seals from the Canadian North were 6 years or more in age.

Levels and trends

(a) Organochlorines

For the pooled data set of seal species, which included all ages and both sexes, geometric means were calculated (Tables 5.30a and 5.30b). No statistically significant differences were found between concentrations of OCs detectable in muscles, liver and kidney of ringed seal, but OC concentrations in blubber were about 50 times higher in comparison with other organs and tissues. Concentrations of OCs in muscles, liver, kidney and blubber of larga seal occured in the approximate ratio 1 : 0.3 : 0.2 : 15.

The highest level of muscle contamination by OCs was found in larga seal. Concentrations of all OCs in the muscle of other seal species were several times lower and close to those found in terrestrial mammals, waterfowl and fish. Concentrations of HCH and DDT and its metabolites in muscle, liver and kidney of seals were below corresponding guidelines established for consumption of seal meat in Russia (0.01 mg/kg for ΣHCH, and 0.03 mg/kg for ΣDDT). No significant difference was observed between concentrations of any OCs in other tissues of seals, with the exception of relatively low HCB and ΣHCH levels in the muscle and blubber of bearded seal. Like in fish muscle, levels of OCs in the blubber of seals were close to the lower margin of concentration ranges reported for seals from the Canadian Arctic in 1998-2001 (CACAR, 2003).

Results of a comparative assessment of OC contamination of ringed seal blubber in the Canadian and the Russian Arctic are shown in Figure 5.26. As can be seen from the Figure, concentrations of major OCs in the blubber of ringed seal in the Canadian Arctic meas-

Seal species, number of samples	Organ or tissue	*p,p'*-DDE	*p,p'*-DDT	ΣDDT	Mirex
Ringed Seal, (n=14)	Muscles	0.99 (0.56-1.7)	0.31 (0.15-0.64)	1.6 (0.92-2.3)	<0.05
	Liver	0.93 (0.60-1.3)	0.56 (0.29-0.93)	1.8 (1.4-2.5)	<0.05
	Kidney	0.67 (0.24-1.3)	0.30 (0.15-0.56)	1.3 (0.67-1.9)	<0.05
	Blubber	43 (14-80)	8.5 (4.3-14)	59 (24-102)	2.7 (1.6-4.7)
Larga Seal, (n=23)	Muscles	2.9 (1.3-5.5)	0.67 (0.30-1.3)	4.5 (2.7-7.1)	<0.05-0.19[a]
	Liver	1.2 (0.25-3.2)	0.21 (0.09-0.41)	2.1 (1.0-4.3)	<0.05
	Kidney	0.66 (0.36–0.97)	0.11 (0.03-0.35)	1.1 (0.56-1.5)	<0.05-0.10[a]
	Blubber	31 (12 –85)	14 (6.7-20)	55 (28-104)	1.7 (0.78-5.2)
Bearded seal, (n=5)	Muscles	0.28 (0.12-0.64)	0.82 (0.50-1.4)	1.3 (0.74-2.1)	<0.05
	Liver	1.3 (1.0-1.6)	0.28 (0.28-0.29)	2.0 (1.8-2.4)	0.12(0.12-0.13)
	Kidney	1.6 (1.1-2.2)	0.52 (0.47-0.58)	2.6 (2.2-3.2)	<0.05
	Blubber	35 (28-45)	8.6 (7.3-10)	49 (40-61)	1.1 (1.0-1.2)

Table 5.30b Concentrations (geometric mean and range; ng/g ww) of OCs in organ and tissues of seal species in the Russian Arctic.
[a] More than a half of concentrations measured were below the detection limit in at least one of the pooled samples.

Table 5.31.
Concentrations (ng/g ww) of of 2, 2', 4, 4'-tetrabromodiphenyl ether in seal species in the Russian Arctic in 2000-2002.

Species	Tissue	Number of samples analyzed	Number of samples with detectable levels	Concentration
Ringed seal	Blubber	6	1	0.51
Bearded seal	Blubber	2	1	1.9
Larga seal	Liver	10	1	0.23
Larga seal	Blubber	10	4	0.24-1.2

ured during the period 1989 to 2001 (CACAR, 1997; CACAR, 2003) were higher when compared with those measured in the Russian Arctic during the period 2000-2002.

(b) Brominated flame-retardants

Samples of tissues of marine mammals were analyzed for 2, 2', 4, 4'-tetrabromodiphenyl, 2, 2', 4, 4', 5-pentabromodiphenyl, 2, 2', 4, 4'-tetrabromodiphenyl ether and 2, 2', 4, 4', 5-pentabromodiphenyl ether. In most samples, these substances occurred below the detection limit of 0.2 ng/g. Only 2, 2', 4, 4'-tetrabromodiphenyl ether was found in few samples at higher levels (see Table 5.31).

(c) Heavy metals

Concentrations of HMs in seal species are shown in Table 5.32. The highest levels of contamination by Hg were found in the tissues of bearded and larga seal, and the lowest levels in ringed seal. Lead and Cd concentrations were similar in all seals. Hg concentrations in the muscle of seal species were significantly higher when compared with those in terrestrial mammals, birds, and fish. Lead levels in seals were somewhat lower than those in birds and terrestrial animals, while Cd concentrations in all mammals, birds, and fish were comparable. All Pb concentrations in the muscle, liver and kidney of seals were below corresponding guidelines established for human consumption of meat, liver, and kidney in Russia (0.5, 0.6, and 1.0 mg/kg, respectively). However, all Hg and most Cd concentrations in seals significantly exceeded corresponding guidelines (Table 5.33).

As seen in Table 5.32, the organ showing the greatest degree of contamination by Hg, in all seal species, was liver, followed by muscle tissue, and kidney. With respect to Cd, the most contaminated organ was kid-

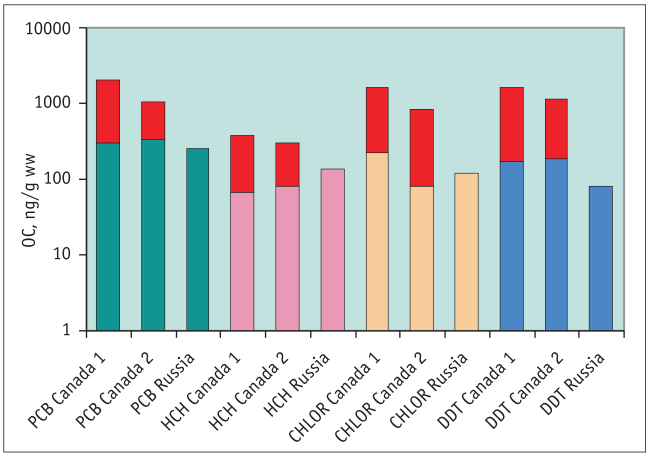


Figure 5.26. Comparison of mean OC concentrations in ringed seal blubber in the Canadian Arctic (Canada 1: 1989-1994, Canada 2: 1998-2001) and Russia (2000-2002). The lower part of each column corresponds to the minimum mean concentration, and the total column height, to the maximum mean concentration. PCB=ΣPCB (sum of 15 congeners in Russia; sum of more than 100 congeners in Canada), HCH=ΣHCH, CHLOR=ΣCHLOR, DDT=ΣDDT.

Table 5.32.
Concentrations (geometric mean and range; µg/g ww) of HMs in tissues and organs of seals in the Russian Arctic in 2000-2002.

Species	Tissue	Hg	Pb	Cd
Ringed seal, (n = 14)	Muscle	0.48 (0.089-1.63)	0.042 (0.007-0.1)	0.047 (0.006–0.56)
	Liver	2.49 (0.41-8.36)	0.09 (0.067-0.155)	3.81 (0.15-18.65)
	Kidney	2.26 (0.83-10.0)	0.079 (0.054-0.124)	15.81 (1.53-50.13)
	Blubber	0.03 (0.002-1.59)	0.064 (0.014-0.686)	0.027 (0.006-0.52)
Bearded seal, (n = 5)	Muscle	1.25 (0.88-2.14)	0.038 (0.021-0.065)	0.030 (0.011-0.062)
	Liver	9.25 (3.71-37.4)	0.109 (0.065-0.186)	2.07 (1.28-3.62)
	Kidney	3.71 (1.71-8.32)	0.077 (0.064-0.11)	5.83 (3.31-11.49)
	Blubber	0.013 (0.003-0.37)	0.025 (0.022-0.03)	0.015 (0.004-0.024)
Larga seal, (n = 23)	Muscle	1.11 (0.14-3.28)	0.045 (0.024-0.070)	0.034 (0.005-0.136)
	Liver	5.64 (1.14-27.0)	0.091 (0.061-0.168)	1.71 (0.18-8.35)
	Kidney	2.78 (0.86-9.53)	0.058 (0.023-0.148)	6.24 (1.42-20.9)
	Blubber	0.022 (0.01-0.046)	0.055 (0.012-0.397)	0.017 (0.006-0.048)

Table 5.33.
Amount by which concentrations of Hg and Cd measured in tissues and organs of seal species harvested in the Russian Arctic exceed guidelines for consumption of meat, liver, and kidney products.

Seal species	Tissue, organ	Hg		Cd	
		Guideline (mg/kg)	Amount by which measured levels exceed guidelines (factor)	Guideline (mg/kg)	Amount by which measured levels exceed guidelines (factor)
Ringed seal	Muscle	0.03	16	0.05	-
	Liver	0.1	24.9	0.3	12.7
	Kidney	0.2	11.3	1.0	15.8
Bearded seal	Muscle	0.03	41.7	0.05	-
	Liver	0.1	92.5	0.3	7
	Kidney	0.2	18.5	1.0	5.8
Larga seal	Muscle	0.03	37	0.05	-
	Liver	0.1	56.4	0.3	5.7
	Kidney	0.2	13.9	1.0	6.2

Sex, number of samples	Organ or tissue	ΣPCB15	HCB	ΣHCH	ΣCHLOR
Males (n = 11)	Muscle	1.3 (0.5-2.9)	0.04 (<0.05-0.08)	0.88 (0.18-3.35)	0.16 (0.15-0.25)
	Liver	3.8 (1.9-7.1)	0.03 (<0.05-0.08)	3.78 (1.7-5.77)	0.26 (0.15-0.41)
	Kidney	1.6 (1.1-3.6)	0.07 (<0.05-0.27)	1.81 (1.23-3.37)	0.22 (0.15-0.47)
	Blubber	84.4 (46-135)	0.25 (<0.05-1.9)	82.4 (38.6-196.9)	5.23 (2.4-12.1)
Females (n = 11)	Muscle	0.95 (0.4-3.4)	0.06 (<0.05-0.09)	0.85 (0.3-3.89)	0.18 (0.15-0.28)
	Liver	3.2 (1.8-7.2)	0.04 (<0.05-0.29)	2.15 (0.98-5.13)	0.24 (0.15-0.34)
	Kidney	1.6 (1.0-2.4)	0.05 (<0.05-0.12)	1.34 (0.54-2.1)	0.19 (0.18-0.21)
	Blubber	66.8 (34-116)	0.12 (<0.05-0.77)	106.9 (40.3-262)	5.59 (2.9-11.8)

Table 5.34a. Concentrations (geometric mean and range; ng/g ww) of OCs in tissues and organs of male and female walrus in the Russian Arctic in 2002.

Sex, number of samples	Organ or tissue	*p,p'*-DDE	*p,p'*-DDT	ΣDDT
Males (n = 11)	Muscle	0.046 (<0.05-0.14)	0.047 (<0.05-0.13)	0.24 (0.15-0.46)
	Liver	0.079 (<0.05-0.25)	0.11 (<0.05-0.39)	0.51 (0.27-0.79)
	Kidney	0.059 (<0.05-0.19)	0.11 (<0.05-1.06)	0.33 (0.18-1.71)
	Blubber	5.64 (1.41-37.9)	2.0 (0.39-4.91)	11.97 (4.33-50.94)
Females (n = 11)	Muscle	0.055 (<0.05-0.11)	0.045 (<0.05-0.19)	0.24 (0.18-0.39)
	Liver	0.07 (<0.05-0.11)	0.07 (<0.05-0.21)	0.39 (0.21-0.60)
	Kidney	0.043 (<0.05-0.09)	0.13 (0.06-0.23)	0.34 (0.24-0.47)
	Blubber	3.32 (1.24-18.9)	2.05 (0.71-6.8)	9.82 (4.22-38.11)

Table 5.34b. Concentrations (geometric mean and range; ng/g ww) of OCs in tissues and organs of male and female walrus in the Russian Arctic in 2002.

ney, followed by liver. Concentrations of Cd in muscle tissue in seal species were below guideline levels.

The ranges of all HM concentrations in muscle, liver and kidney of seals were consistent with concentrations determined in 1998-2001 in ringed seal in the Canadian Arctic (CACAR, 2003). However, HM concentrations in ringed seal from Canada are somewhat lower than those determined in ringed seal in the Russian Arctic, this despite the fact that the were reported on the dry weight basis. HM concentrations in ringed seal muscle in the Russian Arctic fall almost in the middle of concentration ranges determined in Canada in 1987-1994 (CACAR, 1997; see Figure 5.27).

5.5.2.2. Walrus

Walrus (*Odobenus rosmarus*) are long-lived benthic feeders and, as such, are an important indicator species for the bioaccumulation of contaminants in benthic marine food webs. Although they have an important role in the traditional hunts and diets of indigenous peoples, relatively little is known about contaminant levels in walrus. Some individuals, however, are known to feed at higher trophic levels and include ringed seal in their diet, and as a result have much higher contaminant concentrations in their tissues (AMAP, 1998; CACAR, 2003). Walrus tissues and organs, including 22 samples each of liver, kidney, muscle, and blubber, were collected in the summer and fall of 2002 from coastal communities of the Chukotka Peninsula.

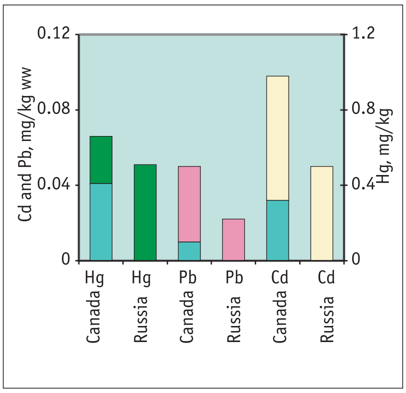


Figure 5.27. Comparison of mean HM concentrations in ringed seal muscle in the Canadian Arctic (1987-1994) and Russia (2000-2002). The lower part of each column corresponds to the minimum mean concentration, and the total column height, to the maximum mean concentration.

PTS concentrations relationship to walrus sex, age and tissue type

The age distribution of male walrus sampled was as follows: 3 individuals aged 1.5 years, 2 individuals aged 3.5 years, 2 individuals aged 4.5 years, and 4 individuals aged 5.5 years. Female walrus sampled showed greater variability in age distribution and were represented by 1 walrus aged 0.5 years, 4 individuals aged 2.5 years, 3 individuals aged 3.5 years, and 1 individual each of 4.5, 5.5 and 6.5 years.

As the mean age difference between male and female walrus was relatively small (3.8 years vs 3.4 years, respectively), average PTS levels in walrus tissues and organs were calculated without distinguishing between age groups. Tables 5.34a, 5.34b show OC concentrations as measured in different organs and tissues of male and female animals.

Sex, number of samples	Organ or tissue	Hg	Pb	Cd
Males (n = 11)	Muscle	0.046 (0.028-0.072)	0.043 (0.03-0.117)	0.014 (0.005-0.03)
	Liver	1.73 (0.58-3.56)	0.059 (0.034-0.133)	2.16 (0.634-6.962)
	Kidney	0.29 (0.18-0.48)	0.049 (0.017-0.104)	13.71 (2.55-27.13)
	Blubber	0.01 (0.006-0.018)	0.049 (0.022-0.154)	0.010 (0.005-0.025)
Females (n = 11)	Muscle	0.038 (0.012-0.057)	0.050 (0.028-0.114)	0.019 (0.006-0.05)
	Liver	1.59 (0.29-4.01)	0.059 (0.031-0.134)	2.72 (0.40-6.231)
	Kidney	0.26 (0.14-0.40)	0.050 (0.028-0.138)	14.46 (2.51-29.4)
	Blubber	0.011 (0.006-0.022)	0.057 (0.022-0.472)	0.010 (0.006-0.026)

Table 5.35. Concentrations (geometric mean and range; µg/g wet weight) of HMs in tissues and organs of male and female walrus in the Russian Arctic in 2002.

Table 5.36a.
Concentrations (geometric mean and range; ng/g ww) of OCs in tissues and organs of walrus in the Russian Arctic in 2002.

Organ or tissue	ΣPCB_{15}	HCB	ΣHCH	ΣCHLOR
Muscle	1.1 (0.4-3.4)	0.05 (<0.05-0.09)	0.86 (0.18-3.89)	0.17 (0.15-0.28)
Liver	3.5 (1.8-7.2)	0.04 (<0.05-0.29)	2.85 (0.98-5.77)	0.25 (0.15-0.41)
Kidney	1.6 (1.1-3.6)	0.06 (<0.05-0.27)	1.56 (0.54-3.37)	0.21 (0.15-0.47)
Blubber	75.1 (34-135)	0.17 (<0.05-1.9)	93.9 (38.6-262)	5.4 (2.4-12.1)

Table 5.36b.
Concentrations (geometric mean and range; ng/g ww) of OCs in tissues and organs of walrus in the Russian Arctic in 2002.

Organ or tissue	*p,p'*-DDE	*p,p'*-DDT	ΣDDT
Muscle	0.050 (<0.05-0.14)	0.046 (<0.05-0.19)	0.24 (0.15-0.46)
Liver	0.074 (<0.05-0.25)	0.09 (<0.05-0.39)	0.45 (0.21-0.79)
Kidney	0.050 (<0.05-0.19)	0.12 (<0.05-1.06)	0.33 (0.18-1.71)
Blubber	4.33 (1.24-37.9)	2.03 (0.39-6.8)	10.85 (4.22-50.94)

Table 5.37.
Concentrations (geometric mean and range; µg/g wet weight) of HMs in tissues and organs of walrus in the Russian Arctic in 2002.

Organ or tissue	Hg	Pb	Cd
Muscle	0.042 (0.012-0.072)	0.046 (0.028-0.117)	0.017 (0.005-0.05)
Liver	1.66 (0.29-4.01)	0.059 (0.031-0.134)	2.43 (0.40-6.962)
Kidney	0.27 (0.14-0.48)	0.050 (0.017-0.138)	14.08 (2.51-29.4)
Blubber	0.011 (0.006-0.022)	0.053 (0.022-0.472)	0.010 (0.005-0.026)

The distribution of HM concentrations in walrus tissues and organs for each sex is shown in Table 5.35. Levels of Hg in the muscle, liver, and kidney of male walrus were slightly higher than in females, but concentrations of Pb and Cd in females, in contrast to Hg, exceeded those in males.

Levels and trends

(a) Organochlorines

For the pooled data set, geometric means were calculated including all ages and both sexes of walrus (Tables 5.36a and 5.36b). No statistically significant differences were found between concentrations of HCB, chlordane-related compounds, or ΣDDT in the muscle, liver and kidney of walrus; however, ΣPCB_{15} concentrations in blubber were approximately 68, 47, and 21 times higher when compared to the muscle, kidney and liver, respectively. Concentrations of ΣHCH in the muscle, kidney, liver, and blubber of walrus were found in the ratio of 1 : 1.8 : 3.3 : 109; levels of ΣCHLOR in these organs and tissues occurred in the ratio of 1 : 1.2 : 1.5 : 32; and ΣDDT levels in muscle, kidney, liver, and blubber were found in the ratio of 1 : 1.4 : 1.9 : 45.

Concentrations of HCH and DDT measured in muscle tissue and the blubber of walrus were compared with existing Russian guidelines for HCH and DDT compounds, in both the meat of marine mammals (including walrus), and in animal fat. The levels of HCH and DDT measured in walrus muscle were found to be, respectively, 12 and 35 times, lower than the corresponding guidelines values (of 10 and 30 ng/g ww). The levels of summed HCH isomers in the blubber of walrus, measured at 93.9 ng/g ww and were approximately 2.1 times lower than the guideline value of 200 ng/g ww.

(b) Heavy metals

Concentrations of heavy metals in walrus organs and tissues are shown in Table 5.37. Levels of Hg were highest in the liver, 42-fold greater than those in muscle, and 6-fold greater than those in kidney. Concentrations of Cd were highest in kidney and exceeded those in muscles by a factor of nearly 700, and those in liver by a factor of approximately 6.

Concentrations of Cd in the liver and kidney of walrus were 8- and 14-times higher, respectively, than the human consumption guideline values for Cd in internal organs, established in the Russian Federation. Levels of Hg in muscle, liver, and kidney of walrus were, respectively, 1.4-, 16.6- and 1.3-times higher than the associated human consumption guidelines values. Although high, these levels of exceedance of guideline values are less than those noted for seal species.

5.5.2.3. Grey whale

Grey whales (*Eschrichtius gibbosus*), taken from the Bering Sea by indigenous hunters of the coastal communities of Chukotka were sampled. The sampled whales included 2 females, with a mean age of 3 years, 3 females with the mean age of 7.3 years, and 2 males with a mean age of 6.5 years.

PTS concentration relationships to whale sex, age and tissue type

Most OCs, except for HCH, were found in lower concentrations in female whales than in males, possibly due to the elimination of these lipophilic compounds during lactation. No significant trend in OC concentration levels with age was found in male grey whale, but a substantial decrease in OC concentration in females occurred after six years of age, which corresponds to the age at which first parturition takes place. For example, the average concentration of PCB congeners in the blubber of grey whale females of 3 years was 135 ng/g ww, whilst in female of 7.3 years, ΣPCBs averaged 87.5 ng/g ww (Table 5.38). The levels of the main OCs in the liver, kidney and blubber of females aged 3 years, exceeded those in females aged 7.3 years 1.4- to 1.8-fold. This is consistent with the influence of parturition and lactation, which are associated with the elimination of contaminants from maternal whales. An

Tissue, organ	Sex, mean age (years), and number of samples	ΣPCB$_{15}$	HCB	Toxaphene	ΣHCH	ΣDDT	ΣCHLOR
Liver	Female, 3 (n = 2)	4.64 3.85-5.59	1.12 0.79-1.58	1.17 0.64-2.13	5.73 6.62-5.84	3.11 2.44-3.96	1.94 1.57-2.39
	Female, 7.3 (n = 3)	2.58 1.59-3.47	0.35 0.33-0.39	0.63 0.49-0.76	3.27 2.48-4.54	1.50 0.79-2.94	0.98 0.68-1.44
	Male, 6.5 (n = 2)	2.78 2.35-3.28	0.57	2.65 2.48-2.83	5.23 5.12-5.41	1.82 1.78-1.86	1.08 0.99-1.19
Muscle	Female, 3 (n = 2)	3.04 2.06-4.49	0.19 0.18-0.21	0.37 0.27-0.50	1.83 1.62-2.06	2.03 1.52-2.72	1.18 1.01-1.38
	Female, 7.3 (n = 3)	2.17 0.69-16.58	0.30 0.06-3.10	0.21 0.14-0.30	1.42 0.46-13.53	3.69 0.71-20.11	1.77 0.38-6.77
	Male, 6.5 (n = 2)	1.13 0.65-1.98	0.09 0.07-0.11	0.53 0.47-0.60	0.71 0.42-1.19	0.80 0.41-1.56	0.55 0.33-0.93
Kidney	Female, 3 (n = 2)	1.69 1.59-1.80	0.58 0.44-0.76	0.26 0.16-0.44	2.03 1.81-2.27	0.96 0.88-1.05	0.62 0.59-0.65
	Female, 7.3 (n=3)	1.08 0.86-1.27	0.51 0.33-0.67	0.22 0.20-0.25	0.86 0.54-1.68	0.59 0.40-0.84	0.36 0.30-0.47
	Male, 6.5 (n=2)	1.19 0.99-1.43	0.81 0.71-0.93	0.47 0.44-0.51	1.56 1.52-1.60	0.48 0.41-0.56	0.29 0.27-0.31
Blubber	Female, 3 (n = 2)	135.1 113.3-161.2	105.8 79.9-140.0	37.1 21.8-63.0	149.7 124.1-180.7	91.1 76.0-109.3	50.8 42.8-60.2
	Female, 7.3 (n = 3)	87.5 36.4-194.6	40.7 26.9-62.8	24.0 19.2-39.1	65.2 36.4-93.0	46.6 18.6-109.2	24.8 12.2-45.6
	Male, 6.5 (n = 2)	231.9 223.3-240.9	164.2 142.0-190.0	63.3 56.0-71.6	145.4 126.8-166.7	150.1 146.7-153.5	71.4 70.1-72.7

Table 5.38. Concentrations (geometric mean and range; ng/g ww) of OCs in tissues and organs of grey whale in the Russian Arctic, by age and sex.

exception to this is seen in muscle tissue, in which levels of DDT, HCB, and chlordane-related compounds were higher in females of over 7 years than in females of 3 years. It is important to note however, that the statistical significance of most age-related differences in concentrations of PTS from the limited dataset available is rather low.

As can be seen from Table 5.39, Hg levels varied according to age and sex, with higher levels observed in males, followed by females of 7.3 years, and lowest levels in females of 3 years of age. Concentrations of Pb and Cd did not follow the same pattern; for Pb, the highest levels were found in older females, followed by males, with lowest levels in females of 3 years of age.

Levels and trends

(a) Organochlorines

For the pooled data set, which included all ages and both sexes, geometric means were calculated for PTS concentrations in grey whale. From Table 5.40 it can be seen that the highest concentrations of all OCs tested were found in the whale blubber. For the other organs and tissues, levels of ΣPCB$_{15}$, toxaphene, ΣHCH, ΣDDT, and ΣCHLOR were highest in liver, although higher in kidney than in liver in the case of HCB.

Tissue, organ	Sex, mean age (years), and number of samples	Hg	Pb	Cd
Muscle	Female, 3 (n = 2)	0.015 0.012-0.019	0.039 0.028-0.056	<0.005
	Female, 7.3 (n = 3)	0.065 0.044-0.089	0.075 0.071 –0.083	0.009 0.006-0.012
	Male, 6.5 (n = 2)	0.070 0.051-0.096	0.042 0.037-0.047	<0.005-0.005[a]
Liver	Female, 3 (n = 2)	0.041 0.026-0.066	0.046 0.038-0.057	0.363 0.352-0.375
	Female, 7.3 (n = 3)	0.158 0.118 –0.197	0.102 0.054-0.225	1.320 0.834-1.748
	Male, 6.5 (n = 2)	0.179 0.12-0.268	0.060 0.05-0.072	0.742 0.666-0.828
Kidney	Female, 3 (n = 2)	0.026 0.02-0.033	0.034 0.031-0.038	0.545 0.455-0.652
	Female, 7.3 (n = 3)	0.085 0.067-0.102	0.039 0.034-0.042	3.268 2.707-4.692
	Male, 6.5 (n = 2)	0.101 0.08-0.128	0.039 0.036-0.042	2.752 2.7-2.805
Blubber	Female, 3 (n = 2)	0.012 0.011-0.013	0.029 0.027-0.032	0.008 0.007-0.009
	Female, 7.3 (n = 3)	0.015 0.015-0.016	0.058 0.054-0.066	0.012 0.011-0.012
	Male, 6.5 (n = 2)	0.017 0.014-0.021	0.043 0.038-0.049	0.011 0.01-0.012

Table 5.39. Concentrations (geometric mean and range; µg/g ww) of HMs in tissues and organs of grey whale in the Russian Arctic, by age and sex.
[a] Range given, as one of the sampled whales had concentrations below the detection limit.

Tissue, organ	ΣPCB$_{15}$	HCB	Toxaphene	ΣHCH	ΣDDT	ΣCHLOR
Liver	3.12 1.59-5.59	0.56 0.33-1.58	1.13 0.49 –2.83	4.38 2.45-5.84	1.95 0.79-3.96	1.23 0.69-2.39
Muscle	1.98 0.65-16.58	0.19 0.06-3.1	0.32 0.14-0.6	1.18 0.37-13.63	2.01 0.41-20.11	1.13 0.33-6.75
Kidney	1.25 0.86-1.8	0.60 0.33-0.93	0.29 0.16-0.51	1.30 0.54-2.27	0.64 0.4-1.05	0.39 0.27-0.65
Blubber	130.9 36.37-240.9	79.65 26.9-190.0	36.66 17.69-71.58	104.0 36.36-180.67	78.16 18.6-153.55	41.43 12.22-73.16

Table 5.40. Concentrations (geometric mean and range; ng/g ww) of OCs in tissues and organs of grey whale in the Russian Arctic.

Tissue, organ	Hg	Pb	Cd
Muscle	0.044 0.012-0.096	0.053 0.028-0.083	<0.005- 0.012[a]
Liver	0.112 0.026-0.268	0.070 0.038-0.225	0.775 0.352-1.748
Kidney	0.065 0.02-0.128	0.035 0.027-0.042	1.865 0.455-4.692
Blubber	0.015 0.011-0.021	0.044 0.027-0.066	0.010 0.007-0.012

Table 5.41 Concentrations (geometric mean and range; µg/g ww) of HMs in tissues and organs of grey whale in the Russian Arctic.
a Range given as more than a half of concentrations were below the detection limit in at least one of the samples contributing to the mean.

Mammal	pg TEQ-WHO/g w.w.	pg TEQ-WHO/g lipids	pg TEQ-WHO/pg*
	Muscle		
Ringed seal	0.10	1.9	0.10
Bearded seal	0.10	4.4	0.10
Larga seal	0.19	4.4	0.10
Grey whale	0.11	15.9	0.13
	Blubber		
Ringed seal	1.10	1.11	0.11
Bearded seal	0.97	1.12	0.065
Larga seal	1.25	1.51	0.15
Grey whale	0.74	1.74	0.068

Table 5.42. Concentrations (expressed as TEQ) of PCDD/Fs in marine mammals harvested in the Russian Arctic in 2000-2002.
* – ratio of PCDD/F concentration in pg WHO-TEQ/g to that in pg/g

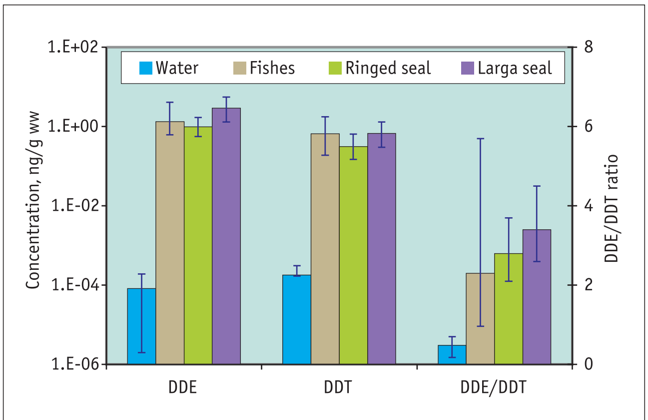


Figure 5.28. Absolute and relative levels of p,p'-DDE and p,p'-DDT in the marine food chain in the Lavrentiya Bay. Geometric means and ranges are shown for DDE and DDT concentrations in muscle tissue, water concentrations are in g/L. Ratios are shown with 95% confidence limits.

The observed concentrations of HCH and DDT in the organs and tissues of grey whale were below the human consumption guidelines values established in Russia for these contaminants. For example, levels of ΣHCH in muscle and blubber were approximately a factor of 8.5 and 2, respectively, lower than the corresponding guideline values (10 ng/g ww for meat, and 200 ng/g ww for animal fat). Observed concentrations of ΣDDT in muscle were two orders of magnitude lower than the guideline value (200 ng/g ww) for human consumption of meat of marine mammals.

(b) Heavy metals

Concentrations of HMs in grey whale are presented in Table 5.41. Levels of Hg and Pb in the liver of grey whale were high compared to concentrations of these metals in other organs and tissues. Hg concentrations in blubber, muscle, kidney, and liver were measured in the ratio 1 : 2.9 : 4.3 : 7.5, while levels of Pb in kidney, blubber, muscle, and liver were found in the ratio of 1 : 1.2 : 1.5 : 2.0.

Concentrations of Hg measured in muscle tissue of grey whale exceeded the human consumption guideline values for Hg in meat by almost 1.5 times. Cd levels in liver were 2.5-fold the guideline value for Cd in internal organs (0.3 µg/g ww), and Cd concentrations in kidney exceeded the associated guideline value (1.0 µg/g ww) by almost 1.9 times.

5.5.3. PCDDs/Fs in marine mammals

Concentrations of 2,3,7,8-substituted PCDDs/Fs were analyzed in samples of marine mammals collected from the coastal survey site off the Chukotka Peninsula. Results are presented in Table 5.42.

PCDDs/Fs levels in the blubber of marine mammals from the Bering Sea measured in 2001 (0.6-1.0 pg I-TEQ/g) were an order of magnitude lower than levels in ringed seals from the Barents Sea in measured in 1987 (6-26 pg I-TEQ/g; AMAP, 1998). This difference is, however, consistent with spatial trends observed for other non-mammalian marine species, presented above.

5.5.4. PTS transfer in the marine food chain

(a) Organochlorines

Levels of *p,p'*-DDT and *p,p'*-DDE, and the DDE/DDT ratio in the water-fish-seal food chain are shown in Figure 5.28. The water-to-fish transfer factors for *p,p'*-DDT and *p,p'*-DDE in the marine food chain are significantly higher than those calculated for the freshwater environment in the Russian Arctic (14000 and 2500 mL/g ww of muscle, respectively). These results may be explained by the lower DOM concentration in sea water, normally, an order of magnitude lower than in freshwater. However, TFWF values for other OCs are similar, around 1000 mL/g ww in both freshwater and marine systems. The high TFWF value for DDE is possibly a result of accelerated transformation from DDT to DDE in marine fish or invertebrates.

Concentrations of OCs found in fish and seals muscles are comparable, which is consistent with the similar lipid content in their muscles. Slightly higher contamination levels occur in larger seals, and slightly lower contamination in ringed seals, compared with other species, however, all differences are of fairly low statistical significance. Similar patterns between species and values for the fish-to-seal transfer coefficient are observed for other OCs and marine mammals. The geometric mean of the fish-to-seal transfer coefficient, calculated using data on all OCs found at detectable levels is equal to 0.5 for ringed seals and 1.4 for larga seals. DDE/DDT ratios in fish and seals are also comparable and are several times higher than the ratio in water. Comparison of OC levels with corresponding lipid concentrations, indicates that OC distribution in the marine environment, as for the terrestrial and freshwater environment, is close to being in a state of equilibrium. However, the difference is clearly seen while comparing OCs in fish and blubber of marine mammals, which is consistent with high lipid difference.

(b) Heavy metals

HM water-to-fish transfer factors (i.e., the ratios of the geometric mean of concentrations) for chum salmon and Arctic char are similar in value. The geometric means of the TFWFs of both species equal 9400, 340 and 2900 mL/g ww for Hg, Pb and Cd, respectively. These are somewhat higher than transfer factors calculated for the freshwater environment, the probable reason being that anadromous fish species absorb HMs from both fresh and sea waters, and that HM levels are normally lower in seawater than in freshwater. HM concentrations in marine fish species (flounder and smelt) are comparable with those in seals and walrus (i.e., TF values are close to unity). The single exception to this is seen for Hg concentrations in seals, which are 7-18 times higher than those in fish.

5.6. Conclusions

Levels

- Concentrations of PCDD/Fs in reindeer muscle from the Kola Peninsula, exceed maximum permissible levels in meat by approximately 10%. Concentrations of ΣHCH and ΣDDT in all tissues of the mammals, birds and fish sampled in the Russian Arctic are far below the corresponding maximum permissible concentrations established by the Russian Ministry of Health. Only in some marine mammal species are concentrations of OC's found to be close to these permissible levels, in some samples.
- Concentrations of PCDD/Fs in muscle tissue are highest in reindeer and lowest in terrestrial birds, however the range is not large and well within an order of magnitude. Other OCs occur in comparable concentrations in marine mammals, salmon species, and waterfowl. In terrestrial mammals and birds, concentrations are, as a rule, several times lower than in other species and are generally highest in reindeer.
- At all sites, Pb concentration in reindeer tissues are at least several times lower than the corresponding maximum permissible concentrations. Cd and Hg levels for all tissues and sites, with the exception of Hg in Chukotka, are either close to the corresponding maximum permissible concentrations or slightly exceed them. The greatest difference between measured and guideline levels is seen in the Pechora basin, where Cd concentration in reindeer kidney are 2.5 times higher than the permissible level. Levels of Pb and Hg in muscle tissue of hares and terrestrial birds are significantly below the corresponding maximum permissible concentrations, while the Cd level in birds is close to, or slightly higher than the maximum permissible concentration.
- Concentrations of Pb and Cd in waterfowl are normally below permissible levels and only in few samples attain a maximum level that exceeds the permissible level by a factor of up to two. Concentrations of Hg in molluscivorous, omnivorous, and piscivorous birds are consistently close to the permissible level, and in most samples actually exceed it, by a maximum of up to 4 times. All concentrations in fish muscle are below the corresponding maximum permissible concentrations established in Russia for fish, with only one exception; this being Hg in whitefish from the Khatanga River, for which concentrations are 1.5 times the permissible level.
- All Hg and most Cd concentrations in seals are significantly higher than the corresponding maximum permissible concentrations. The greatest difference between measured and guideline values is for Hg concentrations in seal muscle, which exceed permissible concentrations by as much as 100 times. All Pb concentrations measured in muscle, liver, and kidney of seals occur at levels below the corresponding maximum permissible concentrations.
- The level of contamination in male animals is normally slightly higher than that measured in females, but in most cases the difference is not statistically significant. The single exception found was for Pb in browsers, where concentrations in male browsers are consistently twice as high as those in females at all 6 sites.
- Concentrations of both OCs and HMs are, as a rule, higher in older animals. However, the greatest differences observed in this study between older and younger age groups is within a factor of two. This was particularly the case for fish species, where the range in the age groups was relatively small. The most pronounced concentration relationship to age was observed for HMs in reindeer. For the first few years of life, this relationship is close to being directly proportional, with the rate of HM elimination calculated as being around 10 years for all 3 metals studied.
- Contamination levels in the liver and kidney are normally higher than those in muscle, especially for HMs. The liver/muscle concentration ratio for Hg in reindeer, and for OCs in burbot, and also the kidney/muscle ratio for Cd in marine mammals can be up to between two and three orders of magnitude. The highest OC concentrations found in this study occur in the liver of burbot, fished from the Yenisey River (580 ng/g ww of ΣPCB_{15}, 470 ng/g ww of ΣDDT, and 39 ng/g ww of ΣCHLOR).
- Levels of brominated flame-retardants are below the detection limit of 0.2 ng/g ww in all samples of soil, vegetation, terrestrial mammals, and birds. However, in a few samples of fish and seal liver, as well as in seal blubber, 2,2',4,4'-tetrabromodipheny ether was found in concentrations ranging from 0.2 to 1.9 ng/g ww.

Trends

- PCDD/F levels in the tissues of reindeer and hare from the Kola Peninsula are an order of magnitude higher than those found at other sites. Concentrations of PCDD/Fs in birds and fish follow similar, but less pronounced, trends.
- No significant spatial trend in concentrations of OCs, other than for PCDD/Fs in terrestrial mammals, birds, and fish, was identified in the Russian Arctic in 2001. Only OC concentrations found in molluscivorous birds show a distinct maximum in eastern Taymir.
- OC levels measured in reindeer are in reasonably good agreement with levels previously reported for Russian, Canadian, and Norwegian Arctic areas. This is consistent with the finding that levels of lichen contamination in Arctic Canada and Russia are comparable.
- OC levels in fish in the Russian Arctic, are at the lower end of corresponding concentration ranges for OCs in fish in the Canadian Arctic, and are similar to those measured at three locations in Norway in 1994.
- As seen for OC concentrations in fish, OC levels in the blubber of seals in the Russian Arctic are found to be close to the lower end of concentration ranges obtained for seals in the Canadian Arctic in 1998-2001.
- Fish muscle from the Grate Slave Lake in northern Canada in 1994/5, contained PCDD/Fs at levels an order of magnitude higher than those determined in samples from Russia in this study. In contrast, PCDD/Fs levels measured in the muscle of freshwater fish at four Scandinavian Arctic sites are close to those found in the Russian North in 2001.
- Concentrations of HMs in terrestrial mammals and birds are lowest in inland Chukotka and in eastern Taymir. However, differences between these and the other studied locations in northern Russia are within a factor of 3.
- Levels of HMs in fish and waterfowl do not follow a pronounced spatial trend.
- Levels of HMs in reindeer tissues determined in recent studies in the Canadian Arctic are, as a rule, somewhat higher than those measured in the Russian Arctic.
- Concentrations of Hg in whitefish species in the Russian Arctic in 2001 are close to those found in the Canadian Arctic in 1996-2000, and in northern Norway in 1995.
- HM concentrations in the muscle, liver, and kidney of seals in the Russian Arctic in 2001 generally occur within ranges similar to those found in ringed seal in the Canadian Arctic in 1998-2001.
- No significant temporal trend in contamination levels in any of the sampled biological species, for either OCs or HMs, is evident when the results of this study are compared with those of previous studies. However, the consistent level of concentrations, and, at some sites, significantly higher concentrations of HCH and Hg in mosses and lichen in 2001, indicates that it is possible that some increase in depositions of these contaminants has taken place in the Russian North during the past few years.

Biomagnification

- OC concentration distribution patterns in both terrestrial and aquatic food chains in the Russian Arctic are similar to those of lipids. This indicates that OCs in Arctic ecosystems, are close to an equilibrium state distribution.
- Concentrations of OCs in lichens reflect those in mosses, with lichen/mosses concentration ratio for OCs close to unity. Concentration of OCs in lichen can therefore provide a direct estimate of the concentration in mosses at a given site, and vice versa.
- The OC lichen-to-reindeer transfer factor obtained in this study is equal to 0.3 (ww muscle to dw lichen) and is consistent with factors previously determined in the Canadian Arctic.
- The OC water-to-fish transfer factors (TFWFs) obtained in this study are in a reasonably good agreement with those predicted using octanol-water partition coefficients.
- Values of Hg and Cd water-to-fish transfer factors are similar for both freshwater and marine fish groups, while the transfer factor for Pb is several times higher for freshwater species. Geometric means of Hg and Cd TFWFs, calculated using pooled sets of data, are 3300 and 570 mL/g ww, respectively. The geometric mean of Pb TFWFs is 280 mL/g ww for freshwater species, and 60 mL/g ww for marine species. Transfer factor values for Hg and Pb are in a good agreement with corresponding default values previously published by the IAEA.

Chapter 6

PTS contamination of indigenous residencies and domestic food

6.1. General overview

Results obtained from a survey targetting the residencies of selected indigenous families, reveal that the indoor environment, including home-processed, stored, and ready-to-eat foodstuffs, is widely contaminated by POPs (Tables 6.1 and 6.2). A high frequency of contaminated foodstuffs in the home environment seems to be consistent with the likelihood of residents showing increased blood concentrations of PCBs congeners and DDT metabolites. The occurrence of persistent organochlorines at detectable concentrations, in both local and imported foodstuffs sampled in indigenous communities, is much higher than that found in national averages obtained from nationwide food safety monitoring programmes (Table 6.3). 8.6% of local foodstuffs were contaminated by heptachlor at concentrations exceeding 0.10 μg/kg (Table 6.4), whilst according to national food safety standards, this toxicant should not be present in any foodstuff. Across the nation as a whole, only 0.1% to 0.4% of monitored foodstuffs contained pesticide residues at concentrations exceeding food safety limits.

DDT and HCH appear to be the pesticides most frequently detected in food consumed by indigenous families. At present, however, their concentrations are generally below guideline levels provided by food safety limits (Tables 6.5–6.8). For native communities of the lower Pechora river basin, the highest PCB concentrations were measured in local freshwater fish and duck fat, whereas on the Taymir Peninsula, the highest concentrations were found in smoked fish and reindeer meat.

A comparison of POPs concentrations in local foods samples from indigenous residencies, with those measured in fish species and reindeer meat sampled in the natural environment, clearly indicates that both the occurrence and level of contamination may well be increased as a result of home storage, processing, and preparation of foodstuffs. Hence, the mean concentration of the sum of PCBs measured in samples of reindeer meat after a period of indoor storage, was three times higher than that measured in fresh reindeer muscle sampled in the natural environment. For the sum of DDTs, there was a 1.6-fold increase in concentrations in samples of reindeer meat that had been stored and processed in the home compared to the fresh environmental samples.

Sample type	PCB contamination	DDT contamination	HCH contamination
Indoor wash-outs	100.0	100.0	100.0
Local foods:			
Meat	93.3	80.0	26.7
Fish	100.0	62.5	50.0
Berries	100.0	100.0	0
Imported foodstuffs	80.0	60.0	0
Human blood:			
Mother	100.0	100.0	100.0
Children	100.0	100.0	57.1
Other family members	100.0	100.0	92.8

Table 6.1. Pechora River Basin household survey. Percentage of specimens contaminated by selected POPs at detectable levels.

Sample type	PCB contamination	DDT contamination	HCH contamination
Indoor wash-outs	100.0	100.0	83.3
Local foods:			
Meat	100.0	66.7	16.7
Fish	60.0	100.0	100.0
Berries			
Imported foodstuffs	100.0	100.0	0
Human blood:			
Mother	100.0	100.0	100.0
Children	100.0	100.0	100.0
Other family members	100.0	100.0	90.0

Table 6.2. Taymir Peninsula household survey. Percentage of specimens contaminated by selected POPs at detectable levels.

Study area	Number of samples analyzed	Foodstuffs contaminated by Heptachlor		Heptachlor, concentration range
		n	%	μg/kg
Chukotka	26	3 (2 of whale meat[1]; 1 of mantak[2])	11.5	0.10 - 0.17
Taymir	18	2 (fish[2] and sunflower oil)	11.1	0.12 - 0.48
Pechora River Basin	26	1 (fish[2])	3.8	0.29
Total	70	6	8.6 (average)	0.10 - 0.48

Table 6.4. Heptachlor occurrence in local and imported foods at detectable levels.
[1] Cooked by boiling for 2hrs.
[2] Prepared for cooking (trimmed and sliced in the kitchen).

Monitored foodstuffs	Percentage of foodstuffs measured having detectable amount of organochlorine pesticides			Percentage of foodstuffs measured having organochlorine pesticides at levels exceeding national limits		
	2000	2001	2002	2000	2001	2002
Vegetables	6.0	6.0	7.2	0.2	0.2	0.4
Fruits and berries	7.2	7.5	11.6	0.6	0.5	0.4
Dairy and milk products	5.7	4.8	5.6	0.4	0.3	0.2
Meat and poultry	9.0	6.0	9.9	0.3	0.1	0.1
Processed sea and freshwater fish	15.7	10.9	16.1	0.4	0.5	0.2
Fresh frozen fish	10.3	5.0	16.3	0.3	0	0.2

Table 6.3. Pesticide monitoring of market food in Russia. Results for 2000-2002.*
* Data courtesy of the Federal Center for Sanitary and Epidemiological Surveillance. Russian Ministry of Health (unpublished data).

Foods	n	ΣPCB	*p,p'*-DDT	*p,p'*-DDE	ΣDDT	ΣHCH	HCB
Local foodstuffs:							
Reindeer meat [1]	3	0.49	0	0	0	0.049	
Reindeer liver [1]	2	1.19	0.14	0.12	0.27	0.61	
Reindeer fat	1	2.24	1.52	0.68	2.2	0	
Duck fat [1]	1	56.4	15.1	87.8	107.2	0	
Frozen fresh fish [1]	1	0.58	0.05	0.10	0.322	0	0.46
Salted fish [2]	5	1.95	0.18	0.56	1.23	0	0.90
Imported foodstuffs:							
Cooking oil	3	1.66	0.3	0	0.3	0	
Millet	1	0.28	0	0.06	0.06	0	
Dried milk powder	1	0	0	0	0.06	0	
Beef [1]	1	0.69	0.253	0.067	0.449	0.054	
National limit values					100 (fish and sea products)	200	10 (cereals)

Table 6.5. Concentrations of POPs (μg/kg wet wt) in foodstuffs sampled in the region of the lower Pechora River Basin.
[1] prepared for cooking (trimmed and sliced in the kitchen);
[2] ready-to-eat food.

Foods	n	ΣPCB	*p,p'*-DDT	*p,p'*-DDE	ΣDDT	ΣHCH
Local foodstuffs:						
Reindeer meet	3	1.27	0	0	0	0.75
Reindeer liver	2	33	1.95	3.2	7.56	16.53
Reindeer fat	1	2.45	0	0.67	0.67	0
Duck fat	1	54.0	15.7	91.7	112	0
Salted and fresh fish	6	124.76	6.41	25.88	54.1	0
Imported foodstuffs:						
Oil	3	1.67	0.3	0	0.3	0
Millet	1	0.28	0.06	0	0.06	0
Dried milk	1	0	0	0	0.06	0
Beef	1	92.8	34.2	9.05	60.7	7.3

Table 6.6. Concentrations of POPs (μg/kg lipid wt) in foodstuffs sampled in the region of the lower Pechora River Basin.

Foods	n	Σ PCB	p,p'-DDT	p,p'-DDE	Σ DDT	Σ HCH	HCB
Local foodstuffs:							
Reindeer meat [1] (fresh)	5	4.07	0.051	0.014	0.065	0	0
Reindeer meat [2] (dry-cured)	1	3.86	0	0	0	0	0
Freshwater fish [1]	2	1.61	0.14	0.415	0.654	0.279	0.22
Smoked freshwater fish [2]	1	7.58	1.05	1.46	3.14	1.38	1.57
Smoked herring [2]	1	0.96	1.63	0.51	2.5	0.108	5.03
Frozen fish mixture [2]	1	1.17	0.38	0.41	0.79	0.321	1.53
Imported foodstuffs:							
Wheat flour prepared for pastry	1	0.21	0	0.22	0.22	0	0
National limit values					100 (fish and sea products)	200	10 (cereals)

Table 6.7. Concentrations of POPs (μg/kg wet wt) in foodstuffs sampled on the Taymir Peninsula.
[1] prepared for cooking (trimmed and sliced in the kitchen); [2] ready-to-eat food.

Foods	n	Σ PCB	p,p'-DDT	p,p'-DDE	Σ DDT	Σ HCH
Local foods:						
Reindeer meat (fresh)	5	121.89	2.16	1.27	2.42	4.76
Reindeer meat (dry-cured)	1	92.0	0	0	0	0
Fish	2	70.2	0	14.98	16.88	3.88
Smoked freshwater salmon	1	0	15.71	108.0	171.0	102.0
Smoked herrings	1	0	63.5	16.5	91.6	3.48
Smoked freshwater fish	2	0	39.61	62.25	131.3	52.74
Sliced frozen fish	1	1.17	6.93	16.5	91.6	3.48
Imported food:						
Wheat flour prepared for pastry	1	0.21	0	0.22	0.22	0

Table 6.8. Concentrations of POPs (μg/kg lipid wt) in foodstuffs sampled on the Taymir Peninsula.

6.2. Effects of cooking on PTS food contamination

6.2.1. Boiling of meat

The contamination levels of POPs in local food can be significantly affected by the choice of cooking method. As seen from the data presented in Table 6.9, boiling meat for a period of at least 2 hours causes a significant reduction in both PCB and pesticide contamination of food. Concentrations of POPs in boiled food are 2.2 to 5 times lower than those measured in the uncooked meat of sea mammals. However, microbially-mediated fermentation in ground pits, and also fermentation by long-term immersion in salt water were found to increase POP concentrations in food.

6.2.2. Fermentation of marine mammal meat

Many native communities still do not benefit from high standards of environmental protection and often do not have access to good sanitation arrangements. Because of these circumstances and also due to economic reasons, home-fermentation of local produce is frequently undertaken in situations that may contribute to their contamination. Examples are the uncontrolled use of discarded plastic containers, which may have contained a range of chemical substances, as well as the use of ground pits which are not properly sealed from waste water drainage or may be sited in potentially contaminated soils.

Fermented walrus meat, known as 'kopalchen', was sampled during targeted surveys in the Chukotka region in 2003. It was found to have the highest level of PCB contamination of all ready-to-eat foodstuffs collected from the selected families (Table 6.10).

Food	State of food	Concentrations of selected POPs			
		ΣPCB	HCB	ΣHCH	ΣDDT
Bearded seal, meat	Fresh	9.42	0.24	0.55	4.0
	Boiled	1.89	0.25	0.25	0.91
Whale, mantak	Fresh	22.63	0.71	2.29	7.50
	Boiled	10.03	n.d	0.58	3.29
Walrus, meat	Fresh	3.1	0.20	0.17	0.30
	Fermented	623	0.16	0.73	7.76
Ringed seal, meat	Fresh	14.6	0.39	0.77	3.19
	Boiled	6.85	0.13	0.12	1.01
Arctic char	Fresh	9.79	0.12	1.00	0.99
	Marinated	3.83	0.13	n.d	0.80
	Dry salted	20.12	0.52	2.43	1.68

Table 6.9. Mean concentrations of POPs (μg/kg wet wt) in fresh (frozen) and cooked local foods.
n.d. - not determined (below the detection limit).

Contaminant	Fresh walrus	Walrus 'kopalchen'
	n=2	n=1
ΣPCB	2.9 - 3.2	623
ΣHCB	0.1 - 0.3	0.16
HCH	0.16 - 0.19	0.73
p,p'-DDE	0.17 - 0.23	6.71
p,p'-DD	0.13	0.09
ΣDDT	0.17 - 0.42	7.76

Table 6.10. Concentrations of POPs (μg/kg wet wt) in fresh walrus meat, and walrus meat fermented for 4 months by traditional methods in a ground pit ('kopalchen').

Kopalchen consists of the eviscerated unsalted flesh of walrus or other sea mammals and includes the skin and adjacent fat and meat tissue, which has been subjected to a period of natural microbial fermentation lasting up to several months, in a ground pit covered by soil. Generally, such pits are situated within residential areas, close to houses and are not properly protected from waste and drainage water incursion. Once dug, these pits are used on a long-term basis.

Ground pits or soil, where kopalchen fermentation takes place, appear to be heavily contaminated by PCBs (as indicated by a 200-fold increase in PCB concentration in kopalchen compared to fresh walrus meat) and also by DDT (20-fold increase in concentration).

6.2.3. Home-made alcoholic beverages

Among the indigenous communities of the western part of the Russian Arctic (for example the Kola Peninsula), where the social and economic status of indigenous people is relatively high, home-made alcohol is not widely consumed. In contrast, in regions such as the Chukotka Peninsula, where marketed alcoholic drinks are very costly, and therefore of limited availability to most indigenous people, moonshining and the making of alcoholic mash "braga"' is common, albeit illegal. Of the two, 'braga' production is throught to be more popular than moonshining due to its lower cost. According to the dietary questionnaire study that was undertaken, 'braga' consumption in northeastern Chukotka ranges from 30-50 litres per adult per year. A significant reduction in concentrations of POPs in the final product is achieved if "braga" is distilled to moonshine ("samogon") (Table 6.11).

Sample	ΣPCB	HCB	β-HCH	HCH	*p,p'*-DDE	*p,p'*-DDT	ΣDTT
Moonshine ('samogon')	82.0	3.3	12.7	33.0	39.0	44.0	86.0
Alcoholic mash('braga')	249.0	12.2	3.3	60.0	458.0	23.0	587.0

Table 6.11. Concentrations of POPs (ng/L) in alcoholic mash 'braga' and moonshine "samogon" sampled in the northeastern area of the Chukchi AO.

Analysis of 'braga' and 'samogon' showed higher PCB, HCH and DDT levels in 'braga', with significantly lower levels in 'samogon'. As found for kopalchen, *p,p'*-DDE is the major contributer to overall DDT metabolite concentrations in 'braga', whereas *p,p'*-DDT concentrations are relatively insignificant, suggesting that DDT contamination may be occuring through the use of waste chemical containers during the production of 'braga'.

The health impacts and importance of secondary contamination of local food can be illustrated by the elevated PCB serum concentrations found in families living in houses where higher levels of contaminantion of local food as a result of storage and processing were found (Table 6.12). Families living in houses where home-processed fish was found to be more highly contaminated (the same fish species being analyzed in each case) had, on average, a 16-fold increase in the relative risk factor of elevated PCB serum concentrations.

Secondary contamination of reindeer meat was not so great as that of fish, probably due to the simpler processing methods used for reindeer, involving more limited contact with waste materials and other contaminanted media.

Table 6.12. Comparison of PCB concentrations measured in foodstuffs sampled in selected households with levels in blood of adults from the same households, and the relative risk values associated with the foodstuffs.

	Households where adults had PCB serum concentrations greater than 1000 ng/g lipid (n=5)		Households where adults had PCB serum concentrations less than1000 ng/g lipid (n=5)	
	median	range	median	range
PCB concentrations measured in reindeer meat (n= 12)	86.17	1.05 - 446.0	40.87	2.48 - 87.10
Relative risk value	**2.9**		1.0	
PCB concentrations measured in freshwater fish (n= 9)	143.95	34.30 - 358.0	8.81	1.17 - 23.40
Relative risk value	**16.3**		1.0	

	High-dose groups			Low-dose groups		
	Levels in blood of family members (ng/g lipid, geometric mean)	Levels in wash-outs from the walls of dwellings (μg/m²)	Correlation coefficient	Levels in blood of family members (ng/g lipid, geometric mean)	Levels in wash-outs from the walls of dwellings (μg/m²)	Correlation coefficient
ΣPCB	1522	1.48	-0.04	788	1.66	0.25
	1275	2.87		99	2.23	
	827	3.24		711	3.11	
	1435	2.28		815	3.13	
	1869	1.86				
ΣDDT	939	0.9	0.43	716	36.8	0.84
	1414	0.86		437	1.4	
	634	10.1		600	2.12	
	729	7.85		936	4501	
	1352	73.58				

Table 6.13.
Linear correlation coefficients between blood POP levels among relatives of high-dose and low-dose groups and POP concentrations in wash-outs from the walls of their dwellings.

Due to significant individual variation in concentrations of the major PTSs found in maternal and cord blood of sampled indigenous people residing the same communities, it was considered of particular importance that contaminant sources and exposure pathways associated with some private and occupational activities involving PTS contaminated materials should be evaluated, even if only approximately. Clear relationships between contamination of dwellings by particular substances (as shown by contamination of water from the wash-outs of the walls of dwellings) and and levels of those same contaminants in the blood of inhabitants was found (Table 6.13).

Although such a restricted (case) study is of limited use (i.e., the resulting data have low statistical power and are generally inconclusive), the information on POPs exposure at the individual indigenous family level, involving the identification of risks associated with the use of specific chemicals in the household, and in occupational settings, may provide some insight into exposure sources and pathways. Generally, such sources of PTS exposure have not yet been adequately evaluated or documented for the types of situation that exist in the Arctic, especially with respect to some of the more vulnerable groups of indigenous people.

Chapter 7

PTS levels in humans

7.1. Sampling strategy

Sampling of human blood was undertaken in parallel with the dietary and lifestyle surveys, with two sets of respondents involved: pregnant women, from whom blood (and cord blood) were sampled at maternity departments of local hospitals, and representatives of the general adult indigenous population in selected indigenous settlements within the areas chosen for project implementation. Additional control samples, from urban populations in Norilsk and the Aral Sea areas, were analyzed to compare their PTS levels with those found in northern indigenous populations. The Aral Sea area is generally acknowledged to be an environmental disaster area, characterized by high usage of a range of pesticides in previous years, whilst Norilsk is a heavily industrialized area, with a wide range of pollutant sources. Information on the numbers and geographical distribution of samples for each area is presented in Table 7.1.

Project area	Pregnant women			General adult indigenous population	
	No. inter-viewed	No. of maternal blood samples	No. of cord blood samples	No. inter-viewed	No. of blood samples
Murmansk Oblast	17	16	14	264	52
Nenets AO	39	25	25	347	44
Taymir AO	80	67	68	354	52
Chukchi AO	101	100	71	611	92
Norilsk (control area 1)	17	17	16	-	-
Aral (control area 2)	30	30	28	-	-
Total	**284**	**255**	**222**	**1576**	**240**

Table 7.1. Numbers of persons interviewed, and blood samples taken.

The World Health Organization (WHO) recommends the use of breast milk as an indicator of the human body load of dioxins, PCBs, and other contaminants of this type. Despite this, AMAP human health assessments are usually based on PTS levels in human blood. This approach was selected after a thorough analysis of all factors, which included the ethical principles of undertaking studies among indigenous peoples, and the population groups to be covered by surveys. In order to ensure that project data would be comparable with both circumpolar and global data, breast milk samples were taken and analyzed in parallel with blood samples from a group of women in the Chukotka peninsula, one of the project areas.

A total of 60 samples of breast milk were analyzed for POPs. The samples were collected from different districts of the Chukchi AO: Chukotsky (27 samples), Anadyrsky (21 samples), and the town of Anadyr (7 samples). Five samples were also collected and analyzed from St. Petersburg, which was chosen as a control area.

Blood sampling was undertaken using vacutainers, fiberglass plungerless vacuum test-tubes with a needle screwed on a holder for dosed intravenous blood sampling. Blood was collected first from the mother's *vena ulnaris* and then from the umbilical cord of the fetus. For further blood treatment, special pipettes and vials, pre-tested to ensure the absence of pollutants that might confuse blood analysis findings, were used. Samples were processed in a 3000 rpm centrifuge and stored in a freezer at −20°C. Special thermally insulated containers were used for the transport of frozen blood samples.

Blood was collected from mothers on the first to the third day after delivery. Cord blood was sampled immediately after the tying and cutting of the umbilical cord. Methods used for blood sampling and blood treatment techniques were identical for maternal and cord blood. Mothers were also interviewed on the third to the fifth day after delivery.

7.2. Analytical methods and quality control

7.2.1. Analysis of POPs

Analysis of blood serum for persistent organic pollutants (POPs) was carried out in the Center for Environmental Chemistry (CEC) of SPA 'Typhoon', and the laboratory of the Regional Center 'Monitoring of the Arctic' (RCMA). Analyses at CEC were based on GC/MS, and those conducted at the RCMA laboratory involved chromatographic separation with electron capture detection. Quantitative calculations were based on external calibration using standard solutions.

Extraction of POPs from blood serum

Prior to extraction, blood serum samples were defrosted at room temperature. Each serum sample was weighed to an accuracy of 0.01 g and placed in an Erlenmeer flask. The isotope-labeled surrogate standards solution was then added and mixed for 30 minutes, after which methanol (MeOH) was added (in a volume equal to that of the sample) and the solution mixed for a further minute.

The sample solutions were initially extracted using a mixture of 1 : 1 hexane-MTBE (methyl-tri-butyl ether), the extraction process repeated twice, using 20–35 ml of an extracting agent. After separation of organic and aqueous layers, the extract was transferred to an Erlenmeer flask using a pipette. The extracts were combined, and the remaining water removed using anhydrous sodium sulfate, for a period of 30 minutes. The extract was then put through a fiberglass filter and concentrated to a volume of 10 mL, using a rotor evaporator. An extract aliquot of 2 mL was used to determine the level of lipids in blood serum. The remaining extract was then further concentrated to a volume of 1 mL, cleaned of lipids using gel-filtration on a Bio-Bead SX-3 column, and impurities were separated out using activated aluminum oxide and column chromatography with columns of silica gel, Florisil, and carbon AX-21.

Determination of the lipid content in blood serum

Lipids in blood serum were determined in the 2 mL aliquot of primary extract that had been prepared for POP analysis, using the gravimetric method.

Determination of polychlorinated biphenyls (PCBs)

PCBs determined in blood serum included the compounds identified by IUPAC nomenclature as: PCB-28/31, PCB-52, PCB-99, PCB-101, PCB-105, PCB-118, PCB-128, PCB-138, PCB-153, PCB-156, PCB-183, PCB-187, PCB-170 and PCB-180. A surrogate standard, consisting of a mixture of PCBs that were isotope-marked with ^{13}C (#28-$^{13}C_{12}$; #52-$^{13}C_{12}$; #101-$^{13}C_{12}$; #118-$^{13}C_{12}$; #138-$^{13}C_{12}$; #153-$^{13}C_{12}$; and #180-$^{13}C_{12}$, manufactured by Wellington Laboratories) was added to samples prior to extraction to control the efficiency of extraction and quantification, using PCB-166 as the recovery standard.

After preparation, sample extracts were analyzed using a Varian SATURN-2200T GC/MS, by operating in electron impact ionization mode. Analytes were identified by comparison of the resulting mass-spectra with chromatographic retention times characteristic of different PCB congeners. The detection limit of individual PCB congeners ranged from 0.002 to 0.2 µg/L.

Determination of organochlorine pesticides (OCP)

Organochlorine pesticides determined in blood serum included the following compounds: HCB, α-HCH, β-HCH, γ-HCH, *p,p'*-DDD, *p,p'*-DDT, *o,p*-DDE, *o,p*-DDD, *o,p*-DDT, heptachlor, *cis*-chlordane, *trans*-chlordane, oxychlordane, *cis*- and *trans*-nonachlor, dieldrin, and mirex.

Analytical determination of OCPs was performed using a Varian SATURN-2200T GC/MS, with identification of components by their characteristic mass-spectra, recorded in the range m/z = 80-420 amu. Control of the efficiency of extraction and quantification was achieved by adding analogues of analytes marked with ^{13}C ($^{13}C_{12}$-*p,p'*-DDE, $^{13}C_{12}$-*p,p'*-DDT, $^{13}C_6$-γ-HCH, and $^{13}C_6$–HCB; supplied by Cambridge Isotope Laboratories) to samples prior to extraction. The internal standard used was PCB #166.

The detection limit for organochlorine pesticides ranged from 0.003 to 0.16 µg/L for the various compounds.

Toxaphene

Analysis of toxaphene In blood serum samples was undertaken for those compounds known to be the most persistent and frequently occurring in the environment; namely, the *octa*- and *nona*- chlorinated toxaphenes that are conventionally referred to as Parlar-26, Parlar-50 and Parlar-62.

Extraction of toxaphenes was carried out in conjunction with other OCPs, as described above. After preparation, extracts were analyzed by GC/MS operating in chemical ionization mode, with detection of negative ions (NCI) characteristic of toxaphene compounds, i.e, selective ion monitoring (SIM). Analyses were performed on a SATURN-1200 MS/MS.

Analytes were identified by the presence of characteristic ions and the coincidence of chromatographic retention times. Due to the lack of available isotope-labeled compounds, calculations were carried out using external calibration based on the analysis of standard solutions of a mixture of individual toxaphene congeners, TOX-482, manufactured by Promochem.

The detection limit for individual congeners of toxaphene ranged from 0.01 to 0.03 µg/L.

Polybrominated diphenyl ethers (PBDE)

Polybrominated diphenyl ethers are widely used in industry as flame retardants. These are lipophilic compounds of low-volatility. The compounds determined in blood serum were those PBDE congeners most frequently used in products, namely:

2,4,4'- tribromodiphenyl ether (BDE-28)
2,2',4,4'- tetrabromodiphenyl ether (BDE-47)
2,2',4,4',5- pentabromodiphenyl ether (BDE-99)
2,2',4,4',6- pentabromodiphenyl ether (BDE-100)
2,2',4,4',5,5'-hexabromodiphenyl ether (BDE-153)
2,2',4,4',5,6'-hexabromodiphenyl ether (BDE-154)
2,2',3, 4,4',5',6-heptabromodiphenyl ether (BDE-183)

Analysis was performed by GC/MS using a SATURN 1200 MS/MS operating in chemical ionization mode, with detection of negative ions (NCI) and selective ion monitoring (SIM). Identification of analytes was based on the presence of characteristic ions and coincidence of chromatographic retention times. For calculations, data from PBDE calibration solutions based on the mixture of EO-4149 standards, manufactured by Cambridge Isotope Laboratories, and containing all determined compounds, was used. The detection limit of individual PBDE congeners ranged from 0.1 to 0.4 ng/L.

Polychlorinated dibenzo-n-dioxins/dibenzofurans (PCDD/PCDFs)

Quality control of the efficiency of extraction, and quantitative calculations was achieved by adding a surrogate standard prior to extraction. This solution (EPA-23 ISS, manufactured by Wellington Laboratories) contains a mixture of PCDD/Fs, isotope-marked with ^{13}C, including:

$^{13}C_{12}$ –2,3,7,8-TCDD
$^{13}C_{12}$ –1,2,3,7,8-PeCDD
$^{13}C_{12}$ –1,2,3,6,7,8-HxCDD
$^{13}C_{12}$ –1,2,3,4,6,7,8-HpCDD
$^{13}C_{12}$ –OCDD
$^{13}C_{12}$ –2,3,7,8-TCDF
$^{13}C_{12}$ –1,2,3,7,8-PeCDF
$^{13}C_{12}$ –1,2,3,6,7,8-HxCDF
$^{13}C_{12}$ –1,2,3,4,7,8-HpCDF

The recovery standard was the mixture NK-IS-A, containing $^{13}C_{12}$ –1,2,3,4-TCDD and $^{13}C_{12}$ –1,2,3,7,8,9-HxCDD.

Analyses we performed on a GC/MS SATURN 1200MS/MS, using chemical ionization with detection of negative ions (NCI) and selective ion monitoring (SIM). Identification of analytes was based on characteristic ions and coincidence of chromatographic retention times. The detection limit for individual congeners of PCDD/Fs ranged from 0.02 to 1.4 ng/kg.

7.2.2. Quality Assurance/Quality Control of POPs analysis

Quality control procedures involved a set of measures to check the accuracy of measurements and to estimate the size of any errors arising during sample preparation for analysis and measurement.

Analysis of samples was performed in series batches. Each batch included no more than 12 samples, a procedural blank, and a sample of a certified reference material or a control sample prepared in the laboratory, which contained known amounts of the analyte being determined. As the weight of individual blood samples delivered to the laboratory was less than 10 g, no duplicate analyses were performed.

The validity and accuracy of measurements was tested using (^{13}C) isotope-labeled surrogate standards introduced to the samples prior to extraction. The surrogate standards used for analysis of each type of compound are described in preceding sections.

Acceptance criteria for analyses were as follows:
- *Content in a blank:* lower than the method detection limit (MDL) for each analyte according to the maximum weight of the sub-sample used for a given type of analysis.
- *Extraction of analytes in a control sample:* within a range of 70–120% for 90% of compounds introduced to the sample.
- *Recovery range for surrogate standards:* 40–120%.

The performance of analytical instruments was checked on a daily basis, and included a check of instrument sensitivity and chromatographic and spectral resolution.

Linearity of instrument calibration was determined by analysis of 5 standard solutions of analytes with concentrations within the range of measured concentrations in samples. The standard deviation of the estimated relative response factor (RRF) in linearity checks had to be less than 15%.

Instrument performance was tested before and after the analysis of each batch of samples, by undertaking an analysis of a calibration solution of medium concentration.

The quality criterion used was that the difference in values of the relative response factor (RRF) calculated before and after the analysis of each series of samples should not exceed ±15%.

Instrument contamination by analytes was checked after each analysis of the calibration standard solution by injecting a clean solvent. The value of background errors due to the instrument had to be no more than 1% of the mean value of determined concentrations.

7.2.3. Analysis of samples for lead, cadmium, mercury, selenium and ferritin

Analysis of whole blood samples for lead and cadmium

Analysis for metals was performed in batches, exh batch comprising no more than 12 samples of blood, a procedural blank, a field blank, and a sample of certified reference material. One of the samples was also analyzed twice (replicated).

Prior to analysis, samples of whole blood were mixed, transferred to vials, and after Triton X-100 solution was added. They were then brought up to 4 mL and 2N with nitric acid and centrifuged for 15 minutes at 3000 rpm. Cadmium and lead were measured by flameless atomic-absorption spectrometry using a Perkin Elmer model Z 3030 spectrophotometer with Zeeman effect background correction, using pyro-coated graphite cells, with a Lvov platform. Analysis was performed by the method of standard additions in the presence of ammonium pyrophosphate, as a modifier. The detection limit for cadmium was 0.1 μg/L, and for lead 5.0 μg/L.

Analysis of whole blood samples for mercury

Each batch included 10 samples of whole blood, a procedural blank, a field blank, and a control sample.

For measurements, three 1.0–1.5 mL sub-samples were placed in three conical flasks, to which potassium permanganate solution and a mixture of concentrated nitric and sulfuric acids (in the ratio 1:3) were poured, and 2 g of dry potassium permanganate was added. The flasks were heated for 4 hours in a water bath at 60°C. After cooling, 15 mL of 10% hydroxylamine chloride was added and the samples were transferred to aeration jars.

Mercury was measured by the 'cold vapor' technique using the MHS-15 device with the Perkin Elmer model B 3030 spectrophotometer. Analyses were carried out using the method of standard additions, adding 5, 10, and 15 ng of mercury to sample aliquots prior to measurement. The reducing agent used was a 20% solution of tin chloride, and the carrier gas used was argon.

Analysis of serum samples for selenium

Each batch analyzed included 12 serum samples, a procedural blank, a field blank, a sample of reference material, and a replicate sample. The serum samples were transferred to conical flasks, to which 0.2 g of ascorbic acid was added, together with sodium molybdate, aqueous solution of potassium permanganate, and a mixture of concentrated nitric and sulfuric acids. Samples were heated for 20 minutes at 120°C. The temperature was then raised to 160°C and the samples heated to complete decomposition. The samples were cooled and transferred to a separating funnel, after which a hydrochloride solution of 1,2 diamino-4 nitrobenzene was added. The resulting 5-nitro-2,1,3-benzoselendiazol was extracted by chloroform.

Selenium was measured by flameless atomic-absorption spectrometry, using a Perkin Elmer model Z 3030 spectrophotometer with Zeeman effect background correction, using pyro-coated graphite cells, with a Lvov platform. For determination of selenium, the modifier used was a mixture of equal volumes of palladium nitrate, at a concentration of 3000 mg/L and manganese nitrate, at a concentration of 2000 mg/L.

Analysis of serum samples for ferritin
Determination of ferritin was undertaken using a DiaSys Diagnostic Systems (Germany) kit for photometric quantification of ferritin in serum, with a 'Specol-11' spectrophotometer. Ferritin concentrations were determined using a calibration curve based on four calibration samples, and a solution of sodium chloride (0.9%) for the determination of the zero value. The lower limit for measurement of ferritin concentration was 16 μg/L.

7.2.4. Quality Assurance/Quality Control of analysis for metals and ferritin

Quality control for lead and cadmium analysis
Analysis of blanks: Procedural blanks were analyzed to detect possible contamination of blood samples during sample preparation. Procedural blanks were included in each batch of samples analyzed.

Analysis of duplicates: For assessing the repeatability of results, replicates were analyzed in each batch. The difference in results of the analysis of replicates varied from 0.4 to 22.1% for lead, whereas for cadmium the difference between the duplicate measurements did not exceed 20%.

Analysis of certified reference material: In order to test the accuracy of the results obtained, a reference material (BCR 195), consisting of a sample of the lyophilized blood of ruminant animals, was analyzed with each batch.. The maximum error detected by the analysis of the certified reference material was 14.2% for lead, and 17% for cadmium.

Quality control for mercury analysis
Procedural blanks were analyzed to detect possible mercury contamination of blood samples during analysis. Procedural blanks were included in each batch of samples.

To assess the accuracy of results, a laboratory control sample was analyzed in each sample batch. The laboratory control sample was a matrix spike prepared with whole animal blood spiked with mercury in concentrations from 5.0 to 10.0 μg/L. The recovery of mercury from the control samples varied from 90 to 100%. The detection limit for mercury was 1.0 μg/L of whole blood.

Quality control for selenium analysis
Quality control procedures for selenium analysis involved the determination of the level of contamination of the containers in which the blood samples were delivered, analysis of replicates, and the analysis of a blood reference material (IAEA-A-13).

In the replicated analyses, results did not diverge by more than 20% and the recovery of selenium from reference material varied from 80 to 100%. The detection limit for selenium was 10.0 μg/L of blood serum.

Quality control for ferritin analysis
For ferritin analysis, quality control procedures involved the analysis of wash-offs from containers in which samples were delivered, analysis of procedural blanks, and analysis of acertified reference material prepared using human blood serum with different levels of ferritin (Lot #01143-01146). Errors in ferritin determination in control samples did not exceed 10%. Replicates were analyzed in each batch, in order to assess the repeatability of results. The differences between replicate measurements did not exceed 19%.

7.3. PTS levels in maternal and cord blood

The results of maternal and cord blood sample analysis were grouped according to sampling site and donor type. Sets of analytical results obtained from the different groups underwent statistical analysis. For the calculation of geometric mean concentrations of PTS in blood and serum, where analysis yielded a result for a particular substance below the detection limit, a value of half of the detection limit for the PTS and method concerned was used in the calculation.

The range of PTS concentrations in different blood groups can be very broad, and up to an order of magnitude (Tables 7.2–7.4). Since errors associated with analytical measurement of PTS in blood samples did not exceed 20% (see section 7.2), such differences can largely be attributed to heterogeneity of factors that affect blood concentrations (such as age, diet, number of children, etc). When assessing geometric means of measured results, therefore, differences in PTS concentrations in a certain group are taken to represent general tendencies rather than specific trends.

Hexachlorobenzene (HCB)
The geometric means of HCB concentrations found in maternal and cord blood serum for four project areas within the Russian Arctic are presented in Figure 7.1. The summary tables 7.2–7.4 and Figure 7.1

Compound	Chukchi AO							
	Chukotsky District		Anadyrsky District		Anadyr town		Iul'tinsky District	
	maternal, n=47	cord, n=41	maternal, n=39	cord, n=19	maternal, n=12	cord, n=6	maternal, n=5	cord, n=4
HCB	1.6 (0.4-6.0)	0.8 (0.01-5.1)	0.6 (0.1-2.7)	0.2 (0.1-0.9)	0.5 (0.2-0.8)	0.2 (0.1-0.7)	0.6 (0.4-2.1)	0.2 (0.1-0.6)
β-HCH	2.0 (0.6-7.6)	0.8 (n.d.-8.0)	0.6 (0.1-2.5)	0.1 (n.d.-0.8)	1.0 (0.4-2.2)	0.2 (0.1-0.5)	0.7 (n.d.-1.0)	0.1 (0.1-0.2)
ΣHCH	2.1 (0.6-7.6)	0.8 (n.d.-8.0)	0.6 (0.1-2.5)	0.1 (n.d.-0.8)	1.0 (0.4-2.3)	0.2 (0.1-0.5)	0.7 (n.d.-1.0)	0.1 (0.1-0.2)
Oxychlordane	1.0 (0.1-7.9)	0.2 (n.d.-3.6)	0.02 (n.d.-0.2)	n.d.	0.02 (n.d.-0.2)	0.01 (n.d.-0.05)	0.2 (0.03-0.6)	0.01 (n.d.-0.13)
p,p` -DDE	2.4 (0.8-7.0)	1.0 (0.3-7.4)	1.2 (0.3-6.3)	0.3 (0.1-1.0)	2.2 (1.3-4.6)	0.7 (0.4-1.5)	1.3 (0.7-2.8)	0.4 (0.2-0.8)
p,p` -DDT	0.2 (n.d.-1.2)	0.1 (n.d.-1.2)	0.2 (n.d.-0.5)	0.04 (n.d.-0.1)	0.4 (0.1-1.0)	0.1 (0.04-0.2)	0.2 (0.1-0.3)	0.06 (0.05-0.09)
ΣDDT	2.7 (0.8-8.0)	1.1 (0.3-8.3)	1.4 (0.3-6.6)	0.4 (0.1-1.0)	2.7 (1.4-5.3)	0.8 (0.5-1.7)	1.5 (0.1-3.2)	0.4 (0.2-0.9)
Mirex	0.1 (n.d.-0.5)	0.03(n.d.-0.5)	0.01 (n.d.-0.03)	n.d.	0.01 (n.d.-0.02)	n.d.	0.03 (0.01-0.05)	0.01 (n.d.-0.02)
ΣPCB	3.8 (0.9 –11)	1.4 (0.01-12)	0.8 (0.2-1.8)	0.2 (0.03-0.7)	1.5 (0.6-6.8)	0.3 (0.05-1.1)	1.5 (1.0-3.2)	0.2 (0.2-0.4)
ΣToxaphenes	0.2 (n.d.-0.8)	0.06(n.d.-0.8)	0.02 (n.d.-0.1)	0.003(n.d.-0.01)	0.02 (n.d.-0.2)	0.003 (n.d.-0.01)	0.04 (0.02-0.1)	0.005(n.d.-0.01)
Cd (blood)	1.1 (0.2-4.7)	0.3 (n.d.-4.0)	0.9 (0.2-2.5)	0.2 (n.d.-0.5)	0.5 (0.1-1.5)	0.2 (n.d.-1.0)	1.0 (0.7-1.5)	0.2 (0.16-0.5)
Pb (blood)	45.0 (18-227)	43.0 (14-210)	34.0 (13-83)	29.0 (14-60)	34.0 (19-92)	34.0 (19-78)	52.0 (36-113)	39.0 (27-100)
Hg (blood)	1.5 (n.d.-6.2)	1.3 (n.d.-3.6)	2.0 (n.d.-7.7)	1.3 (n.d.-4.1)	0.8 (n.d.-3.5)	0.9 (n.d.-3.3)	1.2 (n.d.-2.5)	1.0 (n.d.-2.2)
Se (plasma)	78.0 (22-162)	55.0 (23-132)	59.0 (27-101)	38.0 (16-74)	71.0 (30-136)	43.0 (29-55)	67.0 (55-93)	47.0 (33-69)
Ferritin (plasma)	27.0 (n.d.-343)	87.0 (n.d.-719)	18.0 (n.d.-332)	90.0 (n.d.-305)	11.0 (n.d.-59)	96.0 (29-257)	n.d.	84.0 (58-152)
Lipid %	0.5 (0.8-0.3)	0.2 (0.1-0.8)	0.5 (0.3-0.8)	0.1 (0.05-0.14)	0.4 (0.1-0.6)	0.09 (0.06-0.1)	0.6 (0.5-0.7)	0.1 (0.07-0.1)

Table 7.2. Concentrations (geometric mean and range; μg/L plasma) of PTS in maternal and cord blood from various areas of the Chukchi AO.
n. d. – not detected

show that the highest concentrations of HCBs occur in the Chukchi AO. The highest HCB concentrations of 1.6 μg/L and 0.8 μg/L are found in maternal and cord blood, respectively, from Chukotsky, the most northeasterly, coastal district of the Chukchi AO. Blood samples from other areas of the Chukchi AO (Anadyrsky and Iul'tinsky districts, and the town of Anadyr) contain HCBs at levels 2-3 times lower than in Chukotsky, and more comparable with samples from other regions.

Concentrations of HCB in cord blood are 1.6 to 3 times lower than those in maternal blood. It has therefore been suggested that the placenta may act as a barrier between the mother and fetus and prevents transfer of this toxicant from mother to child, although though this barrier is not fully effective. A similar effect was observed for blood groups of all regions, except the Kola Peninsula, where the difference in maternal and cord blood concentrations was not statistically significant.

In control blood samples, mean HCB concentrations are 6 to 8 times lower than those from other study regions, and 20 times lower than concentrations in maternal blood samples from the Chukotsky district.

A comparison with results from the AMAP circumpolar blood survey (AMAP, 2003a) is shown in Figure 7.2. This comparison suggests that, on the whole, HCB concentrations measured in maternal blood in the Russian Arctic are close to those detected in coastal areas of Greenland and Canada (where means of 1.5 and 1 μg/L of plasma, respectively, were found). Blood concentrations of HCB reported previously (AMAP, 1997, 1998) for residents of the same territories of Greenland and Canada had geometric mean levels of HCB of 0.9 and 0.7 μg/L of plasma, respectively. In the context of these results, the highest concentrations of HCB found in blood samples from coastal Chukotka are a cause of concern.

DDT

High concentrations of total DDT in maternal blood samples, ranging from 1.4 μg/L (Anadyrsky district,

Compound	Taymir AO					
	Khatanga area		Dudinka area		Norilsk (control area)	
	maternal, n=29	cord, n=29	maternal, n=38	cord, n=39	maternal, n=10	cord, n=10
HCB	0.7 (0.2-2.1)	0.2 (0.1-1.0)	0.5 (0.1-1.9)	0.2 (0.03-0.9)	0.4 (0.2-0.9)	0.1 0.08-0.2)
β-HCH	0.6 (0.1-2.8)	0.2 (n.d.-0.9)	0.7 (n.d.-3.0)	0.1 (n.d.-0.9)	1.3 (0.5-4.5)	0.4 (0.2-0.7)
Σ HCH	0.6 (0.1-2.8)	0.2 (n.d.-1.0)	0.7 (n.d.-3.2)	0.1 (n.d.-0.9)	1.3 (0.5-4.6)	0.4 (0.2-0.7)
Oxychlordane	0.03 (n.d.-0.2)	0.01 (n.d.-0.03)	0.02 (n.d.-0.2)	n.d.	0.01 (n.d.-0.04)	n.d.
p,p` -DDE	1.3 (n.d.-5.0)	0.4 (n.d.-1.5)	1.6 (0.2-7.7)	0.5 (0.1-2.8)	2.9 (1.4-7.2)	0.8 (0.5-1.6)
p,p` -DDT	0,2 (n.d.-0.8)	0.1 (n.d.-0.2)	0.2 (n.d.-0.8)	0.1 (n.d.-0.3)	0.4 (0.2-0.6)	0.1 (n.d.-0.2)
Σ DDT	1.5 (0.3-5.7)	0.4 (n.d.-1.8)	2.0 (n.d.-8.0)	0.6 (0.1-3.0)	3.3 (1.8-7.7)	0.9 (0.5-1.7)
Mirex	0.02 (n.d.-0.1)	0.01 (n.d.-0.02)	0.02 (n.d.-0.1)	n.d.	n.d.	n.d.
Σ PCB	1.2 (0.2-3.0)	0.4 (n.d.-1.0)	2.2 (0.8-5.2)	0.5 (n.d.-4.0)	1.4 (0.8-2.6)	0.8 (n.d.-3.0)
Σ Toxaphenes	0.07 (n.d.-0.3)	0.01 (n.d.-0.07)	0.04 (n.d.-1.3)	0.004 (n.d.- 0.04)	0.02 (0.01-0.05)	0.003 (n.d.-0.01)
Cd (blood)	0.6 (n.d.-1.8)	0.1 (n.d.-0.7)	0.8 (n.d.-2.9)	0.2 (n.d.-0.9)	0.6 (0.2-1.2)	0.1 (n.d.-0.4)
Pb (blood)	50 (14-176)	40 (12-144)	48 (15-224)	35 (14-99)	20 (10-37)	13 (6-34)
Hg (blood)	1.4 (n.d.-4.0)	1.4 (n.d.-3.6)	2.3 (n.d.-20)	1.7 (n.d.-17)	0.8 (n.d.-3.0)	0.8 (n.d.-2.2)
Se (plasma)	81 (44-175)	57 (24-148)	61 (19-144)	61 (18-132)	75 (49-123)	58 (39-86)
Ferritin (plasma)	53 (n.d.-547)	139 (35-269)	59 (n.d.-1095)	159 (46-270)	18 (n.d.-84)	101 (39-405)
Lipid %	0.5 (0.3-0.7)	0.1 (0.04-0.2)	0.5 (0.3-0.8)	0.09 (0.04-0.3)	0.6 (0.5-0.7)	0.2 (0.04-0.8)

Table 7.3. Concentrations (geometric mean and range; μg/L plasma) of PTS in maternal and cord blood from various areas of the Taymir AO.
n. d. – not detected

Compound	Kola Peninsula Lovozero District		Nenets AO Nenetsky District		Aral (Control area) Urgench , Khozarast	
	maternal, n=7	cord, n=6	maternal, n=21	cord, n=21	maternal, n=12	cord, n=12
HCB	**0.3** (0.2-0.8)	**0.3** (0.1-0.8)	**0.7** (0.2-2.1)	**0.4** (0.2-1.7)	**0.1** (0.05-0.3)	**0.1** (0.03-0.3)
β-HCH	**0.5** (0.1-1.7)	**0.5** (0.1-2.2)	**0.4** (n.d.-1.1)	**0.04** (n.d.-1.9)	**2.9** (0.6-9.5)	**0.7** (n.d.-3.6)
Σ HCH	**0.5** (0.1-1.7)	**0.5** (0.1-2.2)	**0.5** (n.d.-1.2)	**0.04** (n.d.-2.1)	**3.0** (0.6-9.7)	**0.7** (n.d.-3.6)
Oxychlordane	**n.d.**	**0.01** (n.d.-0.05)	**0.02** (n.d.-0.1)	**0.01** (n.d.-0.08)	**0.03** (n.d.-0.6)	**n.d.**
p,p`-DDE	**2.3** (0.8-6.6)	**2.1** (0.6-7.2)	**1.7** (0.1-5.1)	**0.7** (0.1-2.1)	**8.4** (2.5-18)	**2.7** (0.7-5.7)
p,p`-DDT	**0.3** (0.1-0.8)	**0.3** (0.2-0.6)	**0.3** (n.d.-1.9)	**0.1** (n.d.-0.5)	**0.2** (0.1-0.5)	**0.1** (n.d.-0.2)
Σ DDT	**2.7** (1.0-7.5)	**2.4** (0.8-7.7)	**2.0** (0.1-7.4)	**0.7** (0.1-2.7)	**8.7** (2.7-18.2)	**2.8** (0.9-5.8)
Mirex	**0.007** (n.d.-0.01)	**n.d.**	**0.03** (n.d.-0.3)	**0.01** (n.d.-0.02)	**n.d.**	**n.d.**
Σ PCB	**0.7** (n.d.-3.3)	**1.1** (n.d.-5.3)	**1.6** (0.02-6.5)	**0.4** (n.d.-2.4)	**0.1** (n.d.-2.9)	**n.d.**
Σ Toxaphenes	**0.01** (n.d.-0.05)	**0.01** (n.d.-0.03)	**0.01** (n.d.-0.1)	**n.d.**	**0.003** (n.d.-0.01)	**n.d.**
Cd (blood)	**0.3** (n.d.-1.3)	**0.1** (n.d.-0.6)	**0.5** (n.d.-2.8)	**0.2** (n.d.-0.7)	**0.4** (0.2-0.9)	**0.1** (n.d.-0.5)
Pb (blood)	**28** (17-52)	**21** (12-29)	**32** (n.d.-92)	**23** (n.d.-63)	**44** (24-78)	27 (7-54)
Hg (blood)	**0.9** (n.d.-2.4)	**0.9** (n.d.-1.7)	**0.8** (n.d.-5.6)	**0.7** (n.d.-2.7)	**n.d.**	**0.6** (n.d.-1.5)
Se (plasma)	**73** (40-120)	**80** (62-124)	**81** (48-141)	**52** (16-114)	**63** (31-104)	**62** (20-117)
Ferritin (plasma)	**27** (n.d.-135)	**58** (n.d.-230)	**44** (n.d.-146)	**85** (n.d.-293)	**13** (n.d.-172)	**98** (n.d.-529)
Lipid %	**0.3** (0.1-0.7)	**0.3** (0.1-0.7)	**0.5** (0.05-0.8)	**0.1** (0.05-0.3)	**0.5** (0.3-0.7)	**0.4** (0.1-0.8)

Table 7.4. Concentrations (geometric mean and range; µg/L plasma) of PTS in maternal and cord blood from the Kola Peninsula, the Nenets AO, and Aral (control area). n.d. – not detected

Chukchi AO) to 3.3 µg/L (Norilsk) occur in all four regions, with concentrations in maternal blood being 1.5–3 times higher than in cord blood.

Within the Chukchi AO, the highest concentrations of total DDT in cord blood (1.1 µg/L) were found in Chukotsky district, while concentrations in other districts are 2–3 times lower. Levels of DDT in maternal blood from the town of Anadyr, however, are also high (2.7 µg/L). Samples of maternal and cord blood from the Kola Peninsula are similar, as DDT concentrations are high in both, at 2.7 and 2.4 µg/L, respectively.

It should be noted that control blood groups also contain DDT in significant amounts, with mean values varying from 8.7 µg/L in maternal blood to 2.8 µg/L in cord blood. In control blood samples from the Aral area, the concentration of total DDT was as high as 18.2 µg/L in maternal and 5.8 µg/L in cord blood (Table 7.4).

DDE is the most frequently occurring component of total DDT, with the DDE/DDT concentration ratio varying from 3 to 8. Figure 7.3 shows the geographic distribution of geometric mean concentrations of DDE in maternal and cord blood for the regions of Russia involved in the study.

A comparison with the results of the analysis of maternal blood from residents of the Russian North reported by AMAP (AMAP, 2003a), of 1.25–5.0 µg/L of serum, Figure 7.4, indicates that DDT concentrations in maternal blood from three regions of the Russian Arctic, excluding the control region, (1.4–3.3 µg/L of serum) are very similar to previous results. Comparisons of DDT for the Chukchi population are not possible due to the lack of available data prior to the present study.

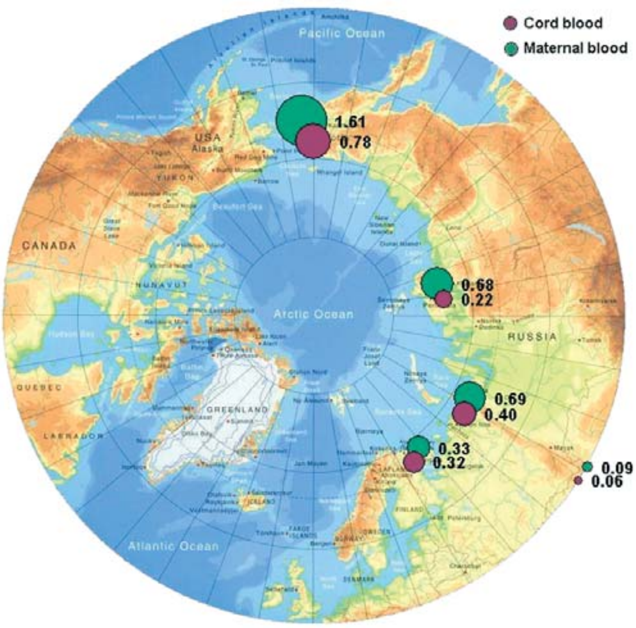


Figure 7.1. Levels of HCB in maternal and cord blood in the Russian Arctic (geometric means, µg/L plasma).

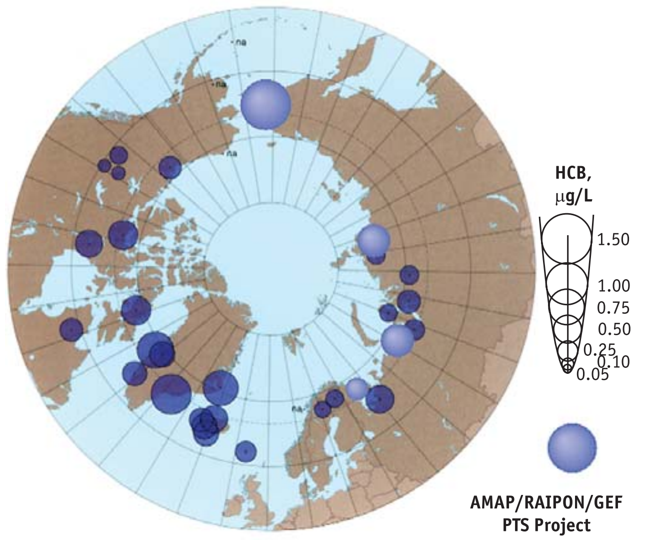


Figure 7.2. Comparison of the results obtained in this project for HCB in maternal blood with results from the AMAP circumpolar blood monitoring study (AMAP, 2003a).

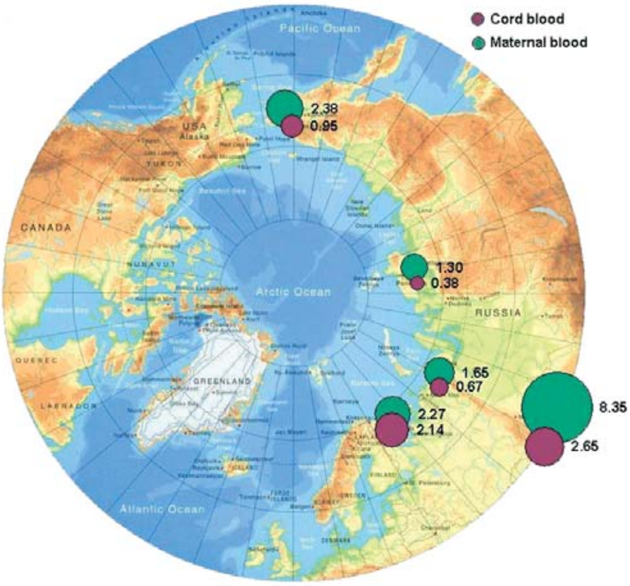


Figure 7.3. Levels of DDE in maternal and cord blood in the Russian Arctic (geometric means, µg/L plasma).

HCH

Total HCH levels in human blood are mainly determined by β-HCH, this being the most stable compound within the HCH group. Consequently, all subsequent discussions in this chapter concerning HCH levels are based on β-HCH results. The geometric mean values of β-HCH concentrations in maternal and cord blood in the four studied regions of the Russian Arctic are shown in Figure 7.5. The distribution of β-HCH in human blood in the Russian Arctic is similar to that of HCB, with the highest levels (0.8–2.0 µg/L) observed in the blood of residents of Chukotka (Table 7.2). However, one difference is that elevated levels of β-HCH are also found in maternal blood from Norilsk (1.3 µg/L). In all other maternal blood samples (apart from those from the Kola Peninsula) the concentrations of β-HCH are 2–4 times higher than in cord blood.

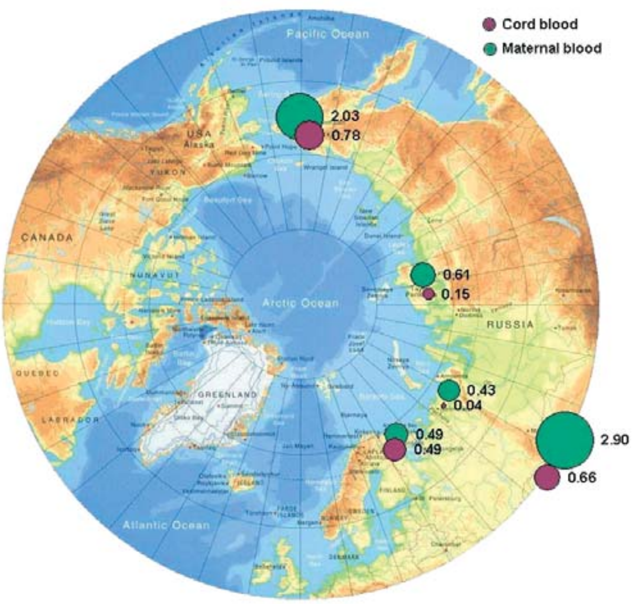


Figure 7.5. Levels of β-HCH in maternal and cord blood in the Russian Arctic (geometric means, µg/L plasma).

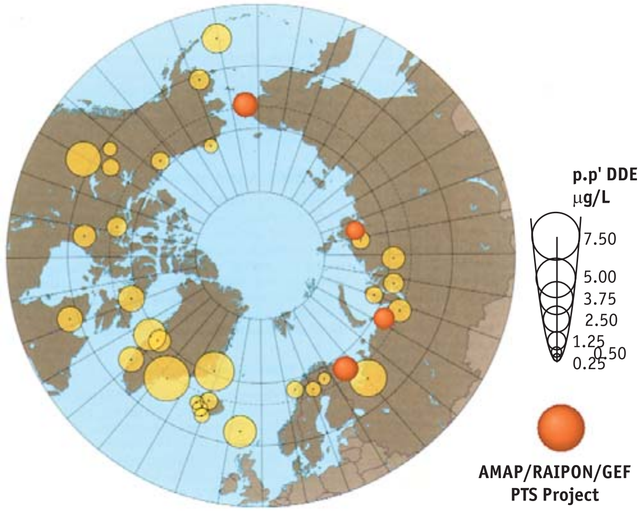


Figure 7.4. Comparison of the results obtained in this project for DDE in maternal blood with results from the AMAP circumpolar blood monitoring study (AMAP, 2003a).

As for DDT, β-HCH concentrations in control samples from the Aral area are high, with a geometric mean of 2.9 µg/L of plasma. In individual samples, concentrations as high as 9.5 µg/L of plasma were found, which is likely to be the result of the long-term use of pesticides such as HCH, lindane, and DDT in this area.

Concentrations of β-HCH in maternal blood do not exceed values reported in earlier studies by AMAP (AMAP, 2003a) for the Russian North (Figure 7.6).

PCBs

The presence of PCBs in human blood is attributed mainly to the consumption of contaminated foodstuffs. In the diet of people living in coastal areas of the Arctic, sources of PCBs include meat from polar bears, seals, whales, and sea birds and bird eggs, as well as from fish; whilst for those living in continental areas, sources include freshwater fish and other meat and fish products (AMAP, 2002).

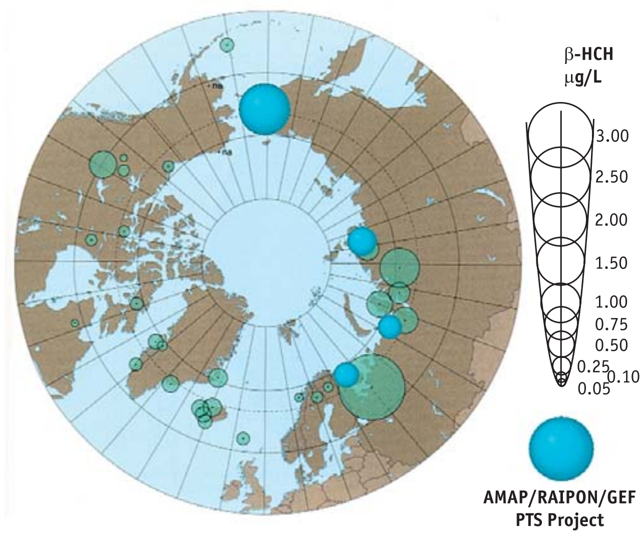


Figure 7.6. Comparison of the results obtained in this project for β-HCH in maternal blood with results from the AMAP circumpolar blood monitoring study (AMAP, 2003a).

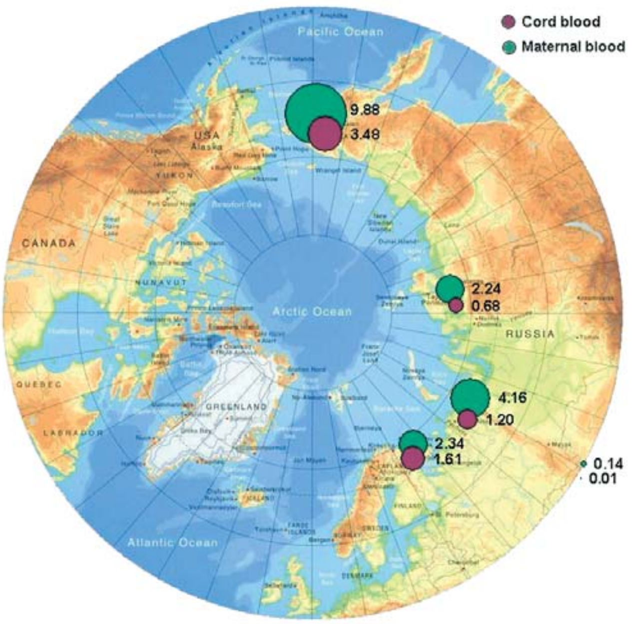


Figure 7.7. Levels of sum of PCBs (shown as Aroclor 1260 equivalents) in maternal and cord blood in Russian Arctic (geometric means, μg/L plasma).

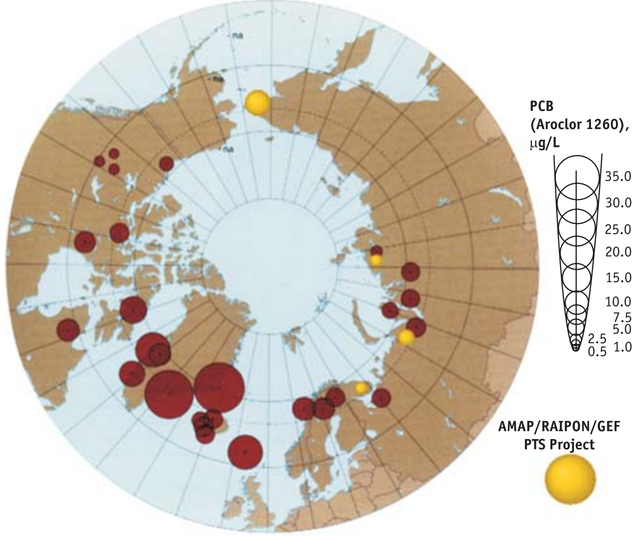


Figure 7.8. Comparison of the results obtained in this project for sum of PCBs (as Aroclor 1260 equivalents) in maternal blood with results from the AMAP circumpolar blood monitoring study (AMAP, 2003a).

The analysis of maternal and cord blood demonstrates that, as for other toxicants, when examining PCB in humans, the transfer of contaminants from mother to fetus via the blood appears to be impeded by the placental barrier. This is reflected by the ratio of PTS in maternal and cord blood, and differs for residents of different districts (as seen in mean values) and between individuals (as seen in deviations from the mean).

Tables 7.2–7.4 show that the maximum values of total PCBs occur in maternal and cord blood samples of residents of the Chukotsky District of the Chukchi AO (3.9 μg/L and 1.4 μg/L, respectively), with PCB levels as high as 11 μg/L in some individual samples from this area. In the Taymir area, the highest concentrations are found in Dudinka (mean concentration of 2.2 μg/L, with a maximum value of 5.2 μg/L). Figure 7.7 shows the spatial distribution of geometric mean concentrations of total PCBs across the Russian Arctic.

The results were compared with data obtained in earlier studies by AMAP (AMAP, 2003a) on PCB concentrations in maternal blood for various Arctic countries. These included Greenland: 25–35 μg/L of plasma (for indigenous people of coastal areas), Iceland: 20 μg/L, Canada: 2–15 μg/L, and Russia: 2–15 μg/L of plasma. It can be seen from data in Tables 7.2–7.4 and Figure

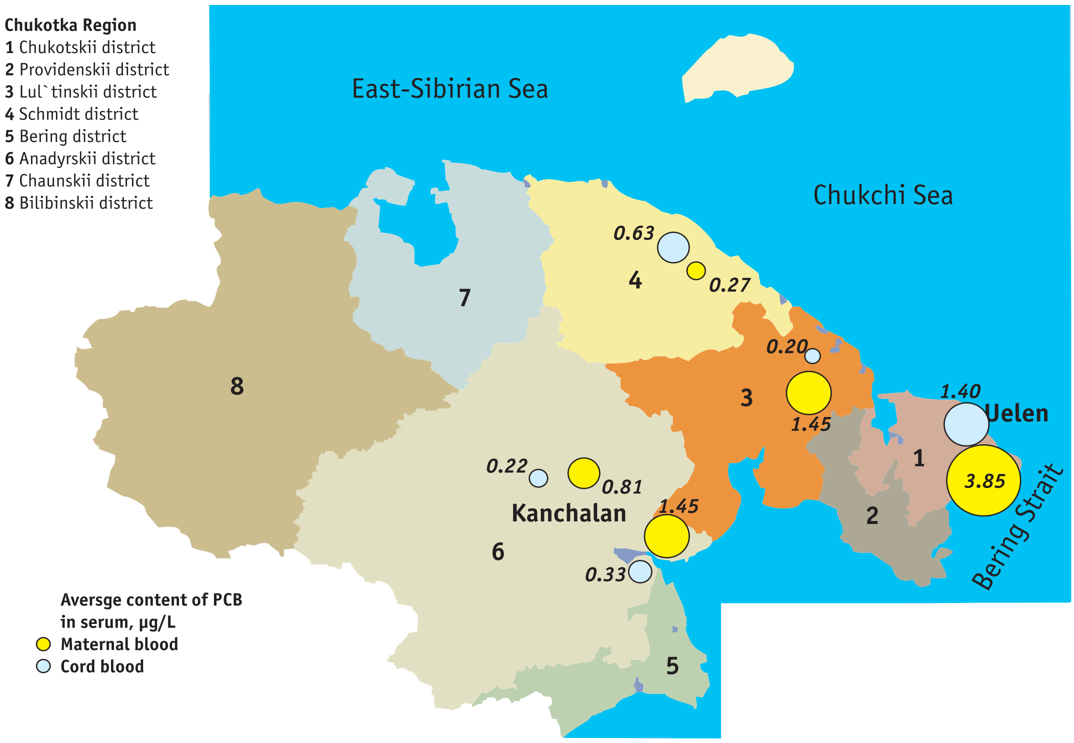


Figure 7.9. PCB levels in various districts of the Chukchi AO.

7.8 that the concentrations of total PCBs in maternal and cord blood sampled in the Russian Arctic during this study, on average, do not exceed the limit value of 5 µg/L of blood, below which toxic effects on humans have not been observed (Klopov, 2000). Figure 7.9 illustrates the distribution of PCBs within different areas of the Chukchi AO.

Of all the PCB congeners, PCB-153 (2,2',4,4',5,5'-hexachlorobiphenyl) occurs in humans most frequently and in the largest amount. Assessment of PCB congeners present in paired maternal and cord blood samples from four regions of the Russian Arctic shows that the distributions of congeners in the paired samples are similar. This means that, when PCBs are transferred to infants via the blood, the PCB congener pattern remains essentially the same. However, the pattern of PCB distribution in the paired blood samples collected on the Kola Peninsula differs from that found in blood of residents of the three other regions. This may be due to peculiarities in the diet of residents in the Kola region. It is worth noting that the distribution patterns found are consistent with data previously obtained from more limited sets of blood samples taken in the same areas (Chashchin *et al.*, 2002).

According to the scientific literature (Chen *et al.*, 1985) the highest recorded levels of total PCBs in blood, were found in those poisoned by PCB-contaminated rice oil in Japan in 1968 (Yusho disease) and in Taiwan in 1979 (Iu-Cheng disease). Blood concentrations of PCBs in the residents of Taiwan who were affected ranged from 10 to 720 µg/L, with the mean value of 38 µg/L. Symptoms of the poisoning showed a close correlation with concentrations of hexachlorobiphenyl (congener PCB-157) in the blood. However, within a year, the maximum concentration in blood had decreased to 99 µg/L (Chen *et al.*, 1985).

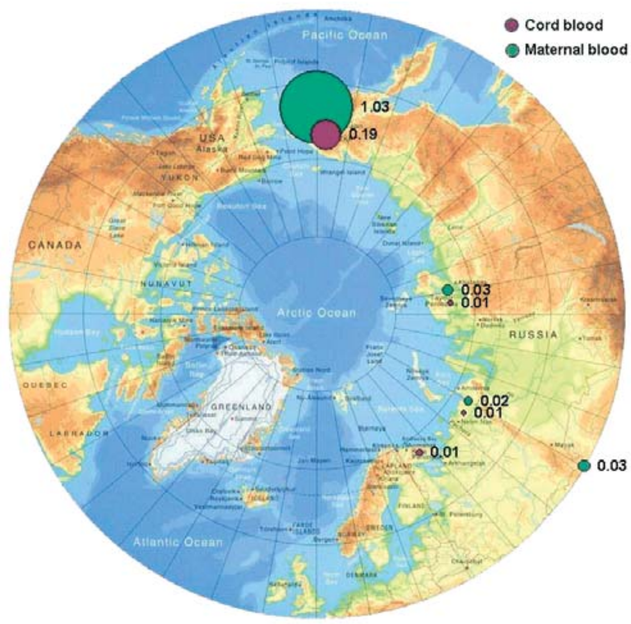


Figure 7.10. Levels of oxychlordane in maternal and cord blood in the Russian Arctic (geometric means, µg/L plasma).

Chlordane and its decomposition products: trans- and cis-chlordanes and oxychlordane

The predominant chlordane component in blood is oxychlordane (often constituting 100% of the sum). It is believed that high concentrations of this compound, found in the blood of indigenous people, are due to the intake of oxychlordane with marine mammal meat. Oxychlordane concentrations in blood from past studies were reported to be 0.25–1.5 µg/L of blood serum for indigenous women in Greenland, and 0.05-0.75 µg/L of blood serum for residents of Canada (AMAP, 2003a). The sum of chlordanes in the blood of women in northwest Greenland, and northern Canada (Quebec) were reported to be 1.4 and 1.6 µg/L of blood serum, whereas for women in the Russian Arctic, levels are found to be 0.1–0.5 µg/L of blood serum (AMAP, 1998).

The results of analysis of maternal and umbilical cord blood in the present study (Figure 7.10) show that the highest concentrations of oxychlordane occur in the blood of women and children living in Chukotsky District of the Chukchi AO (with geometric mean levels of 1.0 and 0.2 µg/L, respectively). This is an order of magnitude higher than in the other regions where samples were taken. However, the elevated levels of oxychlordanes in maternal blood in Chukotsky district are close to levels found in women living in Greenland and consuming the meat of marine mammals. A comparison of levels of oxychlordane found in maternal blood in this study and during previous studies is shown in Figure 7.11.

Toxaphene and mirex

Blood samples were analyzed for three enantiomers of toxaphene, Parlar-26, -50, and -62 (based on the Parlar standards). Of these, Parlar-26 (octachlorocamphene) and Parlar-50 (nonachlorocamphene) were the enantiomers that were primarily detected. Tables 7.2–7.4 provide total concentrations for the toxaphenes studied, as determined in blood samples.

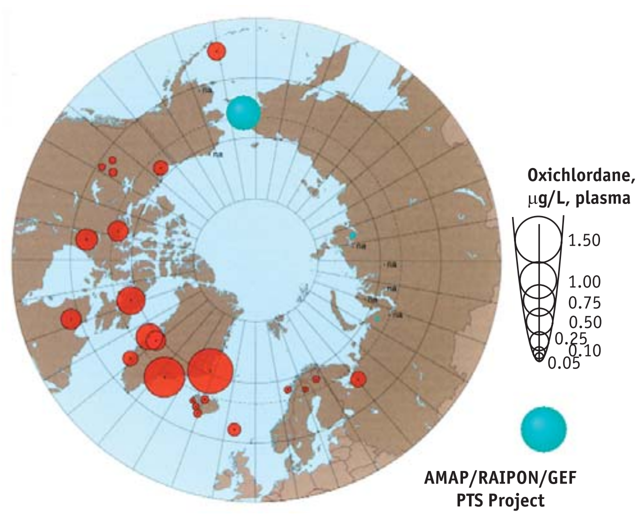


Figure 7.11. Comparison of the results obtained in this project for oxychlordane in maternal blood with results from the AMAP circumpolar blood monitoring study (AMAP, 2003a).

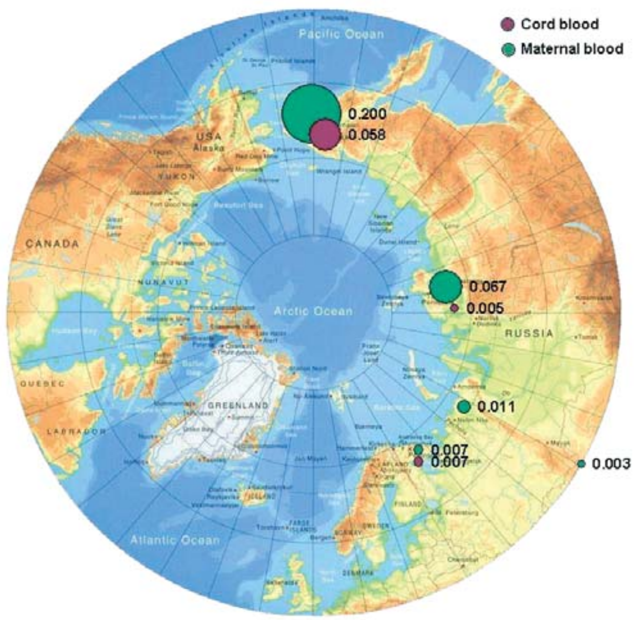


Figure 7.12. Levels of total toxaphenes in maternal and cord blood in the Russian Arctic (geometric means, µg/L plasma).

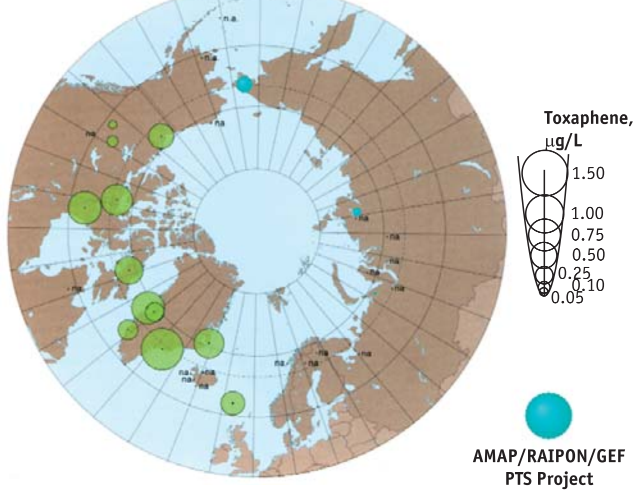


Figure 7.13. Comparison of the results obtained in this project for toxaphene in maternal blood with results from the AMAP circumpolar blood monitoring study (AMAP, 2003a).

The concentration of toxaphenes in human blood, like that of mirex, is known to be higher among indigenous people whose traditional diet includes marine mammals and fish (AMAP, 2003a), with the highest levels of toxaphenes observed in inhabitants of Greenland and northern Canada (up to 1.5 µg/L of blood).

Toxaphene levels occurring in the blood of women in the Russian Arctic are much lower (0.007–0.2 µg/L), and the concentrations in cord blood are found to be lower still, at 0.003–0.06 µg/L. The concentrations of toxaphenes in cord blood areless than 30% of those found in maternal blood, and the placenta barrier, therefore, appears to prevent a major part of the toxaphene transfer to the fetus via blood. An exception to this is the ratio of toxaphene concentrations in maternal and umbilical cord blood for women from the Kola Peninsula.

Figure 7.12 shows the geographic distribution of toxaphenes in the regions of the Russian Arctic studied, and Figure 7.13 compares the results obtained with the earlier AMAP results (AMAP, 2003a). The highest concentrations of toxaphenes were detected in the blood of women from Chukotsky District of the Chukchi AO (geometric mean of 0.20 µg/L), with toxaphene concentrations as high as 0.8 µg/L occurring in individual samples.

The pattern observed for toxaphenes can also be seen in the distribution of mirex in maternal and cord blood in the Arctic regions of Russia. Concentrations of mirex range from 0.007–0.12 µg/L in maternal blood, and from less than the detection limit to 0.03 µg/L in cord blood. The highest geometric mean concentrations of mirex were found for maternal and cord blood from Chukotsky District, up to 0.5 µg/L in individual samples. By comparison, the mirex concentration in umbilical cord blood reported for a group of women in Arctic Canada was determined to be 0.01–0.65 µg/L (CACAR, 1997).

Mercury

Mercury concentrations in human blood are primarily governed by diet. For example, blood mercury concentrations measured in women in the Russian Arctic were 1.6–1.9 times higher for women whose diet included a higher level of intake of traditional foods (fish and reindeer meat), compared to those who consumed these foods rarely, with geometric mean values for blood mercury equal to 2.5 and 1.3 µg/L of blood, respectively (Klopov, 2000). Mercury levels in blood below 20 µg/L are regarded as acceptable according to WHO guidelines (Klopov, 2000).

The results of the analysis of blood taken from women giving birth and from cord blood (Tables 7.2–7.4) show mercury levels within the ranges reported previously for areas of the Russian Arctic (Klopov, 2000). Slightly higher values were found in the blood of women giving birth in Anadyrsky District of the Chukchi AO (2.0 µg/L), and the Dudinka area of the Taymir AO (2.3 µg/L) (see Tables 7.2 and 7.3). In individual blood samples from Dudinka, mercury concentrations were as high as 18–20 µg/L.

For women from the control areas, mercury concentrations were below the detection limit (<1.0 µg/L). In the mother-infant pair samples, mercury concentration in umbilical cord blood did not show a significant decrease in levels when compared to maternal blood samples, suggesting that the placenta is not an effective barrier in protecting the fetus from mercury transfer. The geographic distribution of mercury concentrations in blood in the regions of the Russian Arctic under study are shown in Figure 7.14, whilst Figure 7.15 compares the results obtained with data from AMAP (AMAP, 2003a).

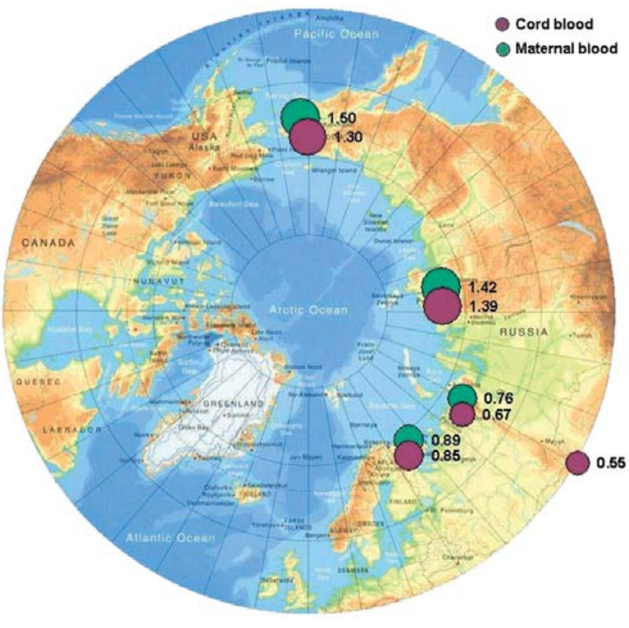


Figure 7.14. Levels of mercury in maternal and cord blood in the Russian Arctic (geometric means, μg/L plasma).

Lead
The distribution of lead concentrations in maternal and umbilical cord blood in the Russian Arctic regions is similar to that of mercury. As for mercury, the placental barrier does not appear to prevent the transfer of lead to the fetus via blood, the lead concentration in umbilical cord blood ranging from 75–93% of the concentration in maternal blood. Lead concentrations are found to range from 13.3 μg/L (Norilsk) to 43 μg/L (Chukotsky District of the Chukchi AO) in cord blood, and 20 μg/L (Norilsk) to 52 μg/L (Iul'tinsky District of the Chukchi AO) in maternal blood (Tables 7.2–7.4).

Figure 7.16 shows the spatial distribution of blood concentrations of lead in the regions of the Russian Arctic under study. As can be seen from the figure, the highest concentrations of lead are found in indigenous women of the Chukchi AO. These levels are somewhat higher than those reported for women living in other regions (which vary from 21.3–32.2 μg/L of blood), but these results may be explained by specific characteristics of selected donor groups (Klopov, 2000).

Cadmium
The results of blood analysis for the four regions of the Russian Arctic indicate that cadmium concentrations in maternal and cord blood range from 0.3–1.1 μg/L, and 0.1–0.3 μg/L, respectively (Tables 7.2–7.4). These concentrations are lower than the WHO guideline value of 2.0 μg/L, for a concentration posing no risk of harmful effects of cadmium exposure (Klopov, 2000). However, there are individual blood samples from both the Chukotsky and Anadyrsky Districts of the Chukchi AO, which exceed this limit by a factor of two.

Figure 7.17 shows the spatial distribution of blood cadmium concentrations in the regions of the Russian Arctic studied. It is worth noting that concentrations of

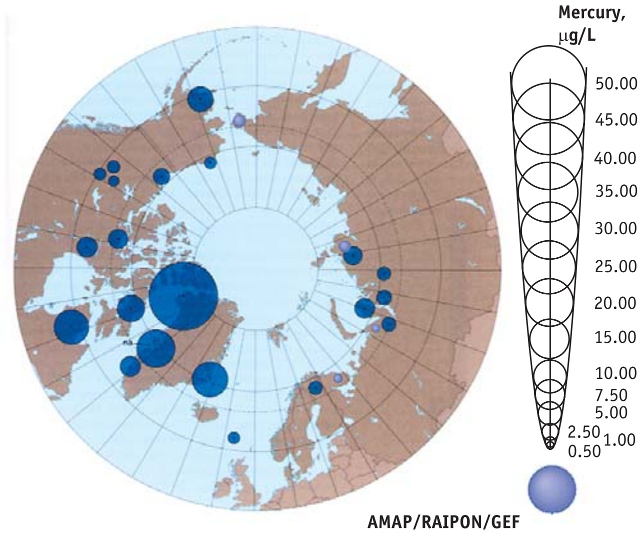


Figure 7.15. Comparison of the results obtained in this project for mercury in maternal blood with results from the AMAP circumpolar blood monitoring study (AMAP, 2003a).

cadmium found in women giving birth were higher for residents of Chukotka and Taymir, than for women living on the Kola peninsula, or in Aral (control area). Concentrations of cadmium in women from the Kola Peninsula were found to be lower than concentrations in the control area samples.

7.4. PTS levels in blood of the general adult indigenous population

7.4.1. Characteristics of PTS levels in blood of the general adult indigenous population

With some exceptions, PTS concentrations in the blood of the general adult population are around 3–5 times, and for mercury, 9 times higher than those in maternal blood in the various areas (Table 7.5). These facts can be explained, at least partially, by the

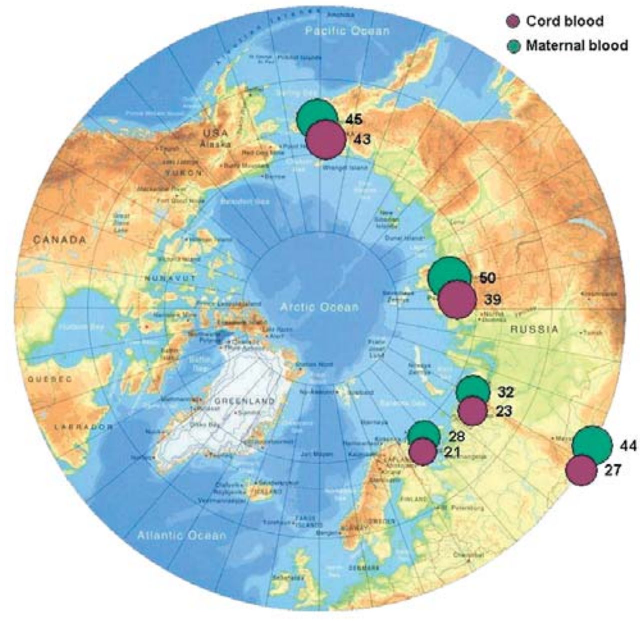


Figure 7.16. Levels of lead in maternal and cord blood in the Russian Arctic (geometric means, μg/L plasma).

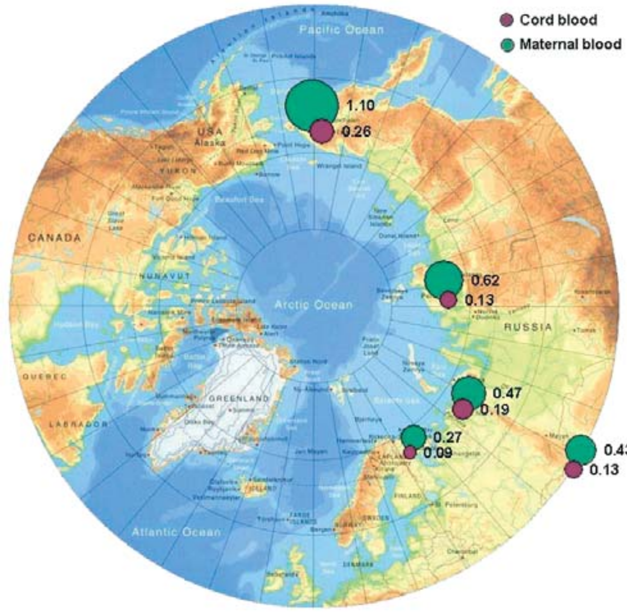


Figure 7.17. Levels of cadmium in maternal and cord blood in the Russian Arctic (geometric means, µg/L plasma).

transfer of pollutants from the mother to fetus through the placenta, although results obtained in this study clearly suggest that the placenta barrier inhibits, to varying extents, the free transport of certain pollutants to the fetus.

It should be noted that in the Chukchi AO, mean concentrations of POPs in the blood of inland indigenous peoples, from the Kanchalan area, are significantly lower than levels in the blood of coastal residents from the Uelen area. This serves as an additional argument that traditional foodstuffs, based on the higher trophic levels of marine food chains, are an important source of PTS intake for indigenous peoples.

7.4.2. Polychlorinated dibenzo-p-dioxins/furans (PCDD/F) in blood of the general adult indigenous population

Because of the small volume of the blood samples taken in the delivery departments of hospitals, and the extremely low concentrations present, it was not feasible to determine chemical compounds such as dioxins/furans (PCDD/Fs) and polybrominated diphnyl ethers (PBDEs) in maternal and cord blood. Studies of these compounds were, however, executed by analysis of pooled samples from the general adult indigenous population (Table 7.5.).

Table 7.5 includes the results of measurements of concentrations of PCDD/F in plasma samples from adults living in the Russian Arctic. Sums for the 17 most toxic dioxin and furan congeners are presented as international toxic equivalent (TEQ) values, in ng/L of plasma and pg/g lipids. The highest TEQ values were detected in the populations of Uelen (Chukchi AO) and Khatanga District (Taymir AO), with levels in the range 0.004-0.03 TEQ ng/L.

Results of PCDD/F analyses in blood samples are more illustrative when normalized to lipid content. Dioxin concentrations (as geometric means) in blood samples from adults of both genders in these regions are within the range 0.3–9.4 pg/g TEQ lipids. The highest concentrations detected in individual samples from the Chukchi and Taymir AOs are as much as 18.7 and 18.1 pg/g TEQ of lipids, respectively. Figure 7.18(a) illustrates the spatial distribution of PCDD/Fs in the areas of Russian Arctic under study.

In earlier studies, workers at facilities producing chlorine-containing pesticides were found to have diox-

Region	Chukchi AO		Kola peninsula		Nenets AO	Taymir AO
Compound	Kanchalan, n=30*	Uelen, n=50*	Krasnoshchelie, n=20*	Lovozero, n=20*	Nelmin-Nos, n=32*	Khatanga area, n=5*
In plasma:						
HCB	**0.6** (0.2-2.4)	**0.9** (0.1-3.4)	**0.8** (0.5-2.0)	**0.8** (0.2-1.7)	**0.8** (0.3-2.3)	**1.0** (0.6-1.9)
β-HCH	**0.7** (0.1-4.8)	**2.1** (0.2-8.2)	**0.7** (0.1-1.6)	**1.0** (n.d.-3.8)	**0.4** (0.1-2.5)	**1.0** (0.5-2.6)
ΣHCH	**0.7** (0.1-5.0)	**2.1** (0.2-8.2)	**0.8** (0.3-1.6)	**1.0** (n.d.-3.9)	**0.6** (0.2-2.6)	**1.0** (0.5-2.6)
Oxychlordane	**0.1** (n.d.-1.2)	**1.1** (0.1-9.7)	**0.01** (n.d.-0.1)	**0.02** (n.d.-0.1)	n.a.	**0.04** (n.d.-0.3)
p,p`-DDE	**1.4** (0.3-3.2)	**2.7** (0.5-8.3)	**2.6** (1.0-6.3)	**7.3** (1.1-45)	**1.6** (0.1-12)	**2.6** (1.0-4.2)
p,p`-DDT	**0.1** (n.d.-0.5)	**0.2** (n.d.-0.7)	**0.3** (0.1-0.8)	**0.7** (0.1-4.1)	**0.3** (n.d.-3.3)	**0.2** (0.04-0.5)
ΣDDT	**1.5** (0.4-3.4)	**2.9** (0.5-9.3)	**2.9** (1.1-6.7)	**8.2** (1.5-50)	**2.4** (0.4-16)	**2.9** (1.3-4.7)
ΣPCB	**1.3** (0.4-5.6)	**6.8** (0.9-34)	**2.1** (1.1-5.2)	**3.0** (0.8-6.5)	**1.6** (0.5-29)	**2.3** (1.2-4.7)
ΣToxaphenes	**0.03** (n.d.-0.2)	**0.3** (0.1-1.6)	**0.04** (0.01-0.2)	**0.06** (0.02-0.5)	**0.2** (n.d.-0.9)	**0.09** (0.05-0.2)
Lipid, %	**0.2** (0.1-0.3)	**0.5** (0.3-0.8)	**0.3** (0.2-0.5)	**0.3** (0.2-0.6)	**0.3** (0.2-0.5)	**0.3** (0.2-0.8)
In whole blood:						
Cd	**1.0** (n.d.-4.6)	**n.a.**	**0.5** (0.1-1.2)	**0.5** (n.d.-1.2)	**0.8** (0.2-3.0)	**1.0** (0.5-1.8)
Pb	**62** (16-196)	**n.a.**	**45** (14-165)	**33** (12-102)	**47** (17-184)	**90** (50-140)
Hg	**6.1** (n.d.-29)	**n.a.**	**7.1** (n.d.-29)	**3.7** (1.0-12)	**1.8** (0.5-4.6)	**3.1** (1.0-7.5)
In plasma:						
PCDD/F (TEQ, ng/L)	**0.003** (n.d.-0.06)	**0.004** (n.d.-0.11)	**0.002** (n.d.-0.06)	**0.01** (n.d.-0.08)	**0.001** (n.d.-0.07)	**0.03** (0.01-0.1)
PCDD/F (TEQ, pg/g lipid)	**0.8** (n.d.-10.6)	**1.1** (n.d.-18.7)	**0.5** (n.d.-10.2)	**1.6** (n.d.-14.9)	**0.3** (n.d.-14.6)	**9.4** (4.5-18.1)
ΣPBDEs (ng/L)	**1.4** (0.2-7.6)	**0.8** (0.3-4.1)	**5.1** (2.0-10.7)	**2.0** (0.3-6.6)	**1.4** (0.3-4.2)	**0.8** (0.4-2.0)
ΣPBDEs ((pg/g lipid)	**307** (25-2800)	**231** (70-1047)	**934** (375-1747)	**441** (45-1155)	**408** (70-843)	**115** (20-615)
Lipid, %	**0.3** (0.2-0.5)	**0.3** (0.2-0.6)	**0.4** (0.3-0.6)	**0.4** (0.3-0.6)	**0.3** (0.2-0.5)	**0.3** (0.2-0.5)

Table 7.5 Concentrations (geometric mean and range; µg/L unless otherwise indicated) in plasma and whole blood of indigenous adults from the Russian Arctic.
* For analyses of PCDD/Fs and PBDEs in plasma, n = 9, 6, 3, 4, 6, and 10 for Kanchalan, Uelen, Krasnoschel'e, Lovozero, Nelim-Nos, and Khatanga area, respectively.
n. d. – not detected; n. a. – not availiable.

in/furan levels ranging from 128-465 pg/g TEQ of lipids (Neuberger *et al.,* 1999; Amirova and Kruglov, 1998); firemen working in situations where chlorine-containing materials have been burnt were reported to have 12.9 pg/g TEQ of lipids (Schecter *et al.*, 1999a); and incinerator workers, 11.3-831.9 pg/g TEQ of lipids (Watanabe *et al.*, 1999).

For comparative purposes, dioxin levels for populations of various towns in Russia, as well as for some other countries, are provided below. The highest levels of dioxins in blood were observed in women living near to a pesticide plant in Chapaevsk. Here, mean values of dioxins in blood were 27–75 pg/g TEQ (Revich *et al.*, 1996). Recorded dioxin levels in Bashkiria rural areas were 24.8 and 39.8 pg/g TEQ of lipids, respectively (Amirova & Kruglov, 1998). In the Irkutsk Oblast, levels of 14.8–37.3 pg/g TEQ of lipids were found (Schecter *et al.*, 1999a), whilst residents of the Sverdlovsk region were found to have 21.7–64.4 pg/g TEQ of lipids (Amirova and Kruglov, 1998). Mean concentrations of dioxins in blood from residents of other countries have been reported as follows: 16 pg/g TEQ of lipids in Furuoka, Japan (Matsueda *et al.,* 1999), 17-57 pg/g of TEQ of lipids in Vietnam (Schecter *et al.*, 1999b), and 18.2 pg/g of TEQ of lipids in Germany (Papke *et al.,* 1999).

The highest concentrations of PCDD/Fs recorded in human blood in the northern regions of Russia (about 25 pg/g TEQ of lipids) are, therefore, close to the minimum concentrations observed for residents of industrial regions elsewhere. Furthermore, the most toxic dioxins (the tetra- and penta-substituted dioxins) which are typically detected in the blood of workers at hazardous facilities, were not detected in people living in the Russian North. Compounds that were detected include primarily the octa- and hepta-dioxins, which are normally found in background environmental samples. The single exception was one sample which showed the presence of pentachlorofuran, although only at the detection limit level.

In all pooled samples, the sum of dioxins was more than 1 pg/g TEQ of lipids (1.5–15.4 pg/g TEQ of lipids) due to dibenzofurans detected in blood.

7.4.3. Polybrominated diphenyl ethers in blood of the general adult indigenous population

PBDE and PCDD/F were determined using the same pooled blood samples taken from the adult population as those analyzed for dioxins/furans. Results of blood analysis for PBDE (showing the geometric mean and range of concentrations) in adults are presented in Table 7.5.

Maximum mean concentrations of PBDE were found in blood samples from adults from Krasnoshchelie on the Kola Peninsula (with a mean of 934 pg/g lipids and range of 375–1747 pg/g lipids). The lowest concentrations were associated with blood samples from populations within the Taymir AO.

Comparing concentrations of PBDEs and PCDD/F in blood samples of the adult population in the four regions of the Russian North, reveals a significant difference in the distribution of these contaminants. This is especially so when considering the Taymir region, the Nenets AO (Nelmin-Nos), and the Kola Peninsula (Krasnoshchelie). Whereas dioxin concentrations detected in blood samples of populations from Taymir were the highest, ranging from 9.4–5.0 pg/g of lipids in Khatanga district and in coastal settlements of Khatanga, PBDE concentrations in those regions were the lowest. Conversely, where dioxin concentrations were lowest, in blood samples from the adult population of Krasnoshchelie (0.5 pg /g lipids) and the Nenets AO (0.3 pg/g of lipids), PBDE concentrations were greatest.

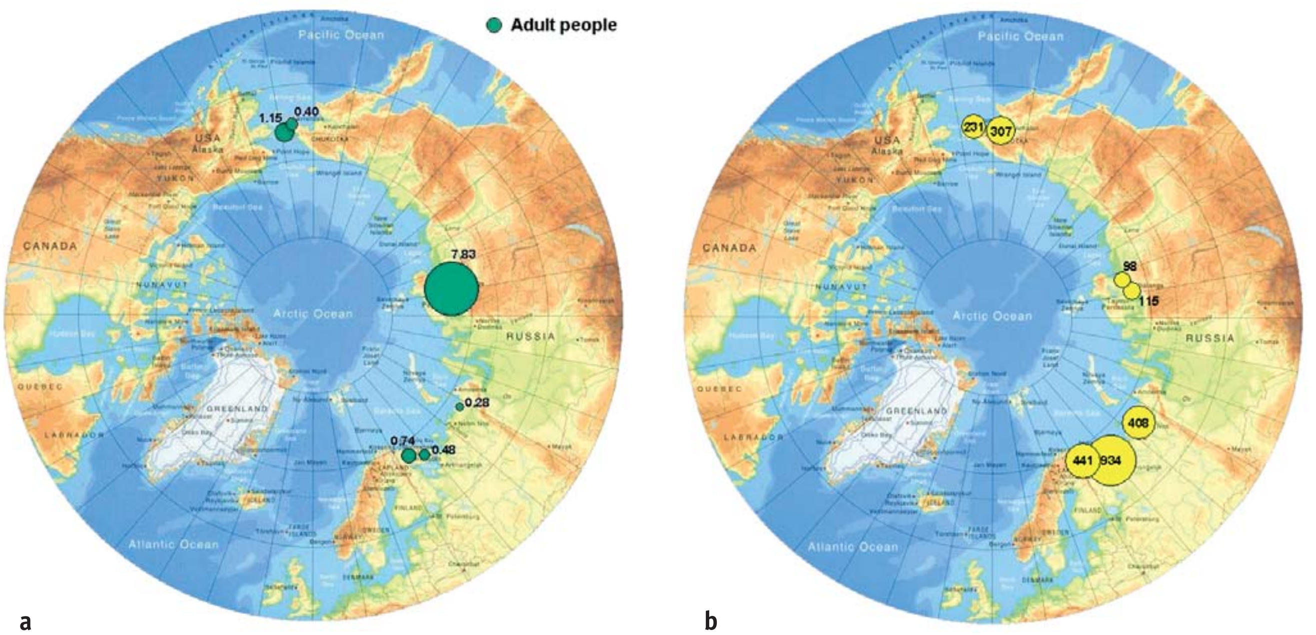


Figure 7.18. Levels of (a) PCDD/F (geometric means; pg/g TEQ of lipids), and (b) PBDE (geometric means; pg/g of lipids) in plasma of adults in Russian Arctic.

Table 7.6.
Concentrations (μg/L) of PCB congeners in breast milk in the Chukchi AO.
n.d. – not detected

PCB Congener (IUPAC)	Chukotsky District n=27	Anadyrsky District n=21	Town of Anadyr n=7	Control n=5
PCB 28/31 [CL3]	0.22 (0.06 – 0.45)	0.11 (0.02 – 0.32)	0.15 (0.09 – 0.37)	0.13 (0.07 – 0.19)
PCB 52 [CL4]	0.10 (0.03 - 0.81)	0.05 (n.d. – 1.24)	0.04 (0.01 – 0.10)	0.04 (0.02 – 0.07)
PCB 99 [CL5]	1.74 (0.22 - 4.83)	0.23 (0.09 – 0.54)	0.40 (0.27 – 0.71)	0.42 (0.28 – 0.66)
PCB 101 [CL5]	0.18 (0.03 - 0.55)	0.04 (n.d. – 0.28)	0.04 (0.003 –0.09)	0.04 (0.03 – 0.08)
PCB 105 [CL5]	0.42 (n.d. – 1.41)	0.06 (n.d. – 0.23)	0.12 (0.08 – 0.21)	0.15 (0.11 – 0.22)
PCB 118 [CL5]	1.89 (0.28 -7.33)	0.25 (n.d. – 0.83)	0.46 (0.35 – 0.67)	0.56 (0.44 – 0.72)
PCB 128 [CL6]	0.02 (n.d. – 0.08)	0.01 (n.d. – 0.05)	0.01 (n.d. – 0.03)	0.01 (n.d. – 0.02)
PCB 138 [CL6]	1.53 (0.25 – 5.63)	0.27 (0.12 – 0.61)	0.47 (0.32 – 0.59)	0.60 (0.28 – 0.89)
PCB 153 [CL6]	6.80 (0.60 – 34.44)	0.69 (n.d. – 2.48)	1.35 (0.75 – 3.72)	1.17 (0.73 – 2.11)
PCB 156 [CL6]	0.33 (n.d. – 3.70)	0.10 (n.d. – 0.34)	0.22 (0.14 – 0.43)	0.11 (n.d. – 0.45)
PCB 170 [CL7]	0.62 (0.08 – 2.26)	0.13 (0.06 – 0.48)	0.17 (0.11 – 0.48)	0.22 (0.15 – 0.31)
PCB 180 [CL7]	1.09 (0.13 – 3.76)	0.21 (0.09 – 0.77)	0.27 (0.17 – 0.86)	0.32 (0.21 – 0.41)
PCB 183 [CL7]	0.18 (n.d. – 0.69)	0.04 (0.02 – 0.12)		

PBDEs have only been identified as an environmental contaminant relatively recently and, therefore, information regarding human contamination by PBDEs, epecially in remote areas, is limited. Concentrations of PBDE in pooled blood samples of people aged 40-50 years from Norway (based on the sum of BDE-28, -47, -100, -99, -153 and -154) (Thomsen *et al.*, 2001) show values of 500 pg/g lipids in 1977, 1000 pg/g lipids in 1981, approximately 2000 pg/g lipids in 1990, and over 3000 pg/g lipids in 1995-1999.

Compared to the PBDE levels provided by Thomsen *et al.* (2001), maximum PBDE concentrations in blood samples of the adult population in Krasnoshchelie, on the Kola Peninsula (934 pg/g lipids), correspond to those found in Norway in 1981. However, levels approaching the PBDE concentrations found in blood samples from populations in Norway from 1990–1999, were detected in individual blood samples. Individual samples from Kanchalan (Chukotka), had levels of 2800 pg/g lipids, from Krasnoshchelie (Kola Peninsula), 1747 pg/g lipids, and from Lovozero (Kola Peninsula),1155 pg/g lipids.

The spatial distribution of PBDEs in the Russian Arctic Figure 7.18(b) suggests that contamination levels are determined by trans-boundary transport. Higher concentrations are observed in the easternmost (Chukchi AO) and westernmost (Kola peninsula) areas of the Russian Arctic, closest to the source areas of North America and Europe, respectively. PBDE levels measured in blood samples in the central regions are either below, or close to the detection limit. Taking into account that PBDEs are relatively recent contaminants

Table 7.7.
Concentrations (μg/L) of chlorinated pesticides in breast milk in the Chukchi AO.
n.d. – not detected

Compound	Chukotsky District n=27	Anadyrsky District n=21	Town of Anadyr n=7	Control n=5
HCB	**7.79** (1.85 – 27.27)	**2.12** (0.48 – 14.14)	**2.62** (1.89 – 5.27)	**1.45** (0.82 – 3.87)
α-HCH	**0.19** (n.d. – 0.64)	**0.05** (n.d. – 0.25)	**0.16** (0.09 – 0.22)	**0.12** (.,06 – 0.21)
β-HCH	**11.59** (2.60 – 59.10)	**2.36** (0.12 – 7.51)	**6.46** (3.64 – 14.28)	**3.33** (2.03 – 11.95)
γ-HCH	**0.02** (n.d. – 0.17)	**0.004** (n.d. – 0.06)	**0.03** (0.02 – 0.05)	**0.005** (n.d. – 0.033)
ΣHCH	**11.88** (2.68 – 59.81)	**2.49** (0.19 – 7.66)	**6.68** (3.89 – 14.48)	**3.49** (2.24 – 12.15)
Heptachlor	**0.01** (n.d. – 0.39)	**n.d.**	**0.002** (n.d. – 0.03)	**n.d.**
Heptachlor epoxide	**0.46** (n.d. – 2.16)	**0.004** (n.d. – 0.14)	**0.05** (n.d. – 0.15)	**0.01** (n.d. – 0.08)
Oxychlordane	**6.35** (0.34 – 43.33)	**0.14** (n.d. – 1.31)	**0.51** (0.18 – 1.65)	**0.09** (0.04 – 0.12)
***trans*-Chlordane**	**0.003** (n.d. – 0.06)	**n.d.**	**0.002** (n.d. – 0.035)	**n.d.**
***cis*-Chlordane**	**0.27** (0.01 – 1.96)	**0.01** (n.d. – 0.10)	**0.02** (n.d. – 0.15)	**0.003** (n.d. – 0.010)
ΣChlordanes	**6.66** (0.35 – 45.36)	**0.14** (n.d. – 1.41)	**0.56** (0.19 – 1.66)	**0.09** (0.04 – 0.13)
Dieldrin	**0.47** (n.d. – 3.62)	**0.01** (n.d. – 0.33)	**0.09** (0.04 – 0.15)	**0.02** (n.d. – 0.09)
***o,p`*-DDE**	**0.01** (n.d. – 0.07)	**0.003** (n.d. – 0.04)	**0.03** (0.01 – 0.05)	**0.01** (n.d. – 0.02)
***p,p`*-DDE**	**7.70** (2.10 – 17.70)	**4.27** (1.64 – 12.71)	**10.90** (7.69 – 17.84)	**10.19** (2.15 – 23.26)
***o,p`*-DDD**	**0.004** (n.d. – 0.21)	**0.003** (n.d. – 0.12)	**0.01** (n.d. – 0.09)	**0.02** (n.d. – 0.20)
***p,p`*-DDD**	**0.19** (0.06 – 0.86)	**0.15** (0.02 – 1.00)	**0.51** (0.21 – 1.62)	**0.25** (0.16 – 0.42)
***o,p`*-DDT**	**0.02** (n.d. – 0.65)	**0.01** (n.d. – 0.45)	**0.14** (0.03 – 0.42)	**0.01** (n.d. – 0.06)
***p,p`*-DDT**	**0.62** (0.11 – 2.67)	**0.58** (0.19 – 1.86)	**1.89** (1.18 – 2.88)	**0.56** (0.36 – 0.81)
ΣDDT	**8.77** (2.40 – 19.85)	**5.12** (1.97 – 15.60)	**13.64** (10.21 – 22.85)	**11.25** (2.67 – 24.42)
Mirex	**0.32** (n.d. – 2.71)	**0.01** (n.d. – 0,20)	**0,01** (n.d. – 0,15)	**n.d.**
***trans*-Nonachlor**	**4,13** (0,52 – 15,08)	**0,26** (0,069 – 0,66)	**0,68** (0,32 – 2,16)	**0,20** (0,03 – 1,78)
***cis*-Nonachlor**	**0,46** (0,08 – 1,75)	**0,04** (n.d. – 0.13)	**0.09** (0.05 – 0.26)	**0.03** (0.02 – 0.10)
Parlar 26	**0.64** (0.06 – 4.83)	**0.04** (0.001 – 0.18)	**0.08** (0.04 – 0.21)	**0.02** (0.004 – 0.06)
Parlar 50	**0.74** (0.07 – 4.01)	**0.07** (0.001 – 0.25)	**0.14** (0.08 – 0.26)	**0.06** (0.01 – 0.27)
Parlar 62	**0.003** (n.d. – 0.10)	**n.d.**	**n.d.**	**n.d.**
ΣToxaphenes	**1.41** (0.14 – 8.84)	**0.11** (0.002 – 0.42)	**0.23** (0.12 – 0.47)	**0.09** (0.01 – 0.33)
Weight, g	**23.0** (11.4 – 33.4)	**22.9** (4.4 – 35.1)	**21.4** (14.9 – 32.6)	**25.7** (23.4 – 33.6)
Lipid, %	**3.14** (0.67 – 5.55)	**2.51** (0.62 – 4.86)	**3.26** (1.86 – 4.78)	**3.38** (2.33 – 6.69)

Table 7.8.
Concentrations (ng/g lipids) of PCB in breast milk in the Chukchi AO.
n.d. – not detected

PCB Congener (IUPAC)	Chukotsky District n=27	Anadyrsky District n=21	Town of Anadyr n=7	Control n=5
PCB 28/31 [CL3]	**7.04** (2.50 – 33.81)	**4.48** (1.24 – 16.43)	**4.46** (2.34 – 9.14)	**3.81** (2.55 – 5.27)
PCB 52 [CL4]	**3.03** (0.87 – 25.48)	**1.93** (0.60 – 50.67)	**1.29** (0.56 – 2.38)	**1.18** (0.52 – 2.75)
PCB 99 [CL5]	**55.35** (12.87 – 158.61)	**9.12** (4.25 – 21.62)	**12.34** (8.28 – 17.44)	**12.30** (4.12 – 28.37)
PCB 101 [CL5]	**4.78** (1.63 – 13.89)	**1.50** (0.18 – 8.78)	**1.15** (0.17 – 2.63)	**1.22** (0.49 – 2.94)
PCB 105 [CL5]	**13.60** (n.d. – 31.26)	**2.66** (n.d. – 32.58)	**3.80** (3.00 – 4.53)	**4.44** (1.94 – 6.16)
PCB 118 [CL5]	**60.25** (18.90 – 159.98)	**9.94** (n.d. – 44.01)	**14.09** (10.78 – 21.35)	**16.65** (8.23 – 20.74)
PCB 128 [CL6]	**0.52** (n.d. – 2.72)	**0.26** (n.d. – 1.34)	**0.32** (n.d. – 0.88)	**0.21** (n.d. – 0.70)
PCB 138 [CL6]	**48.82** (11.59 – 135.06)	**10.95** (4.84 – 38.12)	**14.51** (9.33 – 22.70)	**17.75** (4.26 – 37.99)
PCB 153 [CL6]	**216.76** (34.85 – 1252.46)	**27.39** (15.44 – 95.59)	**41.42** (20.94 – 91.28)	**34.63** (10.91 – 58.84)
PCB 156 [CL6]	**9.96** (n.d. – 66.69)	**4.18** (n.d. – 19.04)	**6.82** (4.08 – 10.50)	**3.03** (n.d. – 12.62)
PCB 170 [CL7]	**19.69** (1.86 – 82.04)	**5.28** (2.08 – 18.72)	**5.19** (2.77 – 11.72)	**6.66** (2.29 – 9.28)
PCB 180 [CL7]	**34.81** (5.23 – 121.58)	**8.25** (4.31 – 33.45)	**8.16** (3.90 – 21.23)	**9.47** (3.10 – 14.07)
PCB 183 [CL7]	**5.39** (n.d. – 17.25)	**1.53** (0.80 – 5.91)	**1.81** (0.97 – 3.73)	**2.01** (0.63 – 3.41)
PCB 187 [CL7]	**16.74** (3.83 – 50.99)	**3.34** (0.14 – 15.73)	**4.48** (2.20 – 11.66)	**3.78** (1.13 – 7.15)
ΣPCB	**521.73** (116.63 – 1702.32)	**97.90** (49.60 – 345.20)	**123.95** (75.62 – 213.79)	**23.34** (43.11 – 169.51)
Weight, g	**23.0** (11.4 – 33.4)	**22.9** (4.4 – 35.1)	**21.4** (14.9 – 32.6)	**25.7** (23.4 – 33.6)
Lipid, %	**3.14** (0.67 – 5.55)	**2.51** (0.62 – 4.86)	**3.26** (1.86 – 4.78)	**3.38** (2.33 – 6.69)

of anthropogenic origin, and that information on their production and use in Russia is not yet available, it has been suggested that PBDEs, used mainly in the industrial developed countries as flame retardants, have the potential to become a new PTS representing a circumpolar hazard, if urgent measures are not taken to limit their production and use.

7.5. POPs in breast milk

7.5.1. POPs levels in breast milk and their correlation with blood levels

A total of 60 samples of breast milk were analyzed for POPs. The samples were collected from different areas of the Chukchi AO: Chukotsky District (27 samples), Anadyrsky District (21 samples), and the town of Anadyr (7 samples). Samples were from the same mothers who participated in the blood study at delivery. 5 control samples from St. Petersburg were also collected and analyzed (Tables 7.6–7.9 and Figure 7.19a-d). Samples in which no POPs were detected were not included in tehdata resened, but represented less than 1% of all cases.

The highest levels of almost all POPs occur in the breast milk of women living in Chukotsky District. Compared to other areas of the Chukchi AO, concentrations were higher in Chukotsky by 3–6 times for HCB; 10–80 times for oxychlordane; up to 10 times for mirex, *trans-* and *cis*-nonachlor, and toxaphene; and 4–5 times for the sum of PCB congeners. Only for the DDT group of compounds were concentrations in breast milk similar in all areas studied within the Chukchi AO. It seems reason-

Table 7.9.
Concentrations (ng/g lipids) of chlorinated pesticides in breast milk in the Chukchi AO.
n.d. – not detected

Compound	Chukotsky District n=27	Anadyrsky District n=21	Town of Anadyr n=7	Control n=5
HCB	**248.5** (73.4 – 934.2)	**84.4** (28.1 – 546.1)	**80.3** (43.3 – 129.4)	**43.1** (31.0 – 108.0)
α-HCH	**5.6** (n.d. – 25.0)	**2.0** (n.d. – 19.3)	**4.9** (3.8 – 9.5)	**3.6** (2.2 – 5.0)
β-HCH	**369.8** (58.1 – 1598.4)	**94.2** (6.1 – 298.1)	**198.4** (100.0 – 505.0)	**98.7** (56.7 – 178.6)
γ-HCH	**0.7** (n.d. – 4.4)	**0.1** (n.d. – 1.6)	**0.9** (0.4 – 2.5)	**0.2** (n.d. – 1.1)
ΣHCH	**378.9** (59.9 – 1627.8)	**99.4** (9.6 – 308.0)	**204.9 (104.3 – 516.9)**	**103.4** (62.5 – 181.6)
Heptachlor	**0.2** (n.d. – 10.4)	**n.d.**	**0.05** (n.d. – 0.66)	**n.d.**
Heptachlor epoxide	**13.9** (n.d. – 99.0)	**0.2** (n.d. – 3.6)	**1.7** (n.d. – 3.8)	**0.2** (n.d. – 2.6)
Oxychlordane	**202.6** (19.4 – 1070.0)	**5.3** (n.d. – 50.6)	**15.6** (6.4 – 36.9)	**2.5** (0.7 – 5.4)
trans-Chlordane	**0.1** (n.d. – 1.6)	**0.0 (n.d. – 0.2)**	**0.1** (n.d. – 1.0)	**n.d.**
cis-Chlordane	**8.6** (0.6 – 73.5)	**0.2** (n.d. – 3.7)	**0.5** (n.d. – 3.8)	**0.1** (n.d. – 0.3)
ΣChlordanes	**212.5** (20.0 – 1099.2)	**5.3** (n.d. – 54.3)	**17.0** (8.1 – 40.7)	**2.6** (0.7 – 5.6)
Dieldrin	**15.1** (n.d. – 106.4)	**0.2** (n.d. – 12.1)	**2.6** (1.3 – 3.8)	**0.7** (n.d. – 3.3)
o,p`-DDE	**0.4** (n.d. – 2.1)	**0.1** (n.d. – 1.7)	**0.8** (0.4 – 1.5)	**0.3** (n.d. – 0.7)
p,p`-DDE	**245.6** (132.6 – 812.1)	**170.0** (53.8 – 768.7)	**334.5** (186.1 – 553.5)	**302.0** (80.7 – 998.5)
o,p`-DDD	**0.1** (n.d. – 7.5)	**0.1** (n.d. – 5.8)	**0.4** (n.d. – 2.2)	**0.6** (n.d. – 5.7)
p,p`-DDD	**6.0** (2.2 – 18.8)	**6.0** (0.9 – 33.4)	**15.6** (8.1 – 35.1)	**7.3** (5.9 – 10.7)
o,p`-DDT	**0.7** (n.d. – 15.5)	**0.4** (n.d. – 9.3)	**4.3** (1.1 – 9.1)	**0.4** (n.d. – 2.5)
p,p`-DDT	**19.7** (2.8 – 74.9)	**23.3** (4.9 – 159.8)	**58.1** (24.8 – 87.1)	**16.5** (5.3 – 34.9)
ΣDDT	**279.7** (150.3 – 910.6)	**204.3** (62.5 – 934.0)	**418.6** (224.4 – 664.6)	**333.2** (100.0–1048.2)
Mirex	**9.9** (n.d. – 61.7)	**0.5** (n.d. – 7.6)	**0.4** (n.d. – 3.7)	**n.d.**
trans-Nonachlor	**131.7** (24.7 – 594.8)	**10.4** (1.8 – 25.5)	**20.8** (10.4 – 53.0)	**6.0** (1.2 – 76.5)
cis-Nonachlor	**14.5** (1.9 – 80.3)	**1.5** (n.d. – 4.7)	**2.9** (1.6 – 6.5)	**1.0** (0.2 – 3.3)
Parlar 26	**20.5** (3.6 – 105.4)	**1.5** (0.03 – 5.2)	**2.5** (1.1 – 5.3)	**0.7** (0.1 – 2.1)
Parlar 50	**23.7** (4.3 – 111.9)	**2.8** (0.04 – 8.7)	**4.4** (3.2 – 6.3)	**1.9** (0.1 – 9.0)
Parlar 62	**0.1** (n.d. – 1.9)	**n.d.**	**n.d.**	**n.d.**
ΣToxaphenes	**45.1** (7.9 – 212.6)	**4.3** (0.1 – 12.2)	**7.0** (4.3 – 11.5)	**2.6** (0.2 – 11.1)
Weight, g	**23.0** (11.4 – 33.4)	**22.9** (4.4 – 35.1)	**21.4** (14.9 – 32.6)	**25.7** (23.4 – 33.6)
Lipid, %	**3.14** (0.67 – 5.55)	**2.51** (0.62 – 4.86)	**3.26** (1.86 – 4.78)	**3.38** (2.33 – 6.69)

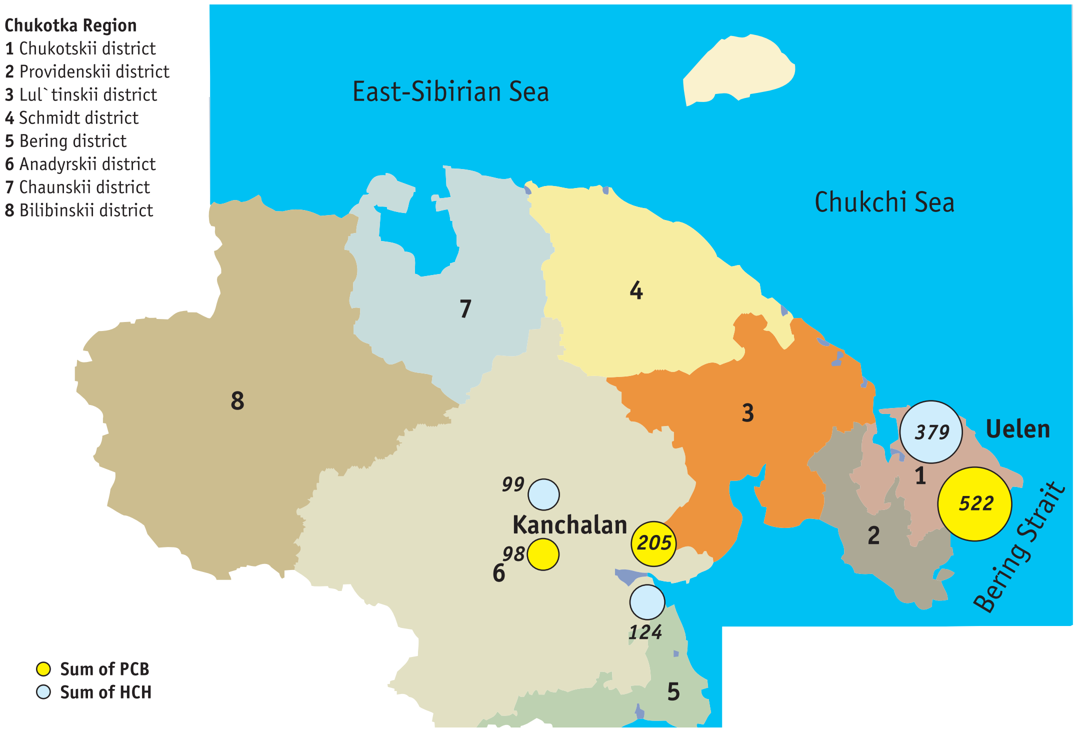


Figure 7.19a.
Levels of PCB and HCH (ng/g lipid) in breast milk of women from various areas of the Chukchi AO.

able to suggest, therefore, that women living in all areas in the Chukchi AO are exposed to a common source of intake for DDT and related compounds.

The results obtained were also compared with levels of breast milk contamination reported for women from Nunavik, Canada (1996–2000), and the Russian Arctic (AMAP, 2002, 2003a; Chashchin *et al.*, 2002).

PCBs

Concentrations of the sum of 14 congeners of PCB in breast milk of women from Chukotsky District are comparable or slightly higher than those in Nunavik, Canada (386 ng/g lipid in Canada compared to 521 ng/g lipid in breast milk from Chukotsky District). The concentrations of individual PCB congeners (118, 138, 153, and 180) detected in breast milk in the towns of Kargopol, Severodvinsk, Arkhangelsk, and Naryan-Mar, occur at levels intermediate to those found in breast milk in Chukotsky District and those reported for other areas of the Chukchi AO.

HCB

Concentrations of hexachlorobenzene (HCB) in breast milk from Chukotsky District, not only exceed those in other areas of the Chukchi AO, but are also 2–5 times

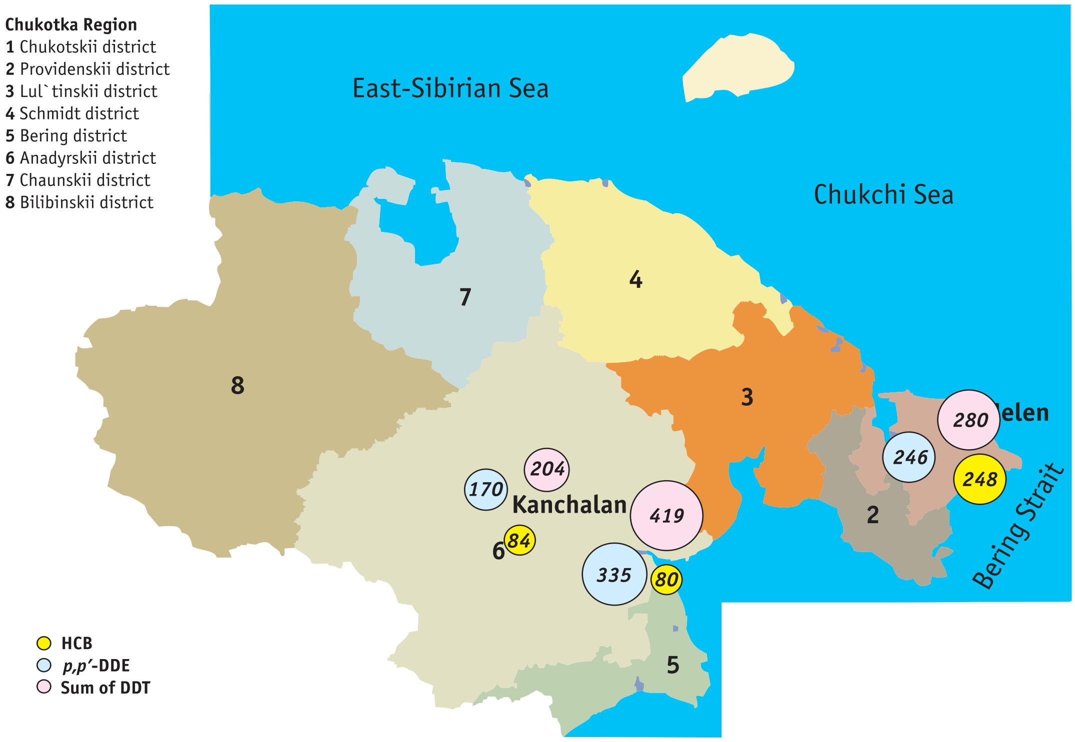
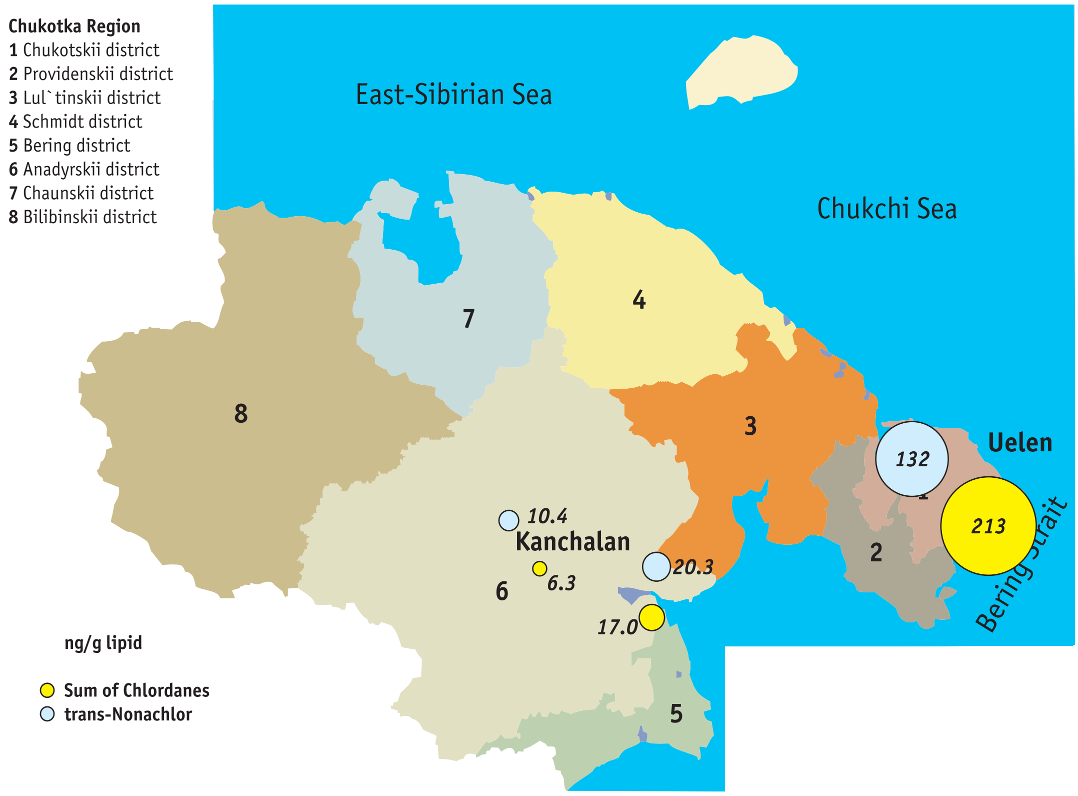


Figure 7.19b.
Levels of HCB and DDT (ng/g lipid) in breast milk of women from various areas of the Chukchi AO.

Figure 7.19c.
Levels of Chlordanes (ng/g lipid) in breast milk of women from various areas of the Chukchi AO.



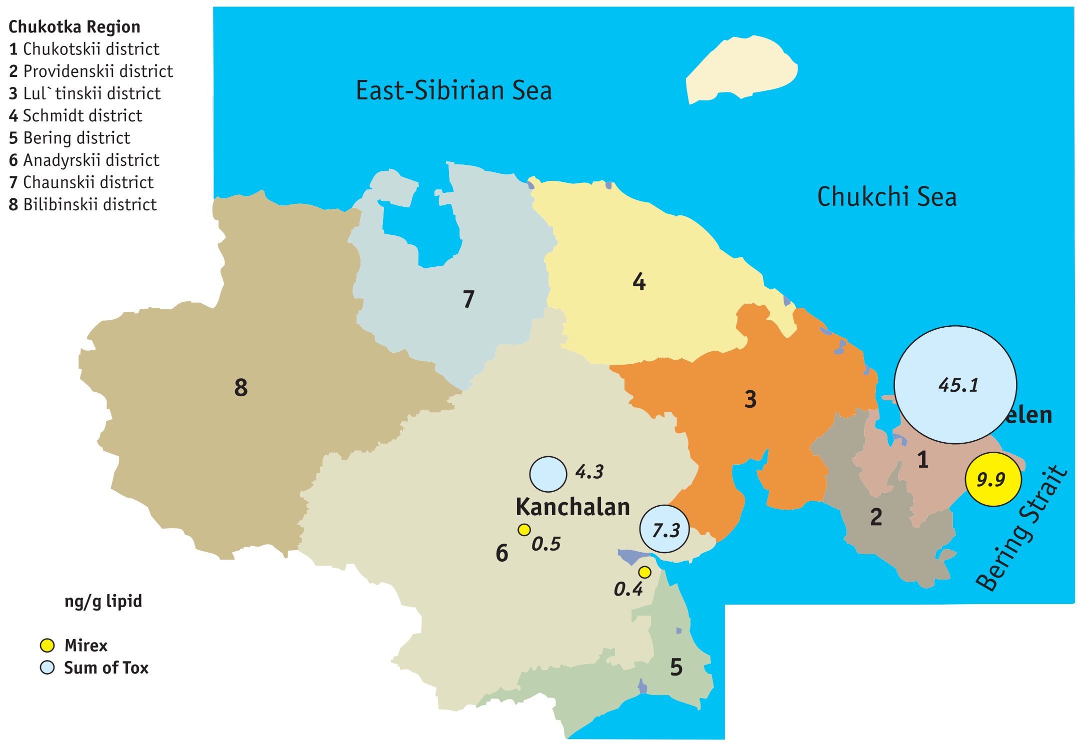
higher than levels reported in Nunavik, Canada, and other northern towns of Russia (AMAP, 2002). Elsewhere in the Russian North, Norilsk (with a geometric mean of 123 ng/g lipids, and range of 29-387 ng/g lipids) shows the closest concentrations of HCB in breast milk to those found in Chukotsky District.

β-HCH

Levels of β-HCH in breast milk of women from the Chukchi AO are distributed in a similar pattern to HCB. Specifically, the highest levels occur in breast milk from Chukotsky rayon (with a mean value of 370 ng/g lipids). Levels are lower, although still relatively high, in the town of Anadyr (198 ng/g lipids). Similar values for β-HCH concentrations in milk are found in Anadyr district (94 ng/g lipids), and also in the control site, St. Petersburg (98 ng/g lipids), however, the range is greater for samples from Anadyrsky District.

Concentrations of β-HCH in breast milk from Chukotsky District exceed levels detected in other areas of the Chukchi AO and other northern towns of

Figure 7.19d.
Levels of Mirex and toxaphene (ng/g lipid) in breast milk of women from various areas of the Chukchi AO.



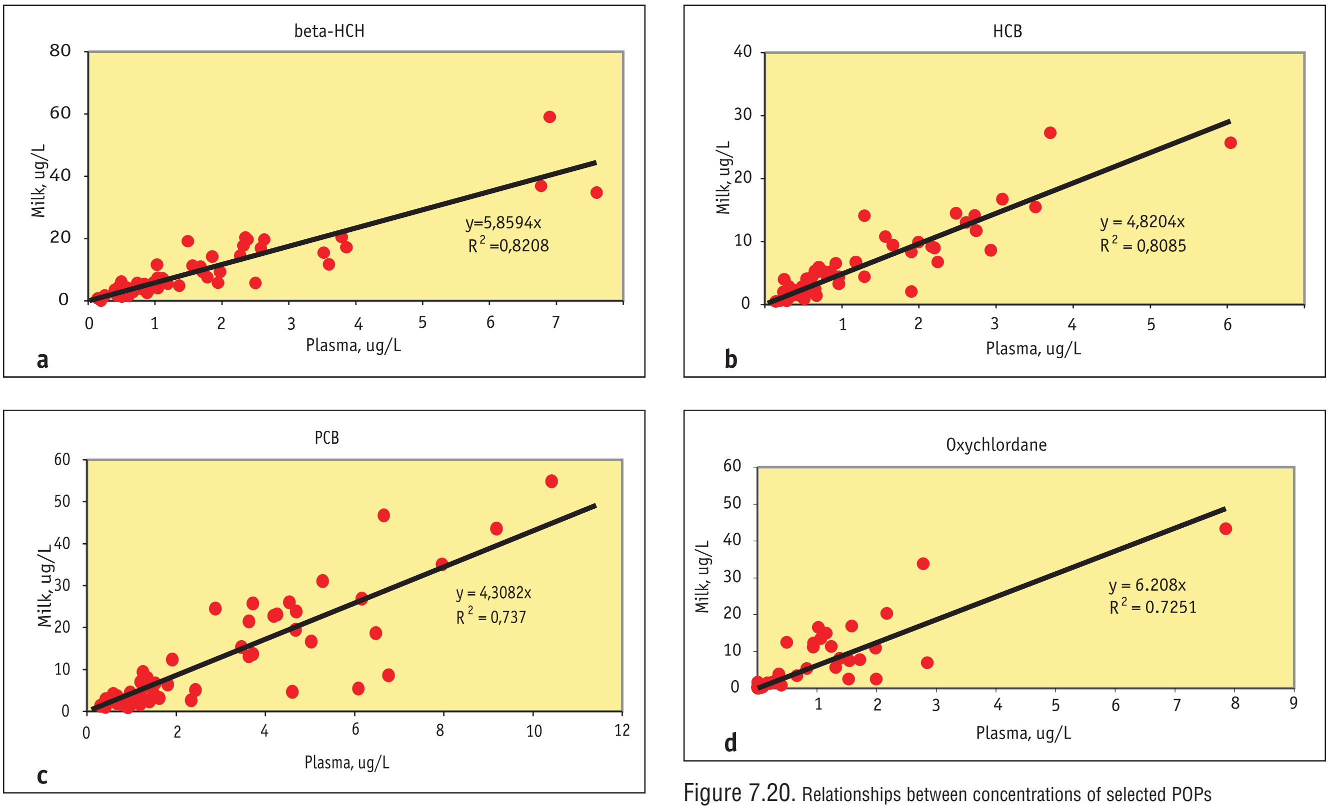


Figure 7.20. Relationships between concentrations of selected POPs in breast milk and plasma of indigenous women of the Chukchi AO.

Russia, as well as levels in Nunavik, Canada (by 30 times). The closest β-HCH breast milk concentrations to those in Chukotsky District, were those found in Arkhangelsk (arithmetic mean of 401 ng/g lipids) and Norilsk (geometric mean of 142 ng/g lipids).

Data from 1984 (Bobovnikova, 1987), include mean levels of total HCH in breast milk samples for various regions of the USSR. For example, total HCH in breast milk was 46 µg/L in Moscow, 66 µg/L in Rostov-on-Don, and 53 µg/L in Baikalsk; mean values were 51 µg/L for Uzbekistan; 136 µg/L for Djambaisky District (an area subject to intense OCP application), and 86 µg/L in 'clean' areas of Uzbekistan. By comparison, total HCH concentrations in breast milk samples from the Chukotka area, found in the current study are much lower, at 2.5–11.8 µg/L (Table 7.7).

Oxychlordane

Oxychlordane is the dominant component in total chlordanes in breast milk. Oxychlordane concentrations in breast milk from Chukotsky District (203 ng/g lipids) are higher than those found in breast milk from northern Canada (Nunavik; 81 ng/g lipids), and exceed concentrations in breast milk from other towns of the Russian North and other districts of the Chukchi AO by 10-100 times.

Distributions of mirex and *trans-* and *cis*-nonachlor are similar. Highest levels of these compounds were also found in breast milk from women in northern Canada (Nunavik) and in Chukotsky District.

DDT

As discussed above, concentrations of DDT and its metabolites in breast milk in different areas of the Chukchi AO are very similar; DDE concentrations range from 245–334 ng/g lipids) and are lower than levels reported in northern Canada (Nunavik; 420 ng/g lipids) (AMAP, 2002). The DDE/DDT ratio ranges from 6 to 18, with the ratio found in samples of breast milk in the town of Anadyr, and in Anadyrsky District of the Chukchi AO, being close to those of industrial cities of the Russian North (e.g., Norilsk, Salekhard, and Dudinka); the ratio found in Chukotsky District, and the control samples are close to those of non-industrial regions of Taymir and Yamal.

The 2003 UNEP/GEF global PTS assessment (UNEP, 2003) presents data on concentrations of DDT and its metabolites in breast milk for different regions of the world. The highest reported levels are those fo China (DDE concentrations of 2850 ng/g lipids, and DDT concentrations of 700 ng/g lipids), which may be explained by continuing use of large amounts of DDT in the region.

The concentrations of total DDT and its metabolites reported previously for various regions of the USSR are as follows: 87 µg/L in Moscow, 128 µg/L in Rostov-on-Don, 45 µg/L in Baikalsk, 191 µg/L in areas of Uzbekistan where pesticides are actively used, and 84 µg/L in the 'clean' areas of Uzbekistan (Bobovnikova,1987). By comparison, total DDT in the areas of the Chukchi AO studied were 5.1 to 13.6 µg/L (Table 7.7).

Table 7.10.
Concentrations (ng/L) of polychlorinated dibenzo-p-dioxins and dibenzofurans in breast milk in the Chukchi AO.
n.d. - not detected

Compound	Chukchi AO: Chukotsky District, n=10	Chukchi AO: Anadyrsky District, n=7	Control (St. Petersburg), n=2
2,3,7,8-TCDD	**n.d.**	**n.d.**	**n.d.**
1,2,3,7,8-PeCDD	**0.13** (n.d. – 0.33)	**0.12** (n.d. – 0.32)	**n.d.**
1,2,3,4,7,8-HxCDD	**n.d.**	**n.d.**	**n.d.**
1,2,3,6,7,8- HxCDD	**0.16** (0.09 – 0.44)	**0.05** (n.d. – 0.17)	**0.05** (n.d. – 0.10)
1,2,3,7,8,9- HxCDD	**n.d.**	**n.d.**	**n.d.**
1,2,3,4,6,7,8-HpCDD	**0.21** (0.05 – 0.67)	**0.022** (0.09 – 0.38)	**0.18** (0.12 – 0.26)
OCDD	**1.54** (0.33 – 22.10)	**1.45** (0.65 – 5.03)	**1.56** (0.81 – 2.99)
2,3,7,8-TCDF	**0.04** (n.d. – 0.27)	**0.03** (n.d. – 0.17)	**n.d.**
1,2,3,7,8-PeCDF	**0.03** (n.d. – 0.11)	**n.d.**	**n.d.**
2,3,4,7,8-PeCDF	**0.23** (n.d. – 0.65)	**0.08** (n.d. – 0.24)	**0.18** (0.14 – 0.24)
1,2,3,4,7,8-HxCDF	**0.07** (n.d. – 0.26)	**0.04** (n.d. – 0.10)	**0.04** (0.04 – 0.05)
1,2,3,6,7,8- HxCDF	**0.06** (n.d. – 0.23)	**0.02** (n.d. – 0.05)	**0.03** (0.03 – 0.03)
2,3,4,6,7,8-HxCDF	**0.02** (n.d. – 0.31)	**n.d.**	**n.d.**
1,2,3,7,8,9-HxCDF	**0.02** (n.d. – 0.12)	**n.d.**	**n.d.**
1,2,3,4,6,7,8-HpCDF	**0.13** (n.d. – 1.00)	**0.04** (n.d. – 0.10)	**0.02** (n.d. – 0.03)
1,2,3,4,7,8,9-HpCDF	**0.02** (n.d. – 1.30)	**n.d.**	**n.d.**
OCDF	**0.56** (0.13 – 2.04)	**0.42** (0.23 – 0.56)	**0.61** (0.46 – 0.82)
Total Concentration in TEQ	**0.23** (0.14 – 0.71)	**0.07** (n.d. – 0.25)	**0.11** (0.08 – 0.14)
Weight, g	**21.97** (11.42 – 30.67)	**29.25** (24.78 – 32.97)	**28.65** (24.43 – 33.60)
Lipid, %	**2.96** (0.67 – 4.58)	**2.52** (0.62 – 4.86)	**3.09** (2.67 – 3.58)

As breast milk and blood samples were collected from the same women, it was possible to investigate the correlation between POP concentrations in these two body fluids. Figures 7.20 (a)-(d) show the associated relationships for a number of POPs.

As seen from Figure 7.20, statistically significant correlations exist between POP concentrations in breast milk and plasma, which can be used in dose and risk assessment when only one of these characteristics is measured. In general, POP concentrations in breast milk are about 4 to 6 times higher than in plasma. This difference corresponds reasonably well to the difference in lipid content of breast milk and plasma.

7.5.2. PCDD/F and PBDE levels in breast milk of indigenous women from the Chukchi AO

A total of 20 samples of breast milk were analyzed for PCDD/Fs and PBDEs. Samples were collected from Chukotsky District (10 samples), Anadyrsky District (7 samples), and Anadyr town (1 sample), as well as 2 control samples from St. Petersburg (Tables 7.10-7.13). The highest average concentrations of total PCDD/Fs were found in breast milk samples from Chukotsky District (Figure 7.21), up to 7.66 pg/g, using the international toxic equivalent (TEQ) of lipids, i.e, 2–2.5 times higher than in samples from Anadyrsky District (2.70 pg/g) or the control area (3.47 pg/g). Maximum values of PCDD/F concentrations were equal to 21.3 pg/g lipids in Chukotsky District, 9.65 pg/g in Anadyrsky District, and 5.24 pg/g in control samples.

In other studies, low levels of mean PCDD/F concentrations in breast milk were detected in Bulgaria at 6.14 pg/g of lipids (range: 5.08–7.11), and highest levels in the Netherlands, at 18.3 pg/g (range: 17.1–21.3) (UNEP, 2003). In other European countries, reported values were 7.30 pg/g lipids (range: 7.16–7.43) in Norway, and 6.91 pg/g (range: 6.19–8.54) in Ireland.

Mean concentrations of dioxin in breast milk in Russia (2001–2002) were equal to 8.88 pg/g lipids, with a range of 7.46–12.93 pg/g (UNEP, 2003). The highest concentrations were detected in the breast milk of women living in towns involved with the production of organochlorine pesticides. For example, breast milk contamination by dioxins at levels of 43.3 pg/g lipids were determined in Chapaevsk (Revich *et al.*, 1996).

From these figures, mean dioxin and furan concentrations detected in the breast milk of women from the Chukotsky District, and in women from Norway and Ireland appear very similar and are lower than concentrations detected in northern and southern Quebec in Canada (CACAR,1997).

Table 7.11.
Concentrations (ng/L) of polybrominated diphenyl ethers in breast milk in the Chukchi AO.
n.d. – not detected

Compound	Chukchi AO: Chukotsky District. n=10	Chukchi AO: Anadyrsky District. n=7	Control (St. Petersburg), n=2
PBDE #28	**0.49** (n.d. – 1.41)	**0.23** (n.d. – 0.82)	**2.26** (1.07 – 4.77)
PBDE # 47	**7.66** (n.d. – 30.91)	**2.14** (0.85 – 3.85)	**34.28** (12.45 – 94.41)
PBDE # 99	**0.56** (n.d. – 2.32)	**0.62** (n.d. – 1.47)	**2.48** (0.93 – 6.59)
PBDE # 100	**0.60** (n.d. – 2.58)	**0.29** (n.d. – 0.78)	**2.60** (0.65 – 10.38)
PBDE # 153	**0.66** (n.d. – 7.26)	**n.d.**	**1.29** (n.d. – 4.15)
PBDE # 154	**n.d.**	**n.d.**	**0.69** (n.d. – 1.20)
PBDE # 183	**n.d.**	**n.d.**	**n.d.**
Sum	**10.55** (n.d. – 36.54)	**3.06** (0.85 – 6.71)	**42.83** (15.10 – 121.5)
Weight, g	**21.97** (11.42 – 30.67)	**29.25** (24.78 – 32.97)	**28.65** (24.43 – 33.60)
Lipid, %	**2.96** (0.67 – 4.58)	**2.52** (0.62 – 4.86)	**3.09** (2.67 – 3.58)

Compound	Chukchi AO		Control (St. Petersburg), n=2
	Chukotsky District, n=10	Anadyrsky District, n=7	
2,3,7,8-TCDD	n.d.	n.d.	n.d.
1,2,3,7,8-PeCDD	**4.75** (n.d. – 39.40)	**4.36** (n.d. – 12.40)	n.d.
1,2,3,4,7,8-HxCDD	n.d.	n.d.	n.d.
1,2,3,6,7,8- HxCDD	**5.31** (2.18 – 12.99)	**1.49** (n.d. – 6.14)	**1.93** (n.d. – 3.71)
1,2,3,7,8,9- HxCDD	n.d.	n.d.	n.d.
1,2,3,4,6,7,8-HpCDD	**7.18** (1.88 – 18.21)	**8.56** (2.37 – 35.32)	**5.78** (4.53 – 7.37)
OCDD	**51.90** (11.85 – 523.7)	**57.53** (17.34 – 177.4)	**50.40** (30.41 – 83.52)
2,3,7,8-TCDF	**1.19** (n.d. – 6.04)	**0.90** (n.d. – 6.50)	n.d.
1,2,3,7,8-PeCDF	**0.94** (n.d. – 2.70)	n.d.	n.d.
2,3,4,7,8-PeCDF	**6.77** (n.d. – 15.38)	**2.68** (n.d. – 8.63)	**5.87** (3.80 – 9.06)
1,2,3,4,7,8-HxCDF	**2.15** (n.d. – 6.16)	**1.19** (n.d. – 2.92)	**1.44** (1.31 – 1.57)
1,2,3,6,7,8- HxCDF	**1.75** (n.d. – 5.40)	**0.80** (n.d. – 2.09)	**0.92** (0.78 – 1.09)
2,3,4,6,7,8-HxCDF	**0.70** (n.d. – 7.32)	n.d.	n.d.
1,2,3,7,8,9-HxCDF	**0.60** (n.d. – 2.94)	n.d.	n.d.
1,2,3,4,6,7,8-HpCDF	**3.75** (n.d. – 23.70)	**1.16** (n.d. – 3.86)	**0.63** (n.d. – 0.78)
1,2,3,4,7,8,9-HpCDF	**0.75** (n.d. – 30.81)	n.d.	n.d.
OCDF	**18.97** (4.78 – 48.34)	**16.46** (7.74 – 48.71)	**19.70** (17.04 – 22.77)
Total Concentration in TEQ	**7.66** (3.60 – 21.34)	**2.70** (0.65 – 9.65)	**3.47** (2.29 – 5.24)
Weight, g	**21.97** (11.42 – 30.67)	**29.25** (24.78 – 32.97)	**28.65** (24.43 – 33.60)
Lipid, %	**2.96** (0.67 – 4.58)	**2.52** (0.62 – 4.86)	**3.09** (2.67 – 3.58)

Table 7.12.
Concentrations (pg/g lipids) of polychlorinated dibenzo-p-dioxins and dibenzofurans in breast milk in the Chukchi AO.
n.d. – not detected

PBDE levels in breast milk of women from the Chukotsky District are more than 3 times higher than levels detected in Anadyrsky District (307 and 112 pg/g lipid, respectively). However, average concentrations of PBDE in control samples of breast milk from St. Petersburg exceeded those found in both Chukotsky District (by 3 times), and Anadyrsky District (by 10 times).

There are a number of publications in the scientific literature that indicate that PBDE contamination in breast milk has increased by a factor of 2 every 5 years during recent years (e.g. Meironyte *et al.*,1999). The USA is one of main producers of PBDE flame retardants (UNEP, 2002), and there is evidence that PBDE contamination in the breast milk of women in America may exceed that of women in Sweden by 40 times. Average PBDE concentrations of approximately 200 ng/g lipids have been reported for breast milk from the United States (Papke *et al.*, 2001), with 60% of this value accounted for by one congener, BDE-47. Furst (2001) reports average concentration of PBDEs in the breast milk of women from Germany at 1.5 ng/g lipids. Overall, however, there available data on PBDE contamination in breast milk are still very limited.

Given the information above, it can be concluded that PBDE concentrations detected in breast milk samples from the Chukchi AO (0.1–0.3 ng/g lipids) are an order of magnitude lower than values found for breast milk in Germany, whilst control samples of breast milk from St. Petersburg contain PBDE in amounts (1.06 ng/g lipids) comparable with levels found in Germany. In all cases, congener BDE-47 is the main component in breast milk samples.

7.6. Conclusions

1. As the occurrence of PTS in human blood in the Russian North is explained to a large extent by the intake of contaminated fish (marine and freshwater), marine mammals, sea birds, and reindeer meat, it follows that PTS concentrations in the blood of women giving birth, and of their children, are also affected by the traditional diet of indigenous people. The highest concentrations of PTS in maternal and umbilical cord blood were detected in Chukotsky District of the Chukchi AO. These high levels of PTS in blood in this particular area may be associated with high levels of consumption of species occupying the upper trophic levels in marine food webs, as part of the traditional diet. Further work is still needed, however, to confirm and further elucidate this.

2. Concentrations of organochlorine pesticides in cord blood of newborns are normally somewhat lower than in maternal blood, which leads to the conclusion that the placental barrier acts to reduce the transfer of

Compound	Chukchi AO		Control (St-Petersburg), n=2
	Chukotsky district, n=10	Anadyrsky district, n=7	
PBDE # 28	**14,77** (n.d. – 42,28)	**6,97** (n.d. – 16,87)	**53,87** (23,36 – 124,2)
PBDE # 47	**222,6** (n.d. – 696,2)	**82,76** (30,69 – 267,7)	**817,5** (271,83 – 2458)
PBDE # 99	**16,05** (n.d. – 77,85)	**19,25** (n.d. – 41,90)	**77,31** (34,83 – 171,6)
PBDE # 100	**17,18** (n.d. – 86,58)	**8,63** (n.d. – 19,15)	**81,12** (24,34 – 270,3)
PBDE # 153	**22,36** (n.d. – 189,1)	n.d.	**38,90** (n.d. – 108,1)
PBDE # 154	n.d.	n.d.	**20,92** (n.d. – 31,25)
PBDE # 183	n.d.	n.d.	n.d.
Sum	**307,1** (48,50 – 823,0)	**112,6** (30,69 – 267,74)	**1058** (354,4 – 3164)
Weight, g	**21,97** (11,42 – 30,67)	**29,25** (24,78 – 32,97)	**28,65** (24,43 – 33,60)
Lipid, %	**2,96** (0,67 – 4,58)	**2,52** (0,62 – 4,86)	**3,09** (2,67 – 3,58)

Table 7.13.
Concentrations (pg/g lipids) of polybrominated diphenyl ethers in breast milk in the Chukchi AO.
n.d. – not detected

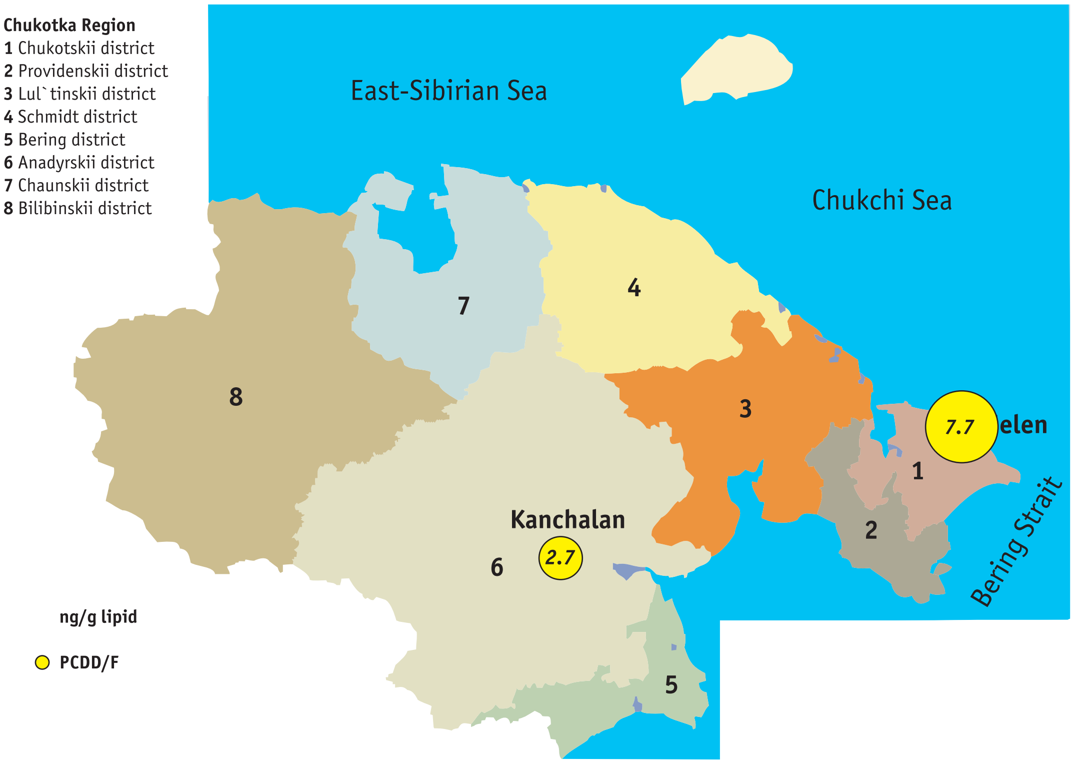


Figure 7.21a.
Levels (ng/g lipid) of PCDD/F in breast milk of women from various areas of the Chukchi AO.

toxic substances from mother to fetus; this is more effective for some contaminants than others. This feature was reflected in blood samples from all regions, except for the Kola Peninsula, and the control area, where the difference between maternal and cord blood concentrations was not statistically significant.

3. Among the DDT group of compounds, DDE is the most prevalent in human blood, the ratio of DDE/DDT concentrations in blood in the various regions ranging from 3-8, although a ratio of 30 was found in the Aral control area.

4. A comparison with results obtained during the 2002 AMAP circumpolar maternal blood survey shows that, on the whole, levels of organochlorine pesticides in human blood samples from the Russian Arctic are similar to those found in coastal areas of Greenland and northern Canada, although for some POPs, such as toxaphene and mirex, the levels found in the Russian Arctic are much lower.

5. Geometric mean concentrations of dioxins in blood samples from adults of both sexes and for all regions, are within the range 0.3–9.4 pg/g TEQ of

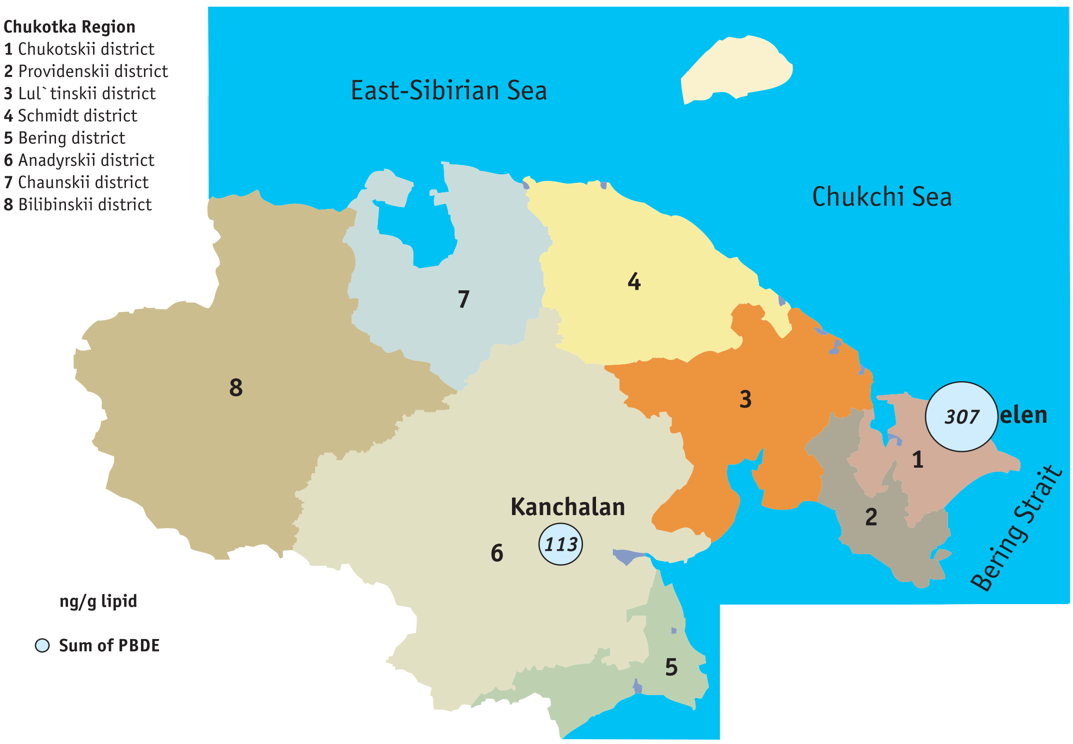


Figure 7.21b.
Levels (ng/g lipid) of PBDE in breast milk of women from various areas of the Chukchi AO.

lipids. The highest concentrations in individual samples were 18.7 and 18.1 pg/g TEQ of lipids (in the Chukchi and Taymir AOs, respectively). The highest concentration of PCDD/PCDFs in human blood from the northern areas of Russia (18.7 pg/g TEQ of lipid) is close to the lowest concentrations found in residents of industrial regions.

6. Among the samples of breast milk from the Chukchi AO, the highest levels of nearly all POPs were found in breast milk from Chukotsky District. Levels here, exceed those found in other areas of the Chukchi AO by 3-6 times for HCB, 10-80 times for oxychlordane, 10 times for mirex, *trans*- and *cis*-nonachlor, and toxaphene, and 4-5 times for the sum of 15 congeners of PCBs. Concentrations of DDT and its metabolites in breast milk did not differ significantly in samples from different areas of the Chukchi AO.

7. With respect to levels of compounds such as PCBs, oxychlordane, DDT, DDE and *trans*-nonachlor, Chukotsky District is similar to Nunavik in northern Canada. However, concentrations of b-HCH and HCB in breast milk from Chukotsky District are 30 and 5 times higher, respectively, than values found in Canada. Concentrations of PCBs, HCBs, b-HCH, and oxychlordane in breast milk from other areas of the Chukchi AO are comparable to those occurring in the breast milk of women from Kargopol, Severodvinsk, Arkhangelsk, and Naryan-Mar.

8. Maximum levels of breast milk contamination, like human blood samples, for all PTS determined, including PCDD/Fs and PBDEs, were found in the Chukotsky District, which is situated in the coastal area of the Chukotka peninsula.

9. Average concentrations of dioxin and furans detected in breast milk of women from Chukotka are the same as levels detected in breast milk of women from Norway and Ireland, and are lower than levels found in Northern Canada (northern and southern Quebec).

10. Comparison of concentrations of PBDE and PCDD/F in blood samples of the adult population reveals a marked difference in the distribution of these PTS in the Russian North, with low levels of PCDD/Fs coinciding with high levels of PBDEs, and vice versa. The difference is most obvious in the Taymir AO, the Nenets AO (Nelmin-Nos), and the Kola Peninsula (Krasnoshchelie). There is not yet sufficient data to ascertain the reasons for the difference in dioxin and PBDE distribution, but it is clear that the sources of pollution and contamination pathways for these groups of substances differ from each other. PBDEs occur at higher levels in areas close to the industrialized source regions of Europe and North America.

11. Maximum PBDE concentrations (of 934 pg/g lipids) in blood samples of populations from the Russian Arctic regions were found on the Kola Peninsula (Krasnoshchelie), and correspond to those observed in sampled populations in Norway in 1981.

12. PBDE concentrations in breast milk samples of women from the Chukchi AO (0.1-0.3 ng/g of lipids) are an order of magnitude lower than concentrations measured in Germany. Control samples of breast milk from St. Petersburg contained PBDE in amounts (1.06 ng/g of lipids) comparable with those from Germany. The predominant congener in all samples is BDE-47.

Local authorities are responsible for monitoring the migration of all social and national groups, as well as their health status. This is necessary for political and economic reasons, as well as to meet the requirements of federal laws which provide social security for certain population groups, including the indigenous peoples of the North. However, in the absence of a unified system for monitoring the health of the indigenous peoples in Russia, the results of monitoring activities in different administrative territories often cannot be easily compared*. This situation presented difficulties when attempts were made to make comparative assessments of the pilot areas included in this project. The data obtained were therefore subjected to an independent uniform medical and statistical analysis, prior to the formulation of conclusions.

Chapter 8

The demographic situation and health status of indigenous peoples in the project study areas

* The most complete and systematic medical and statistical information relating to the indigenous population is obtained from the Chukchi Autonomous Okrug (CAO) and the Nenets Autonomous Okrug (NAO), due to the more numerous population, and the greater social and economic importance of the indigenous peoples in these administrative territories.

8.1. The Chukchi Autonomous Okrug (CAO)

Political and economic changes in Russia have affected the demographic situation in the CAO more than in any other region. The closure of unprofitable mining enterprises, demilitarization, and the destruction of certain social and economic structures led to a massive emigration, in particular of the more recent immigrants, away from the CAO. Such major shifts in population interfere with the evaluation of the natural population dynamics of the newmigrants, and also prevent an objective evaluation of their health status. Therefore, comparisons in this section are limited to the use of demographic and medical data for the indigenous population of two districts (Anadyrsky and Chukotsky), as well as for the CAO as a whole.

8.1.1. General demographic situation

The dominant indigenous peoples in the areas of the CAO studied all belong to the paleoasiatic group and thus demonstrate a similar level of adaptation to the Chukotka environment. The only exception to this are the Chuvans, an indigenous population group arising from Russian, Chukchi, and Yukaghir origins, which emerged in late 18th century in Anadyrsky District. In the 1980s the group was classified as 'Chuva', while before the census of 1989 they were considered to be Chukchi. From Table 8.1 it can be seen that most of the population in the areas studied are Chukchi.

As shown in Figure 8.1, the total population of the CAO has halved in the last 10 years, whilst the population of Anadyrsky and Chukotsky Districts has decreased by 30–40%.

Over the same period, there have been no significant changes in the total populations of indigenous population, either in the CAO as a whole, or in Chukotsky District, both have infact increased slightly (Figure 8.2). The indigenous population in Anadyrsky District has decreased by 17% since 1996, as many of the suburban dwellers have moved into Anadyr city. However in this district, as for everywhere in the CAO, there has been some growth of the indigenous population over the last decade. The indigenous population was at its lowest level during the most difficult years of the recent economic crisis (1994–1996), but has been growing since then (Figure 8.3).

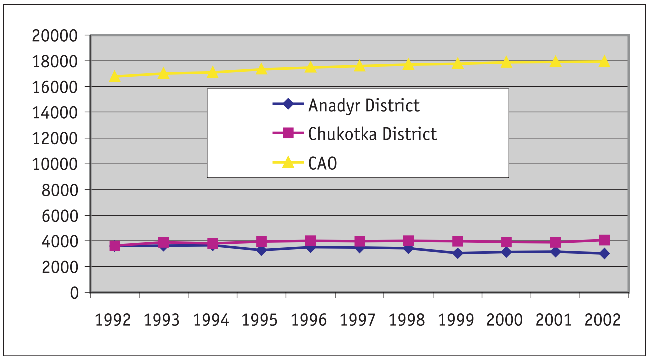


Figure 8.2. The indigenous population of CAO and study areas, 1992-2002.

For continued growth of indigenous populations, their specific age and gender distribution are determining factors, and must be favourable (Table 8.2). More than 70% of the indigenous people in the CAO are younger than 40 years of age, while in Arctic Scandinavia as a whole, this age group constitutes only 30%.

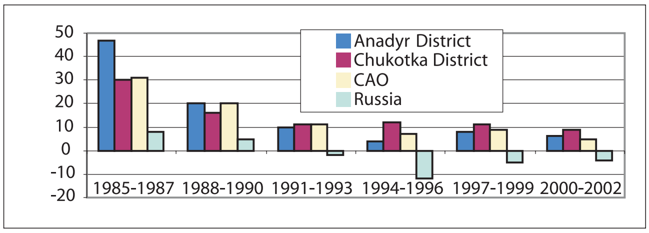


Figure 8.3. Rates of population growth (per 1000 persons) of the indigenous population in study areas in the CAO and the CAO as a whole, compared with that of the total population of the Russian Federation, 1985-2002.

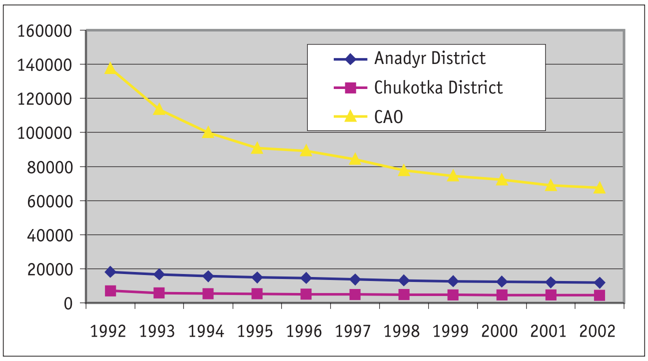


Figure 8.1. Total population of the CAO and study areas, 1992-2002.

8.1.2. Death rates of the indigenous population

The death rate for indigenous people in Anadyrsky and Chukotksky Districts, and in the CAO as a whole, has not altered greatly from 1986 to the present*. Before 1994, it exceeded the rate for all of Russia by 10-50%. More recently, the death rate in Russia has exceeded that of the indigenous population of the areas studied, and of the whole of the CAO.

Table 8.1. Ethnicity of northern indigenous peoples residing in the areas of the CAO studied, according to censuses; population number, and % (in parentheses).

Area	Year of Census	Chukchi	Chuvans	Evens	Eskimo	Others	Total (100%)
Anadyrsky District	1970	2479 (83)	-	369 (12)	57 (2)	104 (3)	3009
	1979	2456 (85)	-	265 (9)	17 (<1)	136 (5)	2874
	1989	2090 (61)	747 (22)	366 (11)	28 (1)	179 (5)	3410
Chukotsky District	1970	2384 (89)	-	4 (<1)	290 (11)	-	2627
	1979	2620 (89)	-	7 (<1)	323 (11)	-	2952
	1989	3067 (89)	6 (<1)	15 (<1)	340 (<10)	4 (<1)	3432
Chukchi Autonomous Okrug	1970	11001 (82)	-	1061 (8)	1149 (9)	171 (1)	13382
	1979	11292 (81)	-	1077 (8)	1278 (9)	236 (2)	13883
	1989	11914 (75)	944 (6)	1336 (8)	1452 (9)	257 (2)	15903

* the observation period in this case and hereafter is based on unpublished information of the Medical Statistics Bureau.

Table 8.2.
Age and gender distribution of indigenous peoples of the CAO in census years, %.

Age Group	Sex	Year of the Census 1970	1979	1989	2002
0 - 19	All	50	51	46	39
	Men	51	53	50	41
	Women	47	47	43	38
20 - 39	All	27	26	35	32
	Men	26	26	33	33
	Women	29	28	35	31
40 - 59	All	20	18	14	21
	Men	20	16	13	20
	Women	20	20	16	22
60 and above	All	3	5	5	8
	Men	3	4	4	6
	Women	4	5	6	9

Due to the small population size of the indigenous peoples, infant mortality in the areas studied varies by as much as a factor of eight. On average, there is no significant difference between infant mortality for the two areas studied and for the whole of the CAO over the past 16 years. However, at the same time, the death rate of indigenous people in Chukotsky District is more than twice the average rate for Russia as a whole.

An assessment of available data on infant mortality among indigenous people, for the period 1991-2001, based on average data and given the high variation in death rates, suggests that unfavourable perinatal development may be affecting infants in Chukotsky District. The death rate due to this cause is twice as high in this district as that for Anadyrsky District, and figures for mortality caused by perinatal pathologies for all indigenous infants exceed those for the CAO by 40% (Figure 8.4).

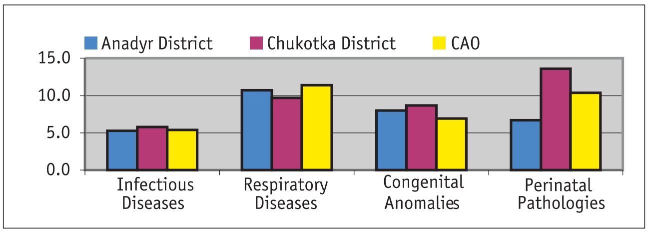


Figure 8.4. Main causes of infant mortality in the indigenous population, 1991-2001; mortality rate per 1000 live-births.

Primary data on causes of mortality among the indigenous population in the areas studied and for the CAO as a whole, also document significant variability in death rates, by as much as a factor of two to three (Figure 8.5). Also, an analysis of averaged data over a period of 11 years (1991-2001) suggests that in Chukotsky District, there is a greater risk of disease of the respiratory and digestive systems, and also from infectious and parasitic diseases, when compared with Anadyrsky District and the CAO as a whole. Only death rates from alcohol intoxication are found to be greater in the CAO, than in the two study areas. In part, this may be due to a 'sympathetic' attitude of health personnel in Chukotsky District, when issuing death certificates to families of those who have died of alcohol intoxication (i.e., attributing death to other causes). A diagnosis of death from alcohol intoxication, apart from causing moral damage, also leads to close relatives being deprived of certain social privileges and subsidies. On the other hand, the high mortality from diseases of the digestive system, and from parasitic and infectious diseases, affecting the indigenous population of Chukotsky District can probably be directly attributed to significant changes in the indigenous diet. During recent years, for various economic reasons, the population of domestic reindeer in the area has rapidly declined, and inhabitants of some settlements (such as Uelen) were forced to switch from a diet based on reindeer meat to one based on whale fat, and walrus and seal meat. One of the traditional methods used in processing meat of marine animals, is its fermentation in containers (often not suitable for food products) or directly in the ground; and it is thought that this process may have been responsible for some of the increase in disease which occurred.

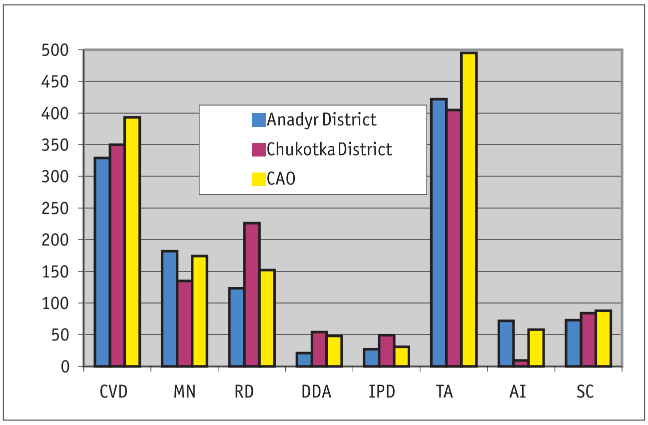


Figure 8.5. Main causes of mortality in the indigenous population of the CAO, 1991-2001; mortality rate per 100000.
Abbreviations: CVD – cardiovascular diseases, MN – malignant neoplasms, RD – respiratory diseases, DDA – diseases of digestive system, IPA – infectious and parasitic diseases, TA – traumas and accidents, AI – alcoholic intoxication, SC – suicide.

8.1.3. Morbidity

The Medical Statistics Service of the CAO monitors morbidity in adults and children according to disease type (Table 8.3). Specific nosologic types, which follow the International Classification of Diseases, are used only for the CAO in general, where the indigenous population is identified separately. Within the districts, only primary causes of morbidity and sickness in adults and children are monitored, although the indigenous population is also identified separately.

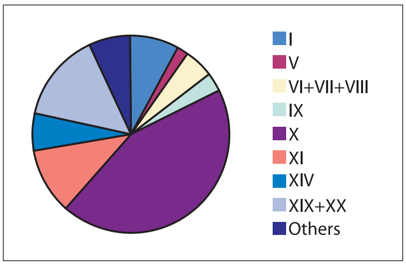


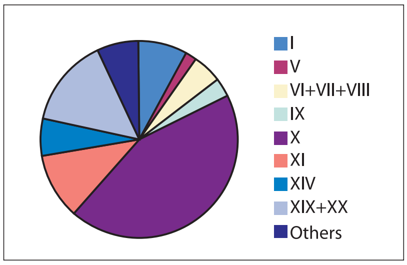
Figure 8.6.
Primary morbidity in the indigenous adult population in the CAO, 1991-2001.

Figures 8.6 and 8.7 show the distribution of primary causes of morbidity for indigenous adults and children in the CAO. For both groups, respiratory diseases (X), constitute a major cause of morbidity, followed by traumas and

Class	Diseases and Health Problems
I	Infectious and parasitic diseases
II	Neoplasm
III	Diseases of blood and hemopoietic organs
IV	Diseases of endocrine system, impairments of digestion and metabolism
V	Psychical and behavioral disturbances
VI	Diseases of nervous system
VII	Eye diseases
VIII	Ear diseases
IX	Diseases of blood circulation system
X	Diseases of respiration organs
XI	Diseases of digestion organs
XII	Diseases of skin and subcutaneous fibre
XIII	Diseases of bones, muscles and connective tissue
XIV	Diseases of genitourinary system
XV	Pregnancy, deliveries and postnatal period
XVI	Specific conditions during perinatal period
XVII	Congenital malformations
XVIII	Symptoms not classified in other headings
XIX	Traumas, poisonings and some other sequences of external influences
XX	External causes of morbidity and mortality
XXI	Factors which have an influence on health status

Table 8.3. International Statistical Classification of Diseases and Related health Problems (ICD-10), (WHO, 1992).

Figure 8.7. Primary morbidity among indigenous children in the CAO, 1991-2001.



poisonings in adults (XIX+XX), and infectious and parasitic diseases in children (I). Diseases of the digestive system (XI) for both adults and children occupy a third ranking, followed for adults by diseases of urogenital system (XIV), and for children, diseases of the skin and subcutaneous tissue (XII), and then traumas (XIX+XX).

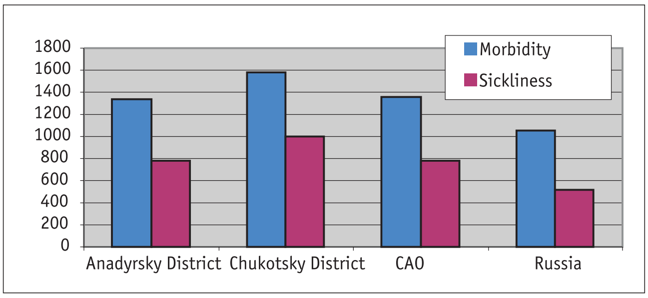


Figure 8.8. Reported sickliness, and primary morbidity of the indigenous adult population in the CAO and the Russian Federation, 1989-2001; rate per 1000 persons over 15 years of age.

Primary morbidity and sickliness in indigenous adults and children in Chukotsky District is, in general, greater than that in Anadyrsky District or in the CAO as a whole, by 15–25 % (Figures 8.8 and 8.9). However, the correlation between primary morbidity and sickliness in the study areas within the CAO, corresponds to average correlations for Russia.

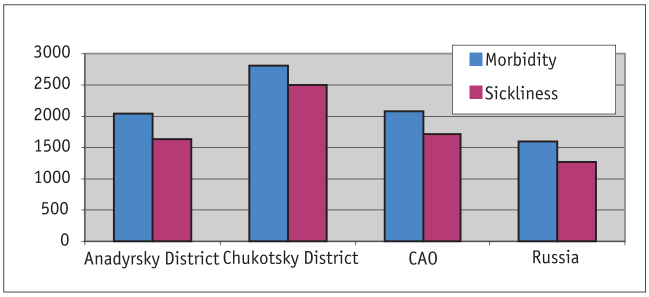


Figure 8.9. Reported sickliness, and primary morbidity of indigenous children in the CAO and the Russian Federation, 1989-2001; rate per 1000 persons, 0-14 years of age.

8.2. The Taymir (Dolgan-Nenets) Autonomous Okrug (TAO)

Whilst a cause of environmental pollution, the economically stable and highly profitable enterprises of the Norilsk Industrial Area (NIA), located in Taymir, also contributes to a relatively higher standard of living for all population groups in the TAO.

Each month an amount is paid to every person in the TAO by the NIA, as compensation for the assumed environmental damage. These payments have subsidised social needs and promoted the settlement of new migrants in the TAO, has and have been a contributing factor to the positive trends seen in social and economic development of the indigenous communities in the TAO.

8.2.1. General demographic situation

Due to the small number of indigenous peoples resident in the region, assessment of the general demographic situation and health status of this population group by the Health Directorate of the TAO Administration, occurs mainly at the TAO level. However, to assist the needs of social and economic development in Khatanga District, the Central District Hospital regularly collects medical and demographic data, mainly regarding natural migration of the indigenous population.

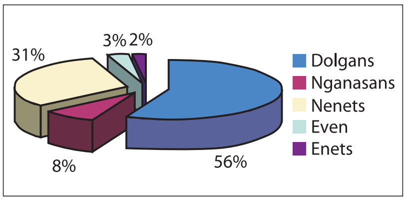
Table 8.4. Population of the the TAO, and Khatanga District, thousands of people, 1993-2002. *total population including indigenous population

Area	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
TAO (total population)*	48.1	47.5	47.2	47.2	46.3	45.2	44.3	43.7	42.5	41.7
TAO indigenous population	8.5	8.5	8.5	8.5	8.6	8.6	8.6	8.8	8.8	8.8
Khatanga District (total population)*	9.2	9.2	9.2	9.1	9.2	9.3	9.4	9.5	9.5	9.5
Khatanga District indigenous population	3.6	3.6	3.6	3.7	3.7	3.7	3.7	3.8	3.8	3.8

As in the CAO, over the past 10 years there has been no significant reduction in the indigenous population of the TAO, although the total population of the TAO has declined (Table 8.4). In fact, the number of indigenous people has increased in the area studied, the whole of Khatanga District, and in the TAO in general.

The indigenous population of the TAO consists of various peoples (Figure 8.10). Dolgans constitute more than half of the indigenous population in the Khatanga District. This is a relatively new inter-ethnic group, of Russian, Yakut, and Yukaghir origin, which emerged in the 18th century. The Nenets, who accomplished their long migration from south-eastern Asia to the Far North in the 14th century, form a further third of the population. Paleoasiatic groups, of which the Nganasans are the most numerous, form 13% of the indigenous population.

Figure 8.10.
Distribution of the indigenous population in the TAO by ethnic group, 2002.



As shown in Table 8.5, the age and gender structure of the indigenous population of the TAO is generally similar to that of the CAO. However, certain changes have taken place over the past 13 years. The number of elderly people has almost doubled; with twice as many women as men in this age group. The proportion of children (under 16 years) has decreased, and that of adults (16-59 years) increased.

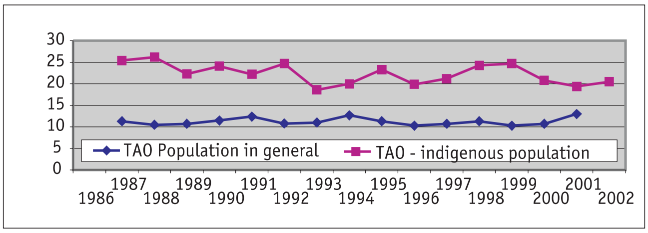


Figure 8.11. Birth rates, per 1000 persons, of the indigenous and general population of the TAO, 1986-2002.

The birth and death rates of the indigenous population, both in the TAO in general, and in Khatanga District, exceed those of the more recently arrived immigrant population (Figures 8.11 and 8.12). Unlike the situation for Russia in general, the combined trends in birth and death rates has ensured the growth of both the indigenous and the non-indigenous populations in the TAO (Figure 8.13).

The reproductive potential is demonstrated by the frequency of births among women of child-bearing age (Table 8.6). In the TAO in general, over the past seven years, women from the indigenous population groups gave birth twice as often as women from the non-indigenous population. However the situation in Khatanga District is different. In some years (1997 and 2001), women from the new migrant population increased their birth rate, and surpassed that of indigenous women.

Area	1996	1997	1998	1999	2000	2001	2002
General TAO population	28.6	30.4	31.3	32.7	34.0	38.3	33.5
TAO - indigenous population	56.2	67.4	65.1	68.3	71.7	45.2	70.1
General Khatanga District population	47.3	50.5	44.2	39.0	44.7	62.2	32.8
Khatanga District- indigenous population	58.8	57.2	66.3	65.4	70.5	50.4	67.8

Table 8.6. Birth rate, per 1000 women of child-bearing age, for the TAO and Khatanga District, 1996-2002.

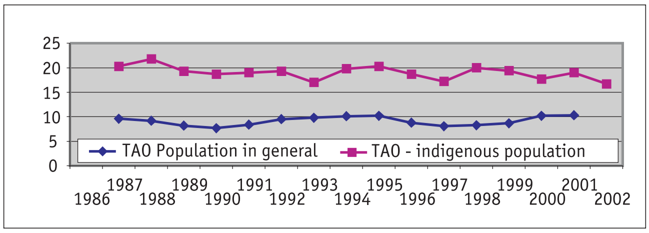


Figure 8.12. Death rates, per 1000 persons, of the indigenous and general population of the TAO, 1986-2002.

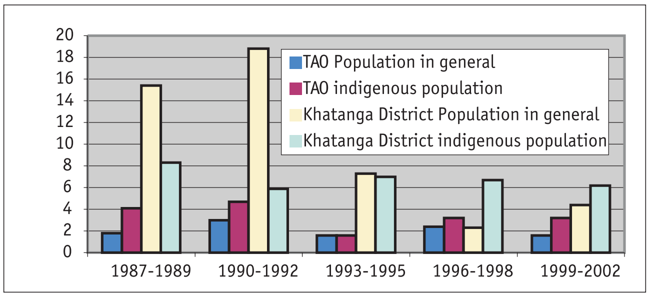


Figure 8.13. Rates of population growth (per 1000 persons) of the indigenous and general population in the TAO, and Khatanga District, 1987-2002.

8.2.2. Death rates of the indigenous population

The annual death rate in Khatanga District for both the general population and for indigenous peoples varies significantly, due to the small size of the community

Year	Both sexes, total	Men				Women			
		0-15	16-59	60 and above	Total	0-15	16-59	60 and above	Total
1989	8511	1940 (47)	2065 (50)	124 (3)	4128	1972 (45)	2147 (49)	264 (6)	4383
1995	8538	1735 (42)	2152 (53)	187 (5)	4074	1758 (39)	2357 (53)	349 (8)	4464
2001	8860	1701 (40)	2313 (56)	181 (4)	4145	1790 (38)	2471 (53)	404 (9)	4665

Table 8.5.
Age and gender distribution of indigenous peoples of the TAO; number in category at year-end, absolute figures and percentage (in parentheses).

(Figure 8.14). However their levels are within the range of annual rates for the total TAO population and for the indigenous population in this Okrug. During the period of study, the death rate of indigenous people in the TAO, who represent 18% of the population of the TAO, was twice as high as that of the general population.

The death rate for the total population in Khatanga District over the period 1987–2001, on average, differed only slightly from the rate for the indigenous population (Figure 8.14). As the indigenous population constitutes only 28% of the total population of the district, this suggests that the death rate of the new migrant population is similar to that of the indigenous population.

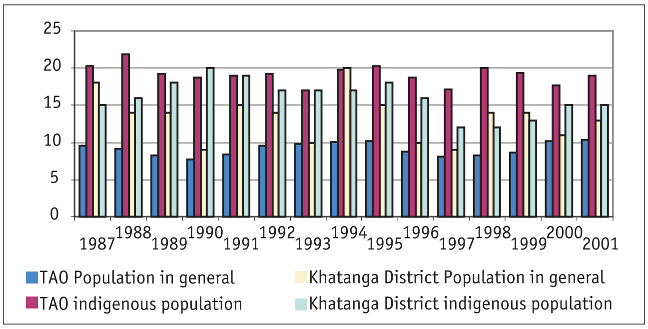


Figure 8.14. Death rates, per 1000 persons, of the indigenous and total population of the TAO, and Khatanga District, 1987-2001

Assessment of infant mortality (Table 8.7) shows similar death rates of indigenous children living in Khatanga District and indigenous children in TAO. However infant mortality rates among general population in Khatanga District and TAO are 1.5 times lower than among natives. Assessment of the health status of the new migrant population is beyond the scope of this project. However any further research in this area should also consider the state of health of the new migrant population of Khatanga.

Data in Table 8.8 shows the changes in causes of death over the last 15 years for the indigenous population and for the total TAO population. The ranking of the main categories of disease, as reflected by the death rate, has changed over time.

Area	1994	1995	1996	1997	1998	1999	2000	2001	2002
General TAO population	21.5	28.2	22.6	13.6	13.4	13.0	19.7	21.6	20.3
TAO - indigenous population	29.6	39.5	31.1	28.7	32.2	30.0	24.5	31.3	33.5
Khatanga District– general population	33.4	55.3	26.2	22.7	18.7	15.7	26.5	33.8	37.5
Khatanga District- indigenous population	35.8	47.7	40.1	31.3	36.5	42.2	42.7	58.3	40.4

Table 8.7. Infant mortality, rate per 1000 live-born, in the TAO and Khatanga District, 1996-2002.

In the period 1983-1987 the ranking of disease categories for the indigenous population of the TAO was as follows: traumas and poisonings, neoplasms, blood circulation diseases, infectious and parasitic diseases and diseases of digestive system. In the following five years, diseases associated with 'western civilization', such as blood circulation pathologies, became more important, while neoplasms, and traumas and poisoning were lower in the ranking. Alcoholic intoxication and suicides continued to be more frequent causes of death than diseases of the digestive system and respiratory organs.

The decrease in deaths of indigenous people, from cancer (an environmentally-conditioned pathology), can be explained by the end of endemic oesophageal cancer reported for Taymir, Yakutia and Chukotka up to 60–70s.

The TAO population as a whole (which consists of over 80% non-indigenous groups) shows a different trend. There is an increase in blood circulation diseases and cancer (which doubled in 1993–1997 compared to 1983–1987). The death rate from other causes, however, remained unchanged.

The low level of death from cancer in the TAO as a whole, compared to that of the indigenous population deserves special note. It could be explained by

Table 8.8.
Death rate, per 1000 people, for the indigenous and (in parentheses) total population of the TAO, 1983-1997.
*the period is limited to pre-1997 due to the introduction of a new form of Russian Passport, which no longer identifies the 'ethnicity' of the holder. Medical death certificates and the Civil Registry Act are now based on the information contained in the passport.

Type	Diseases	1983-1987		1988-1992		1993-1997*	
		Rate	Rank	Rate	Rank	Rate	Rank
I	Infectious Diseases	0.15 (0.05)	7 (7)	0.11 (0.07)	8 (7)	0.17 (0.06)	8 (8)
IX	Blood Circulation Diseases	2.1 (2.5)	3 (1)	2.3 (3.7)	2 (1)	3.8 (3.4)	1 (1)
II	Neoplasms	2.5 (0.4)	2 (5)	2.1 (0.5)	3 (5)	1.7 (0.8)	3 (4)
X	Respiratory Diseases	0.8 (0.7)	6 (4)	1.3 (0.5)	6 (5)	1.0 (0.7)	5 (5)
XI	Diseases of Digestive System	0.13 (0.12)	8 (6)	0.17 (0.11)	7 (6)	0.22 (0.15)	7 (7)
XIX+XX excl.X60-X84 and X51	Traumas and poisonings	3.3 (2.3)	1 (2)	2.7 (1.7)	1 (2)	2.8 (1.8)	2 (2)
X51	Alcoholic Intoxication	1.7 (1.8)	4 (3)	1.6 (1.5)	5 (3)	1.3 (1.0)	4 (3)
X60-X84	Suicides	1.6 (0.7)	5 (4)	1.8 (0.8)	4 (4)	0.8 (0.5)	6 (6)

the fact that the non-indigenous population are able to leave Taymir and return to their homeland for cancer treatment, and that some die there, rather than in Taymir.

8.2.3. Morbidity

There has been an ongoing growth trend in morbidity over a period of 12 years in the Khatanga District population and the TAO as a whole (Figure 8.15), and the indigenous population has been particularly affected by this change.

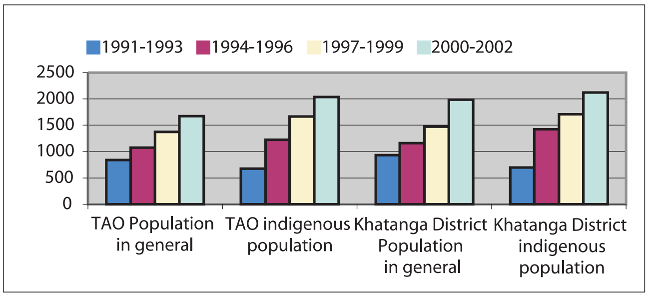


Figure 8.15. Reported morbidity, per 1000 persons, for the indigenous and general population of the TAO, and Khatanga District, 1991-2002.

Data for the last three years (Table 8.9) shows that for most types of disease, the morbidity rate of the indigenous population is higher than that of the population in general. This does not, however, apply to blood or endocrine disorders, blood circulation problems, or eye diseases.

Respiratory diseases are the most frequent health problem for all population groups, followed by diseases of the digestive system, traumas and poisonings, and diseases of the urogenital system. The high rates reported for eyes, are because applications are often made for laser correction.

Since it is more difficult for the indigenous population (which includes reindeer-breeders, hunters, etc.) to visit an ophthalmologist, reported morbidity relating to 'eye diseases' for the indigenous population is lower.

According to data from the Khatanga Central Hospital (Figure. 8.16), the ration "primary morbidity/sickliness" is similar for TAO and Khatanga District both for general and indigenous population. Primary morbidity and sickliness are the highest among natives of Khatanga District.

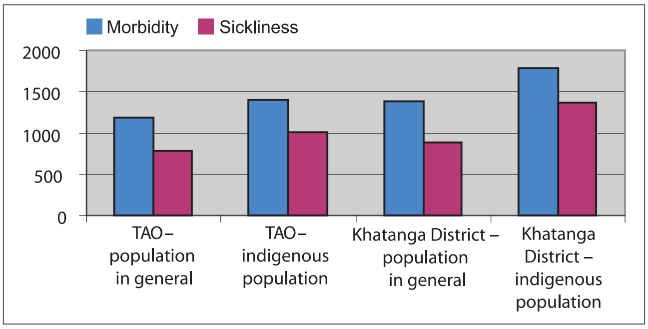


Figure 8.16. Reported sickliness, and primary morbidity for the indigenous and general population in the TAO, and Khatanga District, 1991-2002; rate per 1000 persons.

8.3. The Nenets Autonomous Okrug (NAO)

8.3.1. General demographic situation

The social and economic situation in the NAO is significantly affected by the gas and oil industry, in which, trans-national private companies are involved. Living standards in the NAO are lower than in the CAO and the TAO. The indigenous population in the NAO is officially represented only by Nenets, there being no other indigenous peoples resident there.

More than 50% of the so-called new-migrant population in the NAO consists of Russian immigrants from the Archangelsk Oblast and the Komi Republic. The new-migrants are as numerous as the Nenets, and have adopted a lifestyle largely similar to that of the indigenous population.

Figure 8.17 shows the impact of migration processes on the NAO population. During the period of economic and social changes, from 1990-1998, there was a clear reduction in the non-indigenous population, however,

Type	Disease	2000	2001	2002
	All diseases (total)	**1717.1 (2014.4)**	**1678.6 (2307.2)**	**1610.2 (1776.3)**
I	Infectious and parasitic	28.9 (46.6)	44.1 (50.2)	40.2 (66.5)
II	Neoplasms	10.3 (14.6)	9.7 (13.5)	11.3 (18.7)
III	Blood	8.1 (7.3)	7.5 (5.1)	7.3 (10.5)
IV	Endocrine systems	34.3 (28.4)	27.7 (19.2)	30.8 (25.7)
V	Mental disorders	7.1 (5.6)	8.9 (12.3)	10.8 (14.6)
VI	Nervous disorders	40.7 (78.1)	36.6 (56.4)	41.0 (36.3)
VII	Eye	340.7 (226.4)	334.3 (274.1)	411.1 (237.5)
VIII	Ear	23.0 (77.5)	17.7 (39.2)	23.8 (54.8)
IX	Blood circulation	112.0 (96.4)	98.6 (75.8)	107.5 (87.1)
X	Respiratory organs	476.0 (644.2)	377.3 (534.5)	281.7 (425.3)
XI	Digestive system	76.6 (111.5)	70.2 (93.7)	87.5 (104.1)
XII	Skin and subcutaneous fibre	21.0 (52.3)	55.7 (111.8)	65.7 (88.5)
XIII	Musculoskeletal system	34.3 (42.3)	50.2 (76.2)	41.3 (64.5)
XIV	Urogenital system	87.6 (112.5)	64.4 (97.8)	86.0 (113.1)
XV	Pregnancy, birth*	8.3 (12.7)	6.2 (14.4)	10.5 (17.6)
XVI	Perinatal period	2.0 (2.5)	3.6 (4.1)	2.7 (5.2)
XVII	Congenital anomalies	7.7 (10.7)	6.9 (9.3)	10.8 (11.5)
XIX+XX	Traumas, poisonings	99.3 (159.2)	105.0 (132.3)	112.7 (170.7)

Table 8.9. Total reported morbidity, per 1000 people, for the total and (in parentheses) indigenous population of the, 2000-2002.
*per 1000 women aged 15-49 years.

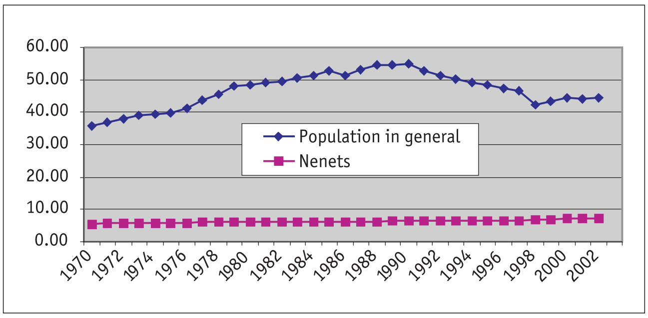


Figure 8.17. The indigenous and general population of the NAO, 1970-2002; annual average population figures in thousands.

the situation has stablised and there is now a general trend of population growth. The indigenous population (Nenets) constitutes about 17% of the total population of the NAO and does not significantly affect either the demographic or medical statistical indices. Therefore, albeit based on certain assumptions, the authorities responsible for medical statistics in the NAO, when evaluating the health status of the indigenous population, refer to the population of the NAO in general. The age and gender structure of the Nenets population, show a clear dominance of younger age groups (Table 8.10)

Age group	Sex	Year of Census		
		1970	1979	1989
0 - 19	Both sexes	2719 (48)	2718 (45)	2505 (39)
	Men	1339 (49)	1314 (46)	1222 (40)
	Women	1380 (48)	1404 (44)	1283 (39)
20 - 39	Both sexes	1699 (30)	1868 (31)	2184 (34)
	Men	820 (30)	885 (31)	1068 (35)
	Women	879 (29)	983 (31)	1116 (33)
40 - 59	Both sexes	963 (17)	1085 (18)	1285 (20)
	Men	437 (16)	485 (17)	580 (19)
	Women	526 (17)	600 (19)	705 (20)
60 and above	Both sexes	283 (5)	360 (6)	449 (7)
	Men	136 (5)	171 (6)	183 (6)
	Women	147 (6)	189 (6)	266 (8)
Total	Both sexes	5664	6031	6423
	Men	2732	2855	3053
	Women	2932	3176	3370

Table 8.10. Age and gender distribution of the Nenets population in the NAO; number in category, and percentage of the total for the age or gender group concerned (in parentheses).

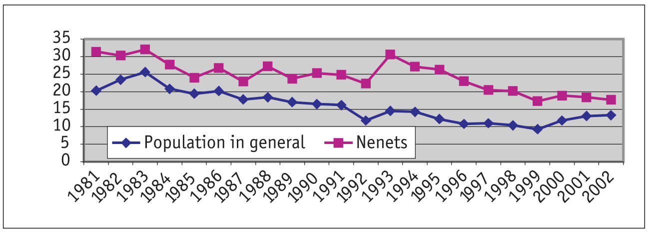


Figure 8.18. Birth rates, per 1000 persons, of the indigenous and general population of the NAO, 1970-2002.

Despite the current age structure, there is an obvious trend towards 'ageing'. Over two decades (between the censuses of 1970 and 1989), the proportion of children decreased, whilst the aged population increased, with a significant predominance of women. The 20-39 year-old age group, which is mainly responsible for reproduction within the population, constituted one third of the total population and grew until 1989. However, despite achieving an optimal age and gender structure for reproduction, the birth rate of the Nenets population has since halved in the period 1981-2002 (see Figure 8.18). The dynamics of the birth rate for the total population of the NAO is similar, but the birth rate for this group is 30-50% lower than that of the Nenets.

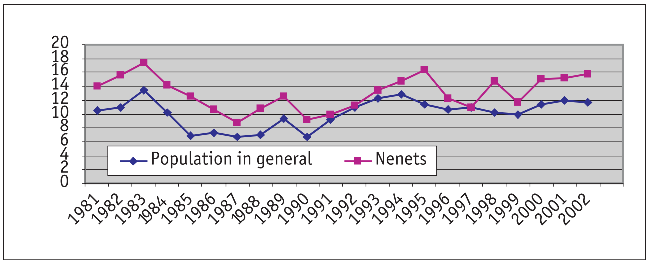


Figure 8.19. Death rates, per 1000 persons, of the indigenous and general population of the NAO, 1981-2002.

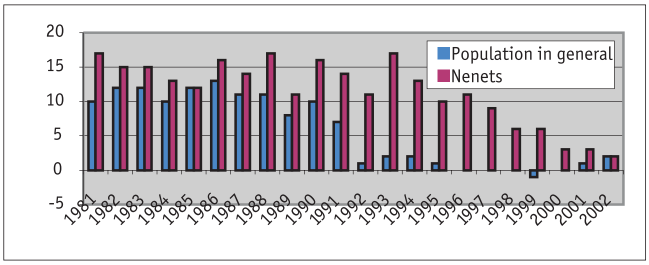


Figure 8.20. Rates of population growth (per 1000 persons) of the indigenous and general population of the NAO, 1981-2002.

Unlike the birth rate, the death rates of the total NAO population and the Nenets do not differ significantly, and even coincide for some years. (Figure 8.19). The high birth rate, together with a death rate which is not significantly above the average for the NAO, has ensured that the Nenets, unlike the total population, have seen a constant, albeit decreasing population growth since 1981 (Figure 8.20).

8.3.2. Death rates of the indigenous population

The general death rate for the total NAO population and for the Nenets in particular has varied in recent years, within the limits of the average Russian rate, however, for both groups there is a trend towards an increase in death rate since the early-1990s.

Infant mortality for both groups, by comparison, was significantly higher than the average for Russia as a whole, and for the Nenets population the rate was more than

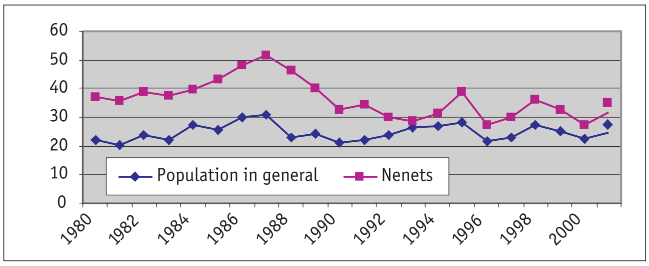


Figure 8.21. Infant mortality, per 1000 live-births, in the indigenous and general population of the NAO, 1981-2002.

twice as high (Figure 8.21). Infant mortality among the Nenets as a result of perinatal pathologies and congenital anomalies is significantly higher than infant mortality in the NAO population in general (Figure 8.22).

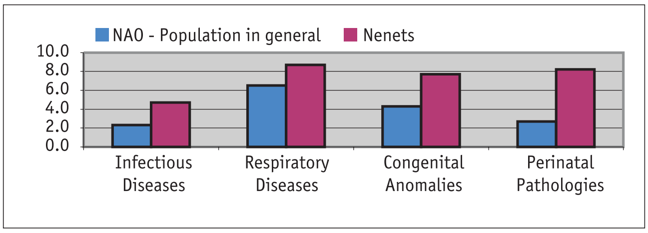


Figure 8.22. Main causes of infant mortality in the indigenous and general populations of the NAO, 1990-2002; rate per 1000 live-births.

The death rate due to respiratory diseases and infectious diseases amongst Nenets infants also exceeds that for the Okrug in general.

The causes of death in the Okrug, and especially in the Nenets population have changed significantly over the last 20 years. From 1982 to 1991, the most frequently reported causes of death for the general population in the Okrug were blood circulation diseases, followed by traumas and poisonings, and alcoholic intoxications (Table 8.11). During the same period, for the indigenous population, traumas and poisonings and alcoholic intoxication were the most frequent causes of death, while blood circulation diseases took third place in the ranking. The percentage of each of the three causes was, however, very similar (Figure 8.23). In the following 10 year period, however, causes of death among the indigenous population are very different (Figure 8.24). Blood circulation diseases caused 42% of all deaths, while the percentage due to traumas and poisonings, and alcoholic intoxication were relatively unchanged (16% and 14%, respectively). Between 1997 and 2001, the number of deaths in the indigenous population caused by blood circulation diseases was 3.7 times greater than the number registered in the period 1982-1986.

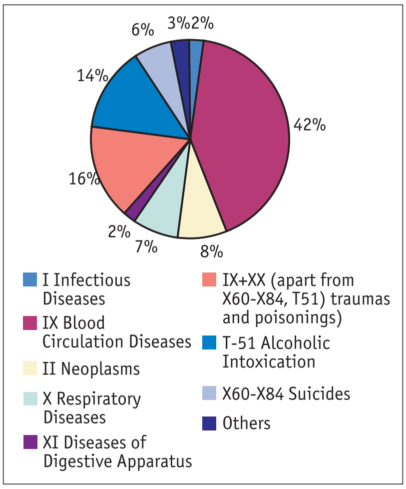
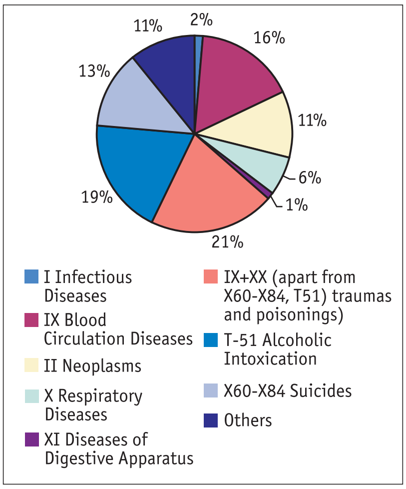


Figure 8.24. Causes of mortality in the Nenets population of the NAO, 1997-2001; %.

Figure 8.23. Causes of mortality in the Nenets population of the NAO, 1982-1986; %.



Over the past 20 years, along with the overall increase in death rates in both the indigenous and general NAO populations, in addition to the increase in blood circulation pathologies, these groups have also experienced more deaths from infectious diseases and diseases of the digestive system. Over the same period, the level of deaths caused by neoplasms, traumas and poisonings, alcoholic intoxication, and suicides has remained stable.

8.3.3. Morbidity

Reported morbidity levels (including those of children) show an even clearer increasing trend than that for death rate (Figures 8.25 and 8.26). Since 1994, this tendency has been stronger for the general Okrug population than for the indigenous population.

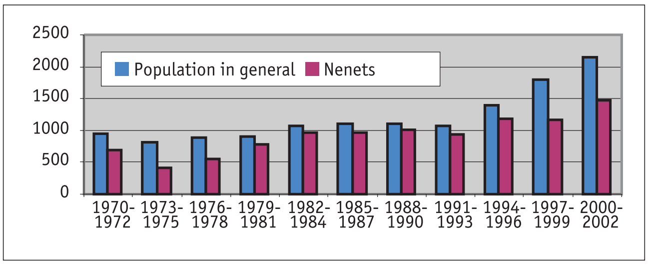


Figure 8.25. Reported morbidity, per 1000 persons, for the indigenous and general population of the NAO, 1970-2002.

Type	Diseases	1982-1986	1987-1991	1992-1996	1997-2001
I	Infectious Diseases	0.17 (0.08)	0.14 (0.05)	0.21 (0.10)	0.34 (0.18)
IX	Blood Circulation Diseases	1.80 (2.20)	2.50 (3.30)	4.00 (3.70)	6.70 (5.50)
II	Neoplasms	1.20 (1.40)	1.10 (0.90)	1.50 (1.30)	1.30 (1.10)
X	Respiratory Diseases	0.70 (0.50)	0.90 (0.70)	0.80 (0.80)	1.20 (0.70)
XI	Diseases of the Digestive System	0.11 (0.12)	0.14 (0.18)	0.22 (0.17)	0.33 (0.21)
XIX+XX Excl. X60- X84 and T51	Traumas and poisonings	2.30 (1.50)	2.00 (1.70)	1.80 (1.10)	2.50 (2.10)
T51	Alcoholic Intoxication	2.10 (1.80)	0.70 (1.40)	1.70 (1.40)	2.20 (1.50)
X60-X84	Suicides	1.40 (0.80)	0.80 (0.50)	0.70 (1.10)	1.00 (0.70)

Table 8.11. Death rate, per 1000 people, for the Nenets and (in parentheses) total population of the NAO, 1983-2002.

Compared to 1990, by 2000-2002 there was a significant increase in reported morbidity in the indigenous population for almost all types of pathologies, in some cases by as much as a factor of five (Table 8.12). However, reported morbidity relating to infectious and parasitic diseases, mental disorders, and pathologies of the nervous system decreased.

Respiratory diseases (38%) are the commonest reported illness (Table 8.13), followed by traumas and poisonings (8%), diseases of the digestive system (7%), blood circulation, and skin problems (6%), and disease relating to the urogenital system and musculoskeletal system (5%).

8.4. Murmansk Oblast

Murmansk Oblast is the most industrially developed, militarised, and densely populated region of the Russian Far North. Indigenous peoples constitute only 0.2% of the total population, and about 50% of these reside in concentrated settlements in the Lovozero area. State statistics authorities monitor only the general demographic processes, and social and economic aspects of life of the indigenous population of Lovozero. Due to the small size of the indigenous population, the Medical Statistics Office does not report on, or assess health indices of indigenous peoples. However, Medical Research Centres in the Russian Federation and in the neighbouring Nordic countries do conduct such research under the auspices of a number of federal and international programs.

8.4.1. General demographic situation

The population of the Lovozero area amounts to 13500 people, of which 3500 live in villages, including about 1000 indigenous peoples and 1200 Komi-Izhem, whose lifestyle is similar to that of the indigenous population. The current assessment compares the demographic and medical conditions of the indigenous population and the rural population in general.

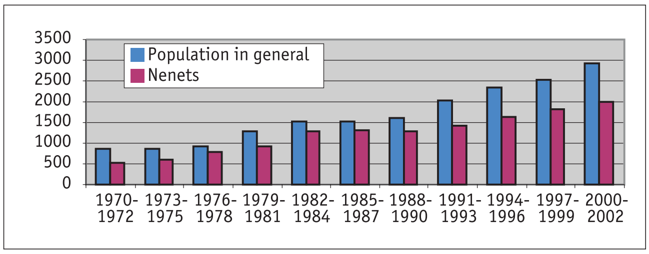


Figure 8.26. Child morbidity for the indigenous and general population of the NAO, 1970-2002; rate per 1000 persons, 0-14 years of age.

Type	Disease	1990	2000	2001	2002
	All Diseases	100	100	100	100
I	Infectious and Parasitic	10.4	4.1	3.7	4.3
II	Neoplasms	0.5	0.8	0.7	0.8
III	Blood	0.3	1.1	0.4	0.9
IV	Endocrine Systems	0.5	1.7	1.7	1.4
V	Mental disorders	11.9	1.1	1.5	2.7
VI	Nervous disorders	5.7	2.7	1.9	1.6
VII	Eye	-	8.8	8.3	8.5
VIII	Ear	-	2.7	2.5	2.0
IX	Blood Circulation	3.1	5.5	6.4	5.2
X	Respiratory Organs	48.5	37.4	36.6	37.9
XI	Digestive System	2.6	7.1	7.4	6.9
XII	Skin and Subcutaneous Fibre	4.0	5.9	8.4	5.6
XIII	Musculoskelet. system	2.3	4.5	4.8	5.7
XIV	Urogenital system	2.0	5.5	5.2	5.0
XV	Pregnancy, birth*	0.4	1.4	1.1	1.1
XVI	Perinatal period	-	0.4	0.2	0.2
XVII	Congenital anomalies	0.3	0.8	0.9	0.9
XIX+XX	Traumas, poisonings	5.9	7.9	7.7	7.9

Table 8.13. Reported morbidity, per 1000 people, of the Nenets population in the NAO as a percentage of the total morbidity.
*per 1000 women aged 15-49 years.

Table 8.12. Reported morbidity, per 1000 people, of the Nenets population in the NAO.
*per 1000 women aged 15-49 years.

Type	Disease	1990	2000	2001	2002
	All Diseases (total)	972.0	1390.0	1387.4	1646.4
I	Infectious and Parasitic	100.9	56.9	51.6	71.5
II	Neoplasms	4.7	10.6	10.2	13.5
III	Blood	3.4	15.6	6.1	15.5
IV	Endocrine Systems	4.6	23.7	23.3	23.5
V	Mental disorders	116.1	15.6	21.5	44.6
VI	Nervous disorders	55.7	38.1	26.8	26.4
VII	Eye	-	123.0	114.7	139.9
VIII	Ear	-	37.7	34.9	44.0
IX	Blood Circulation	30.2	76.7	88.6	85.7
X	Respiratory Organs	471.4	519.3	507.7	625.4
XI	Digestive System	25.2	98.1	102.7	114.7
XII	Skin and Subcutaneous Fibre	39.2	82.5	116.3	92.5
XIII	Musculoskeletal system	22.3	62.4	66.0	94.5
XIV	Urogenital system	19.8	76.6	71.6	83.1
XV	Pregnancy, birth*	4.2	19.9	15.5	18.1
XVI	Perinatal period	-	5.5	3.2	4.0
XVII	Congenital anomalies	2.5	11.7	12.3	14.9
XIX+XX	Traumas, poisonings	57.6	109.6	107.1	130.3

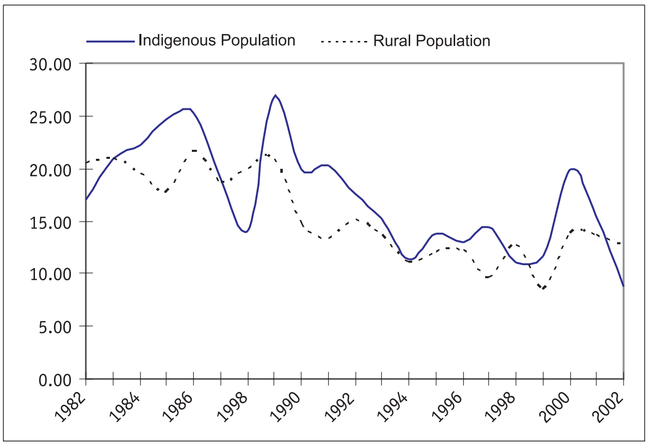


Figure 8.27. Birth rates, per 1000 persons, of the indigenous and total rural population of the Lovozero area, 1982-2002.

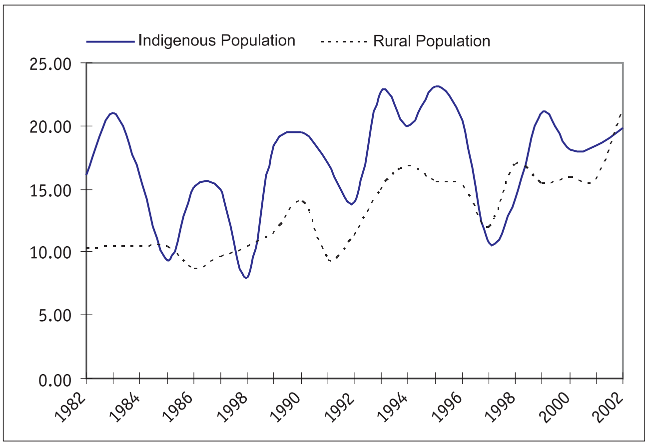


Figure 8.28. Death rates, per 1000 persons, of the indigenous and total rural population of the Lovozero area, 1982-2002.

Table 8.14. The indigenous population in rural areas of the Lovozero District, 2001.

Settlement	Komi	Saami	Nenets
Lovozero	867	722	53
Krasnoshchelje	255	87	64
Sosnovka	7	12	4
Kanevka	0	14	0

From 1973-1996, the general rural population varied within a range of 4500-4800 people. However, as a result of difficult economic conditions in 1997, a process of emigration began, and by 2003 the rural population totalled only 3800 people.

The indigenous peoples are represented in the area by the Saami (920 individuals) and Nenets (121 individuals) (Table 8.14). Their population has not altered significantly for several decades.

Figures 8.27 to 8.29 show the natural dynamics of the rural and indigenous populations. Birth and death rates document an apparent process of depopulation for both groups.

Age group	Sex	Year of the Census		
		1970	1979	1989
0 - 19	Both sexes	445 (43)	379 (37)	367 (34)
	Men	225 (44)	189 (37)	186 (34)
	Women	220 (42)	186 (36)	181 (33)
20 - 39	Both sexes	383 (37)	410 (40)	413 (38)
	Men	189 (37)	204 (40)	209 (38)
	Women	194 (37)	200 (39)	204 (37)
40 - 59	Both sexes	154 (15)	174 (17)	208 (19)
	Men	76 (15)	87 (17)	102 (19)
	Women	78 (15)	92 (18)	106 (19)
60 and above	Both sexes	52 (5)	61 (6)	102 (9)
	Men	21 (4)	30 (6)	46 (9)
	Women	31 (6)	36 (7)	56 (10)
Total	Both sexes	1034	1024	1090
	Men	511	510	543
	Women	523	514	547

Table 8.15. Age and gender distribution of the indigenous population of the Lovozero area; number in category, and percentage of the total for the age or gender group concerned (in parentheses).

The age and gender structure of the indigenous population (Table 8.15.) shows the dominance of younger age groups, which should potentially guarantee population growth. However, some, as yet, unidentified factors are exerting a negative impact on this process.

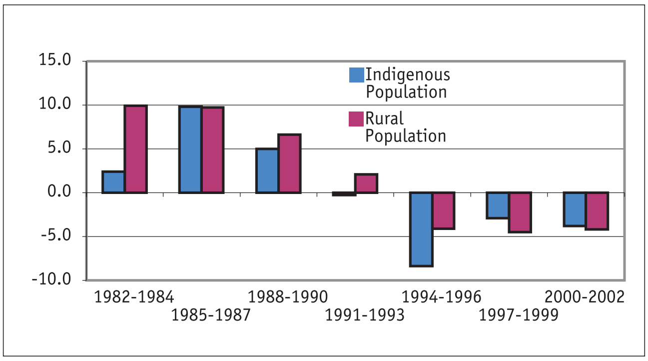


Figure 8.29. Population dynamics of the indigenous and total rural populations of the Lovozero area, 1982-2002; rate of change per 1000 persons.

The frequent scientific and medical surveys of the indigenous populations of Lovozero and Krasnoshchelje are a cause of concern for these indigenous peoples. Recently, death from cancer has become more frequent in Krasnoshchelje village. Given the attention paid by scientists to health of the indigenous population, most local people attribute this increase to the poor local environmental situation.

8.4.2. Death rates of the indigenous population

The death rates for the total rural population and the indigenous population are reasonably similar (Table 8.16). However, rates of death from blood circulation and respiratory diseases, as well as traumas and poisoning are exceptions to this situation. Blood circulation diseases are the most frequent cause of death in the total rural population, but only after 1998 did the death rate from this pathology among the indigenous population become equal to that of the total rural population. The reasons for the continuing higher frequency of deaths in the case of indigenous peoples, from respiratory diseases and external influences (such as accidents) are obvious, and include frequent overcooling and prolonged intensive physical activity in a cold environment, accompanied by the use of weapons, small boats, etc. An exception to this situation occurred, however, during the period 1993-1997, which coincided with significant changes in the economic, social and political system in Russia.

Table 8.16.
Death rates, per 1000 people, for the indigenous and (in parentheses) total rural population of the Lovozero area, 1983-2002.

Type	Death Causes	Periods of Observation			
		1983-1987	1988-1992	1993-1997	1998-2002
I	Infectious Diseases	0.13 (0.11)	0.08 (0.06)	0.10 (0.08)	0.33 (0.27)
IX	Blood Circulation Diseases	2.80 (3.10)	2.20 (3.70)	3.30 (5.80)	7.30 (7.50)
II	Neoplasms	1.40 (1.70)	1.20 (1.50)	1.00 (1.20)	1.80 (1.30)
X	Respiratory Diseases	0.50 (0.20)	0.60 (0.50)	0.40 (0.20)	0.70 (0.40)
XI	Diseases of Digestive System	0.07 (0.15)	0.12 (0.28)	0.21 (0.11)	0.12 (0.07)
XIX+XX Excl.X60-X84 and T51	Traumas and poisonings	1.70 (2.00)	1.50 (1.80)	2.60 (2.30)	3.30 (1.70)
T51	Alcoholic Intoxication	0.50 (2.20)	0.40 (2.70)	2.00 (1.40)	1.70 (1.20)
X60-X84	Suicides	0.90 (0.70)	1.20 (0.60)	0.30 (0.90)	1.10 (0.60)

8.4.3. Morbidity

Data on reported morbidity and the primary classification of pathologies in 2002 are shown in Figure 8.30 and Table 8.17. Population morbidity suggests that the indigenous peoples residing in Murmansk Oblast form an integral part of Kola population, as all three population groups when compared show similar morbidity structures.

Some discrepancies do occur between the groups being compared, in the level of morbidity from certain kinds of pathologies, as shown in Table 8.17. Thus, the frequency of diseases of the endocrine system, skin and subcutaneous fibre, as well as of infectious diseases is significantly higher in Murmansk Oblast in general than in the indigenous population. On the other hand, the indigenous population is more prone to diseases of the respiratory system, the nervous system, and trauma resulting from external factors. By comparison, the rural population of Lovozero shows intermediate values for all indices.

8.5. Conclusions

An analysis of the demographic and health status of the indigenous population in four regions of the Russian Arctic shows notable similarities between Chukotka, Taymir, Lower Pechora, and the Kola Peninsula. Despite ethno-genetic, social and economic differences, the populations of the areas studied, show generally similar population dynamics, age and gender distribution, death and birth rates, and morbidity.

The financial and economic crisis of the 1990s led to massive emigration of the non-indigenous population from the Northern regions, which resulted in a reduction in the total population of some of the areas studied. At the same time, the indigenous populations of all 4 regions have not undergone significant changes over the past 10 years, these populations remaining essentially stable over the past 20-30 years.

The age structure of the indigenous populations in the regions studied, is characterized by a high percentage of young people; in all regions, age groups below 40 years constitute about 70% of the indigenous population, while those over 60 years old represent less than 10%. This is common for northern indigenous populations, where life expectancy does not exceed 50 years. Age structure in Arctic regions is affected by many factors, both internal and external; among the most important are genetic pre-conditioning, and the attrition of physical health brought about by exposure to the severe climate and lifestyle.

The birth rate of the northern indigenous peoples is higher than the average rate for the Russian Federation, however differences appear when comparing the various areas in the study. Whilst the birth rate in Chukotka has been about 15-60 births per 1000 people for the last 10 years, (compared with 8-17 for the Russian Federation), and 18-27 per 1000 for

Table 8.17.
Population morbidity, per 1000 people, in the Murmansk Oblast, and the Lovozero area, 2002.
*per 1000 women aged 15-49 years.

Type	Disease	Murmansk Oblast		Lovozero Area - rural population		Lovozero area - indigenous population	
		Registered	First diagnosed	Registered	First diagnosed	Registered	First diagnosed
	All Diseases (total)	1393.0	774.3	1599.6	866.3	1634.7	911.3
I	Infectious and Parasitic	63.6	46.5	35.8	24.1	32.3	20.6
II	Neoplasms	33.9	10.3	27.2	4.4	31.3	5.8
III	Blood	8.6	3.2	7.0	3.2	5.3	1.8
IV	Endocrine Systems	48.3	12.1	37.7	6.6	22.8	4.5
V	Mental disorders	40.9	6.9	53.3	3.8	66.4	5.1
VI	Nervous disorders	41.8	12.5	68.1	17.5	88.0	31.2
VII	Eye	107.0	28.9	198.8	22.0	211.7	44.8
VIII	Ear	36.5	25.1	40.6	26.9	68.9	37.1
IX	Blood Circulation	137.9	13.5	116.9	17.4	93.6	11.5
X	Respiratory Organs	387	348.7	551.9	436.9	771.7	514.4
XI	Digestive System	95.9	25.6	77.6	29.1	65.4	21.9
XII	Skin and Subcutaneous Fibre	64.3	52.8	38.9	26.8	35.5	23.3
XIII	Musculoskeletal system	112.1	36.8	84.6	49.6	114.7	66.0
XIV	Urogenital system	90.2	41.2	93.4	31.3	118.8	45.5
XV	Pregnancy, birth*	50.3	43.4	35.5	35.5	23.3	23.3
XVII	Congenital anomalies	6.2	0.8	4.0	0.6	5.6	1.3
XIX+XX	Traumas, poisonings	84.2	83.4	97.3	96.5	123.6	119.7

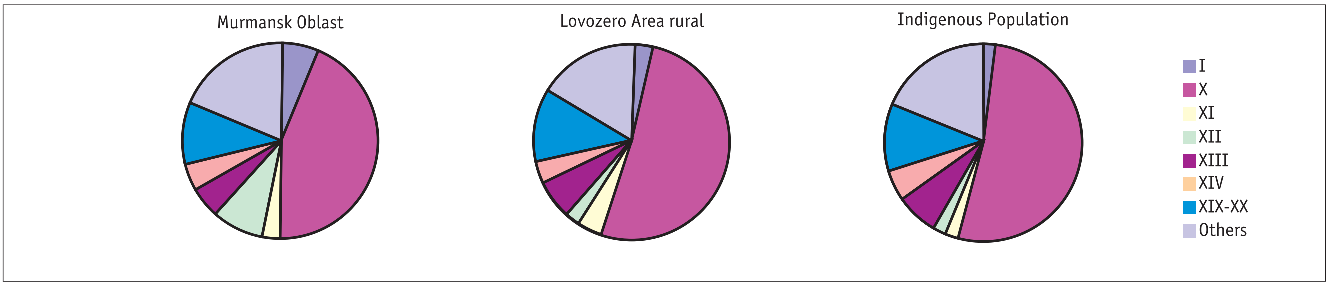


Figure 8.30. Primary morbidity of the indigenous and total rural population of the Lovozero area, and in Murmansk Oblast, 2002.

Taymir; in the Lower Pechora area, the birth rate has decreased over the past 20 years by 33% (from 30 to 20 per 1000), and in the Lovozero area by 40% (from 20-12 per 1000).

The death rate of indigenous people in the areas studied has varied between 10 and 20 per 1000 people over the past 20 years, which corresponds to the average Russian rate. Infant mortality for all areas studied was 30-60 cases per 1000 live-births, which is greater than this index for the Russian Federation as a whole (15-20 cases per 1000 liver-births).

The relationship between birth and death rates has determined population growth in Chukotka and Taymir, while in the Lower Pechora area, population size remains unchanged, and is decreasing in the Lovozero area. From this perspective, the population dynamics of the Nenets people are a cause for concern, whilst the population of the Kola Saami shows a clear tendency towards extinction.

In all areas studied, ‘external causes’, such as traumas, accidents, and suicides, continue to be as important among the causes of death as they were 20-30 years ago. Alcoholic intoxication is, however, often the main underlying factor leading to death from other ’external causes’ among the indigenous populations of the Russian North; frequent consumption of large amounts of alcohol is common in these populations. Taken together, the four above-mentioned causes of death are responsible for about 50% of all deaths in the areas studied.

Cardiovascular disease, which is the main official cause of death in the TAO and the Kola Peninsula, and the second most important in the CAO and the NAO, is also frequently related to the excessive consumption of alcohol. Respiratory diseases, and neoplasms rank below external causes and blood circulation diseases, as the most common causes of death.

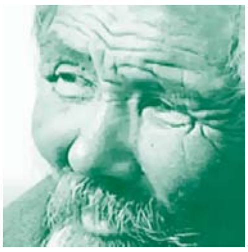
The high level of cancer, seen in the indigenous populations of the Far North in the 1960-1970s (twice as high as in the USSR in general), have not been satisfactorily explained. Some researchers have associated the high level of cancer pathologies with the increased exposure to radiation experienced by reindeer-breeders, as a result of nuclear weapon testing in Novaya Zemlya.

An analysis of spatial and temporal aspects of cancer prevalence shows that in the western part of Russian Arctic (i.e. the Kola Peninsula and the NAO) deaths caused by cancer were significantly less frequent than in the eastern areas (the TAO and the CAO). Furthermore, deaths from cancer in the NAO during this period, were less frequent than in Russia as a whole. The highest indices registered were in Taymir and Yakutia, which were the areas least polluted by the radiation. An analysis of death rate dynamics due to neoplasms, shows stable levels over 30 years of monitoring for all western areas (Murmansk Oblast, the NAO, and the Republic of Komi) and also for the CAO. The gradual increase in indices in western areas corresponds to a general tendency for the development of cancer, common to all regions and to Russia in general. The dynamics in Taymir are slightly unusual, as in 1960-1975 deaths from cancer amongst the indigenous population exceeded the average Russian rate by 3.5-4 times, while in 1975-1980s, the indices suddenly halved.

Deaths from cancer in the areas studied, were mainly caused by tumours in the oesophagus, stomach, and lungs. These three types accounted for more than 80% of deaths caused by neoplasms in 1960 in the Lovozero area, and for more than 60% in the NAO. By the end of 1980s, these figures were 40% and 50%, respectively. Oesophageal growths were, until 1980, the local ‘Northern pathology’. In the 1960s, nearly one half of all tumours among reindeer-breeders in the Lovozero area were in the oesophagus. By the late-1980s, this percentage had reduced by nearly 5%. In the NAO, the percentage of oesophageal growths has remained relatively stable over the 30 years of monitoring, at 15-30%. Today, oesophageal cancer occurs only occasionally, both in Northern areas and in the Russian Federation in general.

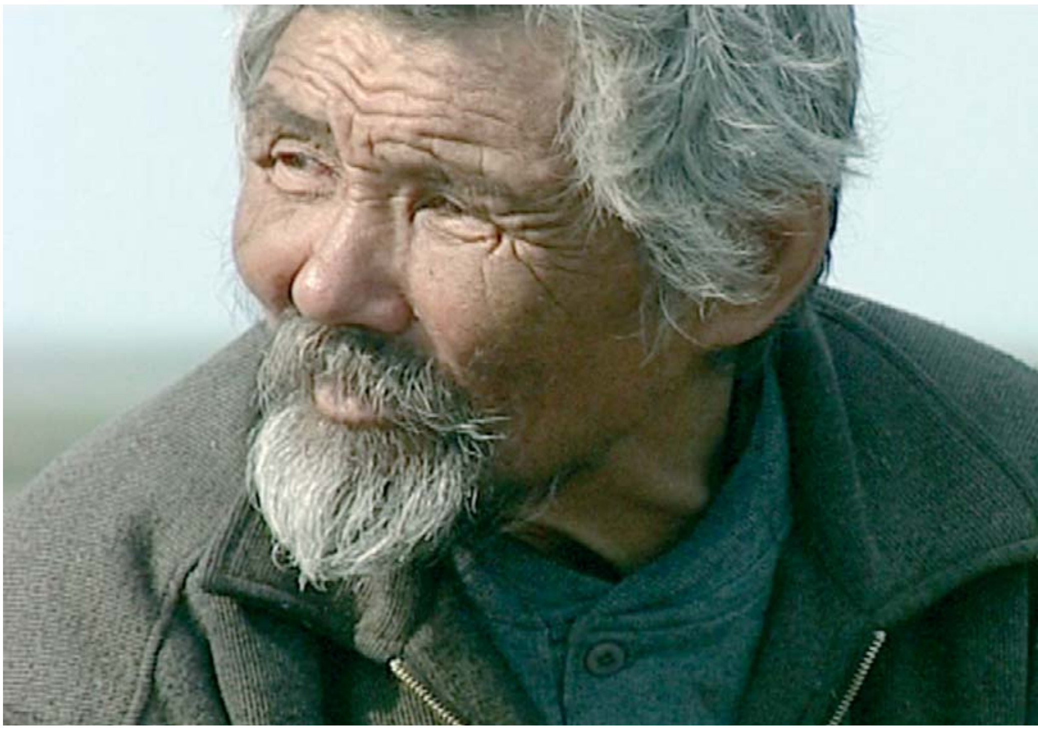
Morbidity and sickliness among the indigenous population is typical for the areas studied. Prevailing diseases are respiratory diseases (up to 30-40% of all diseases), traumas, eye diseases, cardiovascular pathologies, and diseases of the digestive system and of the urogenital system.

An increase in sickliness (reported morbidity) is common for all areas studied, and can be attributed to a number of factors, including greater awareness and accessibility to medical treatment.



Chapter 9

Health effects associated with lifestyle, diet and exposure to PTS



9.1. Health risk factors

9.1.1. Tobacco smoking and alcohol intake

Tobacco smoking is found to be one of most common adverse habits practiced among the indigenous population, and is most prevalent in the Chukchi AO. The dietary and lifestyle survey found that almost 96% of the total adult indigenous population regularly consumes alcoholic drinks, at least once a month. As expected, vodka appears to be the preferred alcoholic drink throughout the Russian Arctic (Table 9.1.). About two thirds of the adult indigenous respondents (74% of men and 42% of women), reported consuming only vodka or vodka-like strong drinks.

Unfortunately, the original questionnaire used in the dietary survey did not provide the option of specifying consumption of homemade alcoholic drinks, which are illegal to produce. However, the average consumption of such beverages is estimated to range from 11 litres per year in communities in Taymir to 50 litres per year among indigenous communities in Chukotka. From the 2003 targeted survey, it was concluded that homemade alcoholic drinks are often consumed as a raw (rather than distilled) brew that may well be highly contaminated by POPs (see Chapter 6).

Alcohol intake in quantities amounting to 3 litres of ethanol per year by indigenous women, has been demonstrated to cause a number of adverse reproductive health effects; such as low birth weight, reduced gestational age of neonates, stillbirth and birth defects (Table 9.2).

In contrast, the smoking of tobacco does not seem to present a severe risk factor with respect to reproductive and developmental disorders in indigenous women and their infants. A statistically positive but moderate correlation has been found only for a reduction in the gestational age of newborns of smokers (Table 9.3).

In the meantime, the prevalence of some chronic diseases, and specifically, pulmonary diseases, appears to show a close correlation with reported intensity of tobacco smoking, illustrating the already well known dose-response relationship between the two traits (Table 9.4). A greater prevalence in reported liver disease is also associated with smoking intensity.

9.1.2. General well-being and other social factors

9.1.2.1. Low family income and level of education

It is commonly accepted that poverty and unemployment are two very important risk factors, which can compromise human health. The global trend is for a change in the nutritional patterns of less-favoured groups in the population, leading to lower animal protein, and higher fat consumption. In contrast, indigenous people of the North with low monetary incomes become more reliant on local food, and in particular fish and wild (marine) animals, which are generally more readily available to

Questions:	CAO		Kola		NAO		TAO	
	n	%	n	%	n	%	n	%
Do you smoke?	401	65.6	115	43.4	148	42.7	189	54.0
Do you drink beer?	97	15.9	55	20.8	137	39.5	181	51.7
Do you drink wine?	36	5.9	20	7.5	106	30.5	60	17.2
Do you drink vodka?	442	72.3	176	66.4	181	52.2	237	67.9

Table 9.1. Self-reported smoking habits and alcohol consumption: proportion of respondents giving a positive answer (Yes) to questions.

Annual alcohol consump-tion[1]	All reported fatal outcomes [2]	Spontane ous abortions	Stillbirths and structural malforma-tions	Low birth weight, <2500 g	Premature births, <37 weeks
Not drinking	11.7	10.0	3.3	4.20	10.8
Under 3 L	14.3	12.7	4.8	6.30	9.5
3 L and more	18.5	11.1	5.6	11.10	14.8
Spearmen's correlation coefficient	0.99	0.25	0.94	0.99	0.82

Table 9.2. Prevalence of lifetime adverse outcomes of pregnancies (%), by reported alcohol consumption. 1 – calculated as ethanol equivalent; 2 – includes spontaneous abortions, stillbirths, ectopic pregnancies

Smoking intensity	Proportion of women reporting adverse pregnancy outcomes, %		
	Spontaneous abortions	Premature births, <37 weeks	Low birth weight, <2500 g
Non smokers (n=151)	13.1%	9.2%	7.2%
Moderate smokers (under 15000 cigarettes a year) (n=41)	9.8%	9.8%	4.9%
Heavy smokers (more than 15000 cigarettes a year) (n=43)	4.7%	20.9%	4.7%

Table 9.3. Prevalence of lifetime adverse outcomes of pregnancies (%), by reported smoking habits.

Smoking intensity	Proportion of respondents given positive answers (Yes) to the question:		
	Do you have any pulmonary disease?	Do you have any liver disease?	Do you have any chronic disease?
Non smokers (n=151)	3.9	9.2	37.9
Moderate smokers (under 15000 cigarettes a year) (n= 41)	7.3	7.3	26.8
Heavy smokers (more than 15000 cigarettes a year) (n=43)	11.6	25.6	44.2
Spearmen's correlation coefficient	0.98	0.82	0.55

Table 9.4. Prevalence of chronic diseases (%), by reported smoking intensity.

them than marketed foodstuffs. Since local fish and marine mammals in many Arctic areas are significantly more contaminated by POPs than imported foodstuffs, for those unable to purchase market products, the total burden of PTS is clearly elevated. Thus, poverty can be, and often is, a predisposing risk factor in the exposure of indigenous people in the Arctic to PTS (Table 9.5). Family income and the educational level of pregnant women, in general, both show negative correlations with PTS blood concentrations. This points to the probable impact of poverty and poor awareness regarding risks to health, on families in less favorable circumstances with respect to both income and educational attainment.

Contaminant	Monthly family income per capita	Duration of education
ΣPCB (ng/g)	-0.322	-0.208
Arochlor 1260 (ng/g)	-0.353	-0.203
ΣHCH (ng/g)	0.155	0.204
ΣChlordanes (ng/g)	-0.276	-0.067
ΣDDT (ng/g)	0.243	0.206
HCB (ng/g)	-0.458	-0.200
ΣToxaphene (ng/g)	-0.319	-0.091
Cd (μg/L)	-0.264	-0.184
Pb (μg/L)	-0.078	-0.660
Hg (μg/L)	-0.287	-0.245

Table 9.5. Spearman correlation coefficient for PTS blood concentrations and family monetary income, and total duration of education, in the group of pregnant indigenous women.

The most pronounced effect of low family income, is to promote the consumption of local sources of food fats which appear to be a major source of PTS exposure for indigenous populations residing in coastal communities (Table 9.6). The lowest level of fat intake was recorded for the indigenous population residing in the location of the Pechora River, where the main type of local food consumed are fresh water fish species which are generally low in fat.

9.1.2.2. Occupation

It was clear from the questionnaire study, that many indigenous people, and especially women, found difficulty in specifying their occupation; as the employment infrastructure in Arctic areas is often not well-developed. Although most women residing in indigenous communities reported some form of employment, job descriptions and job tasks described, as well as monthly incomes earned, indicate a fairly wide difference between formal occupations and the work actually undertaken.

In order to minimize possible misclassifications of occupations, all pregnant respondents were divided into three groups. The first group included women involved in animal farming and herding (outdoors); the second group included maintenance and service workers (indoors); and the third group, technicians, hospital and school personnel, fur/leather handling and workers involved with handcrafts (again indoors).

The groups with the highest exposure to POPs, (except for PCBs), were found to be the indoor occupational groups, who have potentially experienced a longer/higher exposure to household chemicals than outdoor workers (Table 9.7).

9.1.3. Self-assessment of environmental pollution

On the basis of data presented in Tables 9.8. and 9.9, air pollution is of little concern to indigenous people. The majority of people still believe that the Arctic is the least polluted, and most pristine area in the world, although this judgment may be based on inadequate public awareness of their local environmental situation. Women, as expected, are far more concerned about pollution than men.

PTS	Concentrations		Occupational groups (see section 9.1.2.2)			Total
			1st	2nd	3rd	
ΣPCB (n=208)	Over 1.0 μg/L	n	24	145	39	161
		%	70.8	78.5	76.9	
Arochlor 1260 (n=208)	Over 5.0 μg/L	n	6	49	13	68
		%	25.0	33.8	33.3	
ΣHCH (n=202)	Over 1.0 μg/L	n	7	63	20	90
		%	29.1	45.0	52.6	
ΣChlordanes (n=208)	Over 0.1 μg/L	n	14	93	30	137
		%	58.3	64.1	76.9	
ΣDDTs (n=202)	Over 2.0 μg/L	n	5	76	21	102
		%	20.8	54.2	55.2	
ΣToxaphene (n=205)	Over 0.5 μg/L	n	7	72	23	102
		%	29.1	50.7	58.9	

Table 9.7. Proportion of pregnant women (%) with higher PTS blood concentrations, classified by occupation group.

9.1.4. Indoor exposure to PTS

It is important to emphasize that the questionnaire study has, for the first time, provided overt epidemiological evidence of widespread, non-agricultural use of

	Coastal communities		Inland communities		Pechora River Basin community	
	Below 1500 roubles	1500 and over	Below 1500 roubles	1500 and over	Below 1500 roubles	1500 and over
Number of respondents	31	16	106	39	86	19
Country food fat, g	59.78	41.49	21.31	29.20	9.25	8.82
Store food fat, g	17.96	17.44	25.20	32.35	20.28	33.77
Ratio (country/store fat)	3.33	2.38	0.84	0.90	0.46	0.26

Table 9.6. Mean fat consumption (grams per day) and monetary income (monthly income calculated in Russian roubles) by indigenous women.

Answers	CAO		Kola		NAO		TAO		Total	
	n	%	n	%	n	%	n	%	n	%
Clean enough	212	62.4	120	73.2	120	51.5	108	54.5	560	59.9
Polluted	71	20.9	34	20.7	70	30.0	76	38.4	251	26.8
Don't know	57	16.8	10	6.1	43	18.5	14	7.1	124	13.3
Total	340	100.0	164	100.0	233	100.0	198	100.0	935	100.0

Table 9.8. Expressed concern over air pollution (women). Question: What is your feeling about the quality of ambient air in your settlement?

Answers	CAO		Kola		NAO		TAO		Total	
	n	%	n	%	n	%	n	%	n	%
Clean enough	196	72.3	82	82.0	71	62.3	99	63.5	448	69.9
Polluted	27	10.0	15	15.0	18	15.8	40	25.6	100	15.6
Don't know	48	17.7	3	3.0	25	21.9	17	10.9	93	14.5
Total	271	100.0	100	100.0	114	100.0	156	100.0	641	100.0

Table 9.9. Expressed concern over air pollution (men). Question: What is your feeling about the quality of ambient air in your settlement?

highly toxic substances in areas of the Arctic. Indoor and occupational sources of PTS exposure are likely to be a significant underlying contributor to the higher blood concentrations of persistent contaminants found in the arctic indigenous populations of Russia. Thus, for instance, almost half of the respondents in the Chukchi AO and Kola peninsula (Table 9.10) reported the regular use of a number of highly toxic substances against insects and rodents. The majority of those chemicals have not been properly labeled and their use is practically uncontrolled (see Chapter 4, Table 4.34). It was discovered, that at least some of these substances (most of which were imported from China) contain significant amount of POPs such as PCBs, DDT and HCH. The most contaminated substance, proved to be an insecticide named "Medifox super". This has been in widespread use since the early 1990's for general household use, as well as being applied to human skin and hair, especially of children, for the treatment of skin parasites such as itch-mites and lice. Considering the official reported prevalence of pediculosis and scabies, which affect from 11% to 35% of the total population resident in arctic indigenous communities, it is clear that the use of such insecticides could pose a significant risk of human exposure to POPs.

Questions Yes/No	CAO		Kola		NAO		TAO	
	n	%	n	%	n	%	n	%
Do you use any toxic chemicals against rodents?	279	45.7	113	42.6	90	25.9	54	15.4
Do you use any toxic chemicals against insects in your vegetable garden?	6	1.0	1	0.4	1	0.3	2	0.6
Do you use any toxic chemicals against insects in occupational settings?	18	2.9	1	0.4	16	4.6	1	0.3
Do you use any toxic chemicals against insects indoors?	270	44.2	111	41.9	55	15.9	50	14.3

Table 9.10. Use of insecticides/pesticides and other chemicals. Proportion of those giving a positive answer (Yes).

A large proportion of indigenous people surveyed (23 – 45%) reported routine use and sometimes domestic production, of materials containing lead (such as paint, ammunition, fishing equipment, etc.) (Table 9.11). This information suggests that more effort should be given to evaluating local sources of exposure, and caution applied in approaching the evaluation of risks associated with the global transport of PTS.

Questions	CAO		Kola		NAO		TAO	
	n	%	n	%	n	%	n	%
Have you used lead-containing paintings or other construction materials?	128	20.9	14	5.3	105	30.3	18	5.1
Do you use lead-containing materials for fishing?	199	32.6	32	12.1	76	21.9	29	8.3
If yes, do you make them yourself by means of lead melting?	119	19.5	20	7.5	34	10.0	14	4.0
Do you use lead-containing ammunition for hunting?	171	28.0	60	22.6	80	23.1	135	38.6

Table 9.11. Use of materials containing lead. Proportion of respondents given a positive answer (Yes) to questions.

Region	Women		Men	
	Yes	%	Yes	%
CAO	320	94.1	252	93.0
Kola peninsula	165	100.0	100	100.0
NAO	233	100.0	114	100.0
TAO	193	99.0	155	100.0
Total	911	98.3	621	95.8

Table 9.12. Consumption of local food (Question: Do you regularly consume local foods?).

Source of food	Kola Peninsula		Pechora River Basin		Taymir Peninsula		Chukotka Peninsula	
	Yes	No	Yes	No	Yes	No	Yes	No
Local food, including:								
Wild animal meat	100.0	0.0	97.1	2.9	100.0	0.0	100.0	0.0
Wild birds	37.7	62.3	89.4	10.6	93.8	6.2	87.4	12.6
Fish	99.6	0.4	97.6	2.4	99.2	0.8	99.8	0.2
Berries	98.5	1.5	98.2	1.8	76.8	23.2	98.2	1.8
Locally cultivated vegetables	98.3	1.7	46.1	53.9	0.0	100.0	24.5	75.5
Imported food, including:								
Farmed animal meat	82.0	18.0	89.8	10.2	96.9	3.1	89.4	10.6
Fish	45.9	54.1	11.1	88.9	6.8	93.2	28.3	71.7
Vegetables	93.2	6.8	87.5	12.5	99.2	0.8	94.5	5.5

Table 9.13. Proportion of respondents (%) reporting consumption of local foods.

9.1.5. Diet

Clearly, the Russian Arctic population is highly dependent on local foods (Table 9.12 and 9.13). Practically all the indigenous population in the project pilot areas reported dependence on traditional local food in their diet. The high consumption of marine mammal meat and fat by the indigenous population of coastal Chukotka, is of particular note (Table 9.14).

Intake	seal meat	seal fat	walrus meat	walrus fat	whale meat	whale fat	Total average		
							Blubber	Meat	Total
Annual, kg	22	8.8	23	8.8	17	7.2	24.8	62	86.8
Daily, g	60	24.0	63	24.0	46	20.0	68.0	169	237.0

Table 9.14. Consumption of marine mammal meat and blubber by indigenous coastal population (in Uelen).

9.2. Health effects associated with exposure to PTS

9.2.1. Self-evaluation of health status

With the exception of the TAO population, most respondents believe that they are in good health. However, between 28 to 60% also reported that they had been told by a doctor that they might have a chronic disease (Table 9.15). However, the prevalence of health complaints made by native people is generally lower than that observed in non-indigenous arctic populations of the same age (62–79%) (Kovalev *et al.*, 2000). Given the extremely low life expectancy in Arctic indigenous populations (see Chapter 2), the low prevalence of reported health problems is likely to relate to lack of awareness regarding existing or developing health problems.

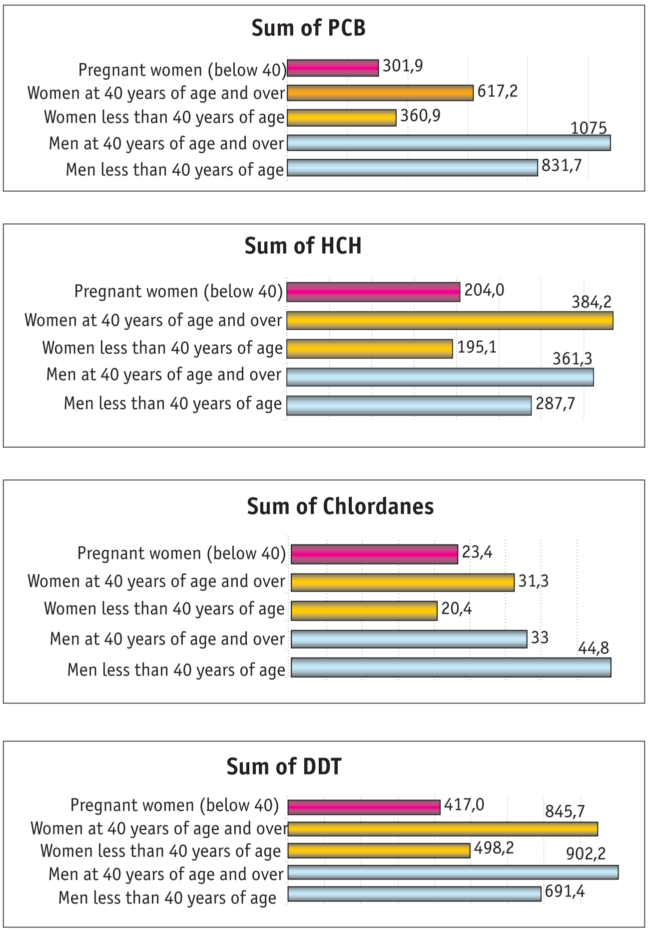


Figure 9.1. Concentrations (geometric means, ng/g lipid weight) of OCs in blood of indigenous people by age.

9.2.2. Blood concentrations of PTS: Variation

POP concentrations in serum are known to vary due a number of individual factors, e.g. age, diet, parity etc. This study has shown that the most pronounced differences are associated with gender and age. Thus, men older than 40 years of age showed a 1.3-fold increase in concentrations of total PCBs, DDT and HCH, compared to younger men living in the same communities (Figure 9.1). The differences between the two age groups in indigenous women are found to be greater than between men, with up to a 2-fold increase in POP concentrations occurring in older women. Pregnant women showed the lowest serum concentrations for a number of organochlorines, such as HCB, total toxaphenes, and, to a lesser extent, the sums of PCBs and DDT. A possible explanation for this phenomenon is that pregnant women, in accordance with medical recommendations, are often admitted to delivery departments 3–4 weeks prior to the expected date of birth, in

Question	CAO		Kola		NAO		TAO	
	Yes	%	Yes	%	Yes	%	Yes	%
Do you believe that you are healthy?	398	65.1	145	54.7	197	56.8	141	40.3
Has a doctor ever told you that you may have a chronic disease?	170	27.9	116	44.8	118	34.0	207	59.1

Table 9.15. Self-reported health problems.

Number of live births		ΣPCB	ΣHCH	ΣChlordane	ΣDDT	HCB	ΣToxaphene
1	n	78	75	78	75	78	78
	Mean	526.65	327.44	68.54	637.78	194.65	23.31
2	n	72	69	72	69	72	70
	Mean	404.67	202.16	48.69	475.40	180.77	19.27
3	n	30	30	30	30	30	29
	Mean	472.44	205.00	71.36	443.05	212.33	20.73
4 and more	n	28	28	28	28	28	28
	Mean	657.53	314.41	151.23	494.43	284.21	34.66

Table 9.16. Relationship between concentration (geometric means; ng/g lipid) of POPs in serum and parity.

Number of live births		Cd	Pb	Hg
1	n	75	75	75
	Mean	0.93	48.11	1.79
2	n	67	67	67
	Mean	0.97	44.18	2.26
3	n	29	29	29
	Mean	1.05	53.76	2.52
4 and more	n	28	28	28
	Mean	1.35	57.38	3.22

Table 9.17. Relationship between concentration (geometric means; μg/L) of metals in blood and parity.

Table 9.18. Spearmen correlation coefficients between concentrations of selected PTS in blood of pregnant indigenous women.

	Arochlor 1260 (ng/g)	ΣPCB (ng/g)	ΣHCH (ng/g)	ΣChlordanes (ng/g)	ΣDDT (ng/g)	ΣHCB (ng/g)	ΣToxaphene (ng/g)	Cd (μg/L)	Pb (μg/L)	Hg (μg/L)
Arochlo 1260 (ng/g)	-	0.870	0.285	0.606	0.173	0.665	0.589	0.205	0.143	0.236
ΣPCB (ng/g)	0.870	-	0.340	0.558	0.265	0.719	0.606	0.138	0.122	0.183
ΣHCH (ng/g)	0.285	0.340	-	0.427	0.674	0.231	0.356	0.015	0.026	-0.160
ΣChlor-danes (ng/g)	0.606	0.558	0.427	-	0.130	0.614	0.632	0.268	0.250	0.151
ΣDDT (ng/g)	0.173	0.265	0.674	0.130	-	0.051	0.146	-0.205	-0.064	-0.209
HCB (ng/g)	0.665	0.719	0.231	0.614	0.051	-	0.598	0.152	0.164	0.259
ΣToxa-phene (ng/g)	0.589	0.606	0.356	0.632	0.146	0.598	-	0.189	0.179	0.218
Cd (μg/L)	0.205	0.138	0.015	0.268	-0.205	0.152	0.189	-	0.303	0.238
Pb (μg/L)	0.143	0.122	0.026	0.250	-0.064	0.164	0.179	0.303	-	0.091
Hg (μg/L)	0.236	0.183	-0.160	0.151	-0.209	0.259	0.218	0.238	0.091	-

	ΣPCB (ng/g)	Arochlor 1260 (ng/g)	ΣHCH (ng/g)	ΣChlordanes (ng/g)	ΣDDT (ng/g)	HCB (ng/g)	ΣToxaphene (ng/g)	Cd (μg/L)	Pb (μg/L)	Hg (μg/L)
ΣPCB (ng/g)	-	0.937	0.613	0.260	0.565	0.421	0.569	0.173	0.104	0.369
Arochlor 1260 (ng/g)	0.937	-	0.590	0.288	0.565	0.377	0.604	0.224	0.111	0.367
ΣHCH (ng/g)	0.613	0.590	-	0.313	0.467	0.460	0.224	0.063	0.250	0.118
ΣChlordanes (ng/g)	0.260	0.288	0.313	-	0.043	0.059	0.055	0.036	0.211	0.155
ΣDDT (ng/g)	0.565	0.565	0.467	0.043	-	0.601	0.309	-0.147	-0.298	0.060
HCB (ng/g)	0.421	0.377	0.460	0.059	0.601	-	0.062	-0.442	-0.350	0.290
ΣToxaphene (ng/g)	0.569	0.604	0.224	0.055	0.309	0.062	-	0.394	0.035	0.335
Cd (μg/L)	0.173	0.224	0.063	0.036	-0.147	-0.442	0.394	-	0.508	0.277
Pb (μg/L)	0.104	0.111	0.250	0.211	-0.298	-0.350	0.035	0.508	-	0.163
Hg (μg/L)	0.369	0.367	0.118	0.155	0.060	0.290	0.335	0.277	0.163	-

Table 9.19. Spearmen correlation coefficients between concentrations of selected PTS in blood of women of the general indigenous population.

Table 9.20. Spearmen correlation coefficients between concentrations of selected PTS in blood in adult indigenous men.

	ΣPCB (ng/g)	Arochlor 1260 (ng/g)	ΣHCH (ng/g)	ΣChlordanes (ng/g)	ΣDDT (ng/g)	HCB (ng/g)	ΣToxaphene (ng/g)	Cd (μg/L)	Pb (μg/L)	Hg (μg/L)
ΣPCB (ng/g)	-	0.974	0.656	0.222	0.501	0.163	0.647	0.523	0.389	0.588
Arochlor 1260 (ng/g)	0.974	-	0.636	0.250	0.476	0.107	0.630	0.461	0.354	0.545
ΣHCH (ng/g)	0.656	0.636	-	0.080	0.348	0.224	0.370	0.390	0.372	0.327
ΣChlor-danes (ng/g)	0.222	0.250	0.080	-	0.204	0.022	0.115	0.285	-0.073	0.064
ΣDDT (ng/g)	0.501	0.476	0.348	0.204	-	0.582	0.232	-0.001	0.089	0.063
HCB (ng/g)	0.163	0.107	0.224	0.022	0.582	-	-0.288	-0.303	-0.159	-0.104
ΣToxa-phene (ng/g)	0.647	0.630	0.370	0.115	0.232	-0.288	-	0.478	0.467	0.360
Cd (μg/L)	0.523	0.461	0.390	0.285	-0.001	-0.303	0.478	-	0.605	0.524
Pb (μg/L)	0.389	0.354	0.372	-0.073	0.089	-0.159	0.467	0.605	-	0.413
Hg (μg/L)	0.588	0.545	0.327	0.064	0.063	-0.104	0.360	0.524	0.413	-

order to receive proper health care. This includes special nourishment, which is completely based on imported foodstuffs. A further issue to be taken into consideration, is that the group of pregnant women are representative of the whole study area, rather than of specific communities. Therefore, the possibility of some inter-community variation cannot be ruled out.

Parity (more precisely the number of breast fed children) also needs to be considered as a factor capable of reducing POP serum concentrations (Tables 9.16 and 9.17). As previously mentioned, between 68% to 94% of indigenous infants are breast fed for a period longer than 6 months and almost a half of them for over one year. Those women having more than one child, but less than 4 children, showed significantly lower concentrations of HCB, DDE and PCBs. The relative increase seen in POP levels of mothers having 4 or more children, is likely to reflect the age-dependency effect in POP levels, mentioned above, which is potentially greater in this group of women.

Most of the organic contaminants show positive correlations to each other, whilst for inorganic contaminants this is not the case (Tables 9.18–9.20). For pregnant women a closer relationship is found between total PCBs and HCB (neither of which are pesticides), and which presumably have one or more common exposure routes. Organochlorine pesticides are also positively correlated to each other.

The correlation pattern obtained from statistical analysis of PTS blood concentrations for the general indigenous population appears differ slightly from that observed in pregnant women. In fact, relationships between concentrations of individual POPs in blood are generally not very close. The majority of r-values range from 0.2 to 0.6. For inorganic contaminants, only the Pb-Cd pair shows a moderate association.

9.2.3. Health effects associated with PTS blood concentrations

9.2.3.1. Reproductive and developmental effects

9.2.3.1.1. Main associations between exposure and effects

A number of experimental findings suggest that exposure to PTS is associated with reproductive health effects. Epidemiological evidence of this, however, is very limited. A basic statistical analysis of recorded adverse outcomes of pregnancy in indigenous women, and their current PTS blood concentrations, has shown that there is a statistically significant, but relatively low association (RR-value from 2.05 to 2.77) between the prevalence of premature births and blood concentrations of lead exceeding 30 μg/L, cadmium exceeding 1.0 μg/L and PCBs (as Arochlor 1260) exceeding 5.0 μg/L (Table 9.21). In addition, the identical concentrations of PCBs and Cd measured in both maternal and cord blood are found to correlate with reduced birth weight of newborns (either below 2500 g or 3000 g), at a similar level of statistical significance (Table 9.22).

There have been four reported cases of serious structural malformation and six stillbirths in the study group of pregnant indigenous women. The geometric means of concentrations of total PCBs, DDTs and Hg in the maternal blood found in these adverse cases, proved to be 1.7–2.0 times higher than in women where there were no reported adverse outcomes (Table 9.23).

PTS			Gestational age: Under 37 weeks	Gestational age: 37-40 weeks	Total
Pb	below 30 μg/L	n	3	50	53
		%	5.70	94.3	100.0
	30 μg/L and over	n	23	123	146
		%	15.80	84.2	100.0
RR			2.77		
Chi-Square Tests (p-value)			0.05		
Spearman correlation coefficient			-0.132		
Cd	below 1 μg/L	n	10	105	115
		%	8.7	91.3	100.0
	1 μg/L and over	n	15	69	84
		%	17,9	82.1	100.0
RR			2.06		
Chi-Square Tests (p-value)			0.05		
Spearman correlation coefficient			-0.126		
ΣPCB	below 1.0 μg/L	n	13	127	140
		%	9.3	90.7	100.0
	1.0 μg/L and over	n	14	54	68
		%	20.6	79.4	100.0
RR			2.22		
Chi-Square Tests (p-value)			0.023		
Spearman correlation coefficient			-0.158		

Table 9.21. Prevalence of preterm pregnancy and concentrations of PTS in blood of indigenous women.

Contaminant			Birth weight, g: Below 2500	Birth weight, g: Below 3000	Total
Hg	below 2 μg/L	n	20	92	112
		%	17.9	82.1	100.0
	2 μg/L and over	n	17	41	58
		%	29.3	70.7	100.0
RR			1.64		
Chi-Square Tests (p-value)			0.08		
Spearman correlation coefficient			- 0.132		
Cd	below 1 μg/L	n	32	128	160
		%	20.0	80.0	100.0
	1 μg/L and over	n	5	5	10
		%	50.0	50.0	100.0
RR			2.50		
Chi-Square Tests (p-value)			0.02		
Spearman correlation coefficient			-0.171		
ΣPCB	below 1.0 μg/L	n	25	110	135
		%	18.5	81.5	100.0
	1.0 μg/L and over	n	13	30	43
		%	30.2	69.8	100.0
RR			1.93		
Chi-Square Tests (p-value)			0.10		
Spearman correlation coefficient			-0.122		

Table 9.22. Prevalence of low birth weight newborns and concentrations of PTS in cord blood.

Table 9.23.
Concentrations (geometric mean; µg/L) of PTS in blood of indigenous women reporting stillbirths and structural malformations.

Group	Number	ΣPCB	Aroclor 1260	ΣHCH	ΣChlordanes	ΣDDT	HCB	ΣToxaphene	Cd	Pb	Hg
No adverse outcome reported	204	2.29	5.38	1.26	0.51	2.53	0.97	0.19	1.02	48.91	2.26
Women reporting stillbirths and serious birth defects	8 (3.4%)	3.90	10.22	1.67	0.87	4.48	1.42	0.19	1.20	33.43	3.48

Table 9.24.
Concentrations (geometric mean; µg/L) of PTS in blood of indigenous women reporting lifetime spontaneous abortions.

Study area and effects	n	ΣPCB	Aroclor 1260	ΣHCH	ΣChlordanes	ΣDDT	HCB	ΣToxaphene	Cd	Pb	Hg
Kola Peninsula											
No adverse outcome reported	15	1.24	2.94	0.58	0.02	3.21	0.42	0.04	0.42	29.83	1.23
Spontaneous abortion	2 (11.8%)	2.13	4.22	1.18	0.07	2.12	0.48	0.01	0.32	30.50	0.50
NAO											
No adverse outcome reported	36	1.96	4.81	0.63	0.09	2.70	0.76	0.07	0.84	41.38	1.19
Spontaneous abortion	3 (7.7%)	3.24	7.15	0.50	0.03	2.02	0.86	-	1.24	41.65	0.75
TAO											
No adverse outcome reported	66	1.93	3.80	1.08	0.08	2.43	0.69	0.12	0.94	59.99	2.82
Spontaneous abortion	11 (13.8%)	1.98	4.14	1.08	0.07	2.38	0.85	0.09	0.83	52.78	2.59
CAO (inland)											
No adverse outcome reported	58	1.80	3.93	1.12	0.53	2.21	0.84	0.06	0.95	41.03	2.14
Spontaneous abortion	3 (4.8%)	1.01	2.26	1.11	0.08	2.12	1.18	0.06	0.70	32.83	4.60
CAO (coastal)											
No adverse outcome reported	29	4.62	12.37	2.65	1.29	3.07	2.14	0.69	1.59	57.66	1.92
Spontaneous abortions	7 (18.4%)	2.93	7.77	1.46	0.74	2.22	1.14	0.22	1.12	48.33	2.37

PCB concentration range		Birth weight, g			
		below 2500	2500-2999	3000 and over	Total
below 1.0	n	5	10	67	82
	%	6.1	12.2	81.7	100.0
1.0 – 1.9	n	3	14	73	90
	%	3.3	15.6	81.1	100.0
2.0 – 4.0	n	4	14	34	52
	%	7.7	26.9	65.4	100.0
Over 4.0	n	4	8	19	31
	%	12.9	25.8	61.3	100.0

Table 9.25. Prevalence of low birth weight newborns (%) and concentrations (µg/L) of total PCB in maternal serum.

PCB Concentration range		Gestational age, weeks		
		Under 37	Over 37	Total
Less than 1.0	n	7	75	82
	%	8.5	91.5	100.0
1.0 – 1.9	n	5	85	90
	%	5.6	94.4	100.0
2.0 – 4.0	n	10	42	52
	%	19.2	80.8	100.0
Over 4.0	n	5	26	31
	%	16.1	83.9	100.0

Table 9.26. Prevalence of premature births (%) and concentrations (µg/L) of total PCB in maternal serum.

Some weak associations were also found between the prevalence of lifetime spontaneous abortions and the level of blood concentrations of PCBs and HCHs in pregnant indigenous women of the Kola Peninsula and the Nenets AO, whereas for the Chukchi AO group of pregnant women, the prevalence of spontaneous abortions is closely associated with blood concentrations of total Hg (Table 9.24). Unfortunately, the study protocol did not allow for the separation of organic and inorganic mercury compounds, which are known to have very different toxic profiles including that of reproductive toxicity.

9.2.3.1.2. Dose-response relationships

Dose-response relationships for reproductive health effects observed in the entire group of pregnant women can be demonstrated by a more detailed breakdown of PTS blood concentrations (Tables 9.25 and 9.26). It is clear that total PCB serum concentrations in maternal serum above the level of 2.0 µg/L, seem to be capable of affecting both the birth weight and gestational age of newborns; whereas the prevalence of fatal outcomes of pregnancy increase significantly at higher levels of PCB exposure, above 4.0 µg/L (Table 9.27).

Among inorganic contaminants, a clear dose-response relationship has been found between total mercury concentrations in maternal blood and the prevalence of low birth weight. Other adverse outcomes showed a U-shape curve, with a higher lifetime prevalence occurring in the group of women with Hg concentrations below 1 µg/L, and with the highest response from the group with concentrations over 1.4 µg/L (Table 9.28).

9.2.3.1.3. Gender dependent health effects

It has been found that the gender of indigenous offspring can be significantly affected by an increase in maternal blood concentrations of lead, Arochlor 1260 and total PCBs. Mothers are more likely to have daughters, if their exposure to POPs was relatively high. This did not appear to be the case, with increased blood concentrations of Pb, Cd or total mercury. (Table 9.29). In total, the study group of indigenous newborns showed a higher ratio of males/females (1.32) than the national average (1.06), with this ratio higher even than that found in the top 'male prevalent' nations such as Korea (1.14) and China (1.09) (www.globalstat.com), (Figure 9.2). Interestingly, these reproductive and developmental effects appear to show a closer association with blood concentrations of the lower chlorinated congeners of PCBs, such as 28; 31; 52; 99 and 118 (Figure 9.3). It was also found that female newborns are at a higher risk of low birth weight and premature births than male newborns. The frequency of these adverse out-

PCB concentration range		Adverse outcomes: All fatal outcomes	Adverse outcomes: spontaneous abortions	Adverse outcomes: Birth defects and stillbirths	Total number of wome n
Below 1.0	n	9	8	1	82
	%	11.0	9.8	1.2	100.0
1.0 – 1.9	n	16	13	2	90
	%	17.8	14.4	2.2	100.0
2.0 - 4.0	n	6	6	1	52
	%	11.5	11.5	1.9	100.0
Over 4.0	n	7	4	4	31
	%	22.6	12.9	12.9	100.0

Table 9.27. Prevalence of fatal outcomes of pregnancy (%) and concentrations (µg/L) of total PCB in maternal serum.

Biomarker of effect (n)		Maternal blood concentrations, µg/L: Less than 1.0	1.0 - 1.4	Over 1.4	Total (199)
Baby weight at birth, g	Less then 2500 (14)	14.3	21.4	64.3	100
	2500-2999 (39)	28.2	15.4	56.4	100
	3000 and over (146)	37	15.1	47.9	100
Adverse outcomes	Spontaneous abortions (24)	29.2	12.5	58.3	100
	Stillbirths and malformations (8)	50	12.5	37.5	100
	All fatal outcomes (30)	36.7	13.3	50	100

Table 9.28. Prevalence of lifetime adverse outcome of pregnancies (%) and concentrations (µg/L) of mercury in blood.

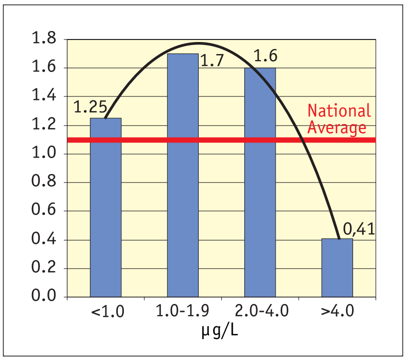


Figure 9.2. Relationship between pregnancy outcome (male/female sex ration of newborns) and total PCB concentrations in maternal serum.

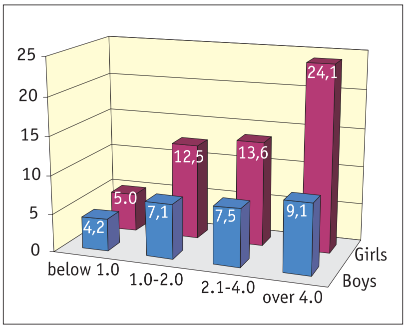


Figure 9.4. Relationship between premature births (earlier than 37 weeks; %) of male and female newborn and total PCB concentrations in maternal serum.

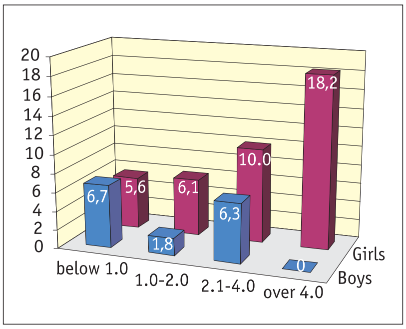


Figure 9.5. Relationship between low birth weight (under 2500g, %) in male and female newborn and total PCB concentrations in maternal serum.

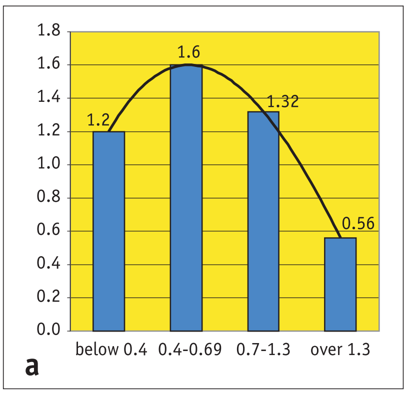
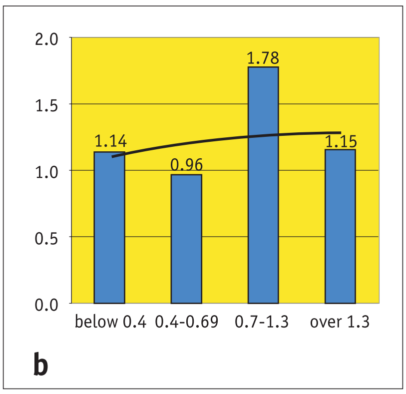


Figure 9.3. Relationship between pregnancy outcome (male/female sex ration of newborns) and PCB concentrations in matreial blood serum (µg/L) for lower (a) and higher (b) chlorinated PCBs.



comes for female newborns is closely correlated with total PCB concentrations measured in maternal serum (Figures 9.4 and 9.5).

9.2.3.1.4. Confounding factors

Unlike tobacco smoking, alcohol abuse has been confirmed as a severe reproductive health risk factor, and thus, might act as a confounder to PTS induced reproductive health effects. In order to rule this out, data for women who did not report drinking hard liquor, was analyzed separately by levels of PTS exposure, for selected pregnancy outcomes.

Lead concentrations of over 30.0 μg/L in maternal blood and PCB concentrations in serum of over 2.0 μg/L, may have affected gestational age, as well as the prevalence of stillbirths and spontaneous abortions, and compound with alcohol intake. However, it is important to note that for other contaminants (DDTs, HCHs, toxaphens, chlordanes) at observed exposure levels had no prevalence of reproductive health and developmental effects for non-drinking women and women who reported moderate and hard alcohol intake.

9.2.3.2. Prevalence of chronic diseases

The prevalence of reported health problems related to known chronic diseases among indigenous men over the age of 40, was not found to show a close association with measured current blood concentrations of PTSs (Table 9.30). This was possibly due to poor awareness regarding the manifestations and symptoms of the various health disorders.

Contaminants	Blood concentrations in maternal blood	
	Boys	Girls
Total PCBs (ng/g)	391 ± 61	471 ± 79
Arochlor 1260 (ng/g)	872 ± 142	1089 ± 230
ΣHCHs (ng/g)	279 ± 74	413 ± 66
ΣChlordanes (ng/g)	48 ± 27	78 ± 18
ΣDDTs (ng/g)	618 ± 51	773 ± 92
HCB (ng/g)	160 ± 49	187 ± 41
ΣToxaphene (ng/g)	18 ± 7	22 ± 8
Cd (μg/L)	0.9 ± 0.1	1.0 ± 0.2
Pb (μg/L)	45 ± 7	50 ± 11
Total Hg (μg/L)	1.9 ± 0.4	2.2 ± 0.3

Table 9.29. Concentrations (geometric mean) of PTS in maternal blood and gender of newborns.

In contrast the indigenous women of the same age showed quite a significant association between the prevalence of reported chronic diseases and elevated blood concentrations of some PTS, particularly that of Pb. (Table 9.31).

PTS			Do you have a chronic disease?		Total
			No	Yes	
ΣHCHs	below 1.0 μg/L	n	6	5	11
		%	54.5	45.5	100.0
	1.0 μg/L and over	n	9	13	22
		%	40.9	59.1	100.0
RR				1.30	
ΣClordanes	below 0.1 μg/L	n	8	7	15
		%	53.3	46.7	100.0
	0.1 μg/L and over	n	3	7	10
		%	30.0	70.0	100.0
RR				1.50	
ΣDDTs	below 2 μg/L	n	4	4	8
		%	50.0	50.0	100.0
	2 μg/L and over	n	11	14	21
		%	38.1	61.9	100.0
RR				1.24	
HC B	below 1.0 μg/L	n	7	6	13
		%	53.8	46.2	100.0
	1.0 μg/L and over	n	9	12	21
		%	42.9	57.1	100.0
RR				1.24	

Table 9.30. Reported chronic diseases and concentrations of PTS in blood of indigenous men over 40 years of age.

PTS			**Do you have a chronic disease?**		**Total**
			No	**Yes**	
Pb	**below 30 μg/L**	n	9	2	11
		%	81.8	18.2	100.0
	30 μg/L and over	n	22	26	48
		%	45.8	54.2	100.0
Chi-square test (p-value)				0.03	
RR				3.0	
ΣHCHs	**below 0.1 μg/L**	n	13	7	20
		%	65.0	35.0	100.0
	0.1 μg/L and over	n	23	37	60
		%	38.3	61.7	100.0
Chi-square test (p-value)				0.10	
RR				1.8	

Table 9.31. Reported chronic diseases and concentrations of PTS in blood of indigenous women over 40 years of age.

Chapter 10

Discussion on human health effects

10.1. Main findings of health importance

The representative survey groups from indigenous populations in each of the study areas, including 255 mother-child pairs and 1576 adults, have provided comprehensive data on gender, age, place of residence, the nature of traditional activities undertaken, diet, life-style details, self-evaluated health status and family health history. In addition, this database is supported by reliable medical information, obtained from personal medical records held by local hospitals and measurements of blood levels of all major PTSs. All of which information, helps to suggest that the study populations used in this report adequately reflect the general conditions characteristic of the indigenous population of the Russia Arctic as a whole.

Blood PTS concentrations show that all indigenous communities residing in the areas of the Russian Arctic studied, have suffered moderate exposure to the major groups of global environmental pollutants known to be transmitted through food chains, such as PCBs, DDT, HCH, HCB, lead and mercury. Only lead concentrations in blood, however, were found to exceed the threshold level currently recommended by WHO (100 μg/L) and then only in some cases. The main sources of lead exposure in the arctic are assumed to be the contamination of local food through both long-range transport of lead and the uncontrolled use of materials containing lead, such as paints and homemade ammunition (from pellet and bullet casting).

Actual serum concentrations of total PCBs (Arochlor 1260) were frequently found at levels of 5-8 μg/L. Regardless of the fact that national guideline levels for these toxic substances in blood have not been established, this may still be considered as a matter of concern for human health. Recent evidence suggests that PCBs may cause adverse reproductive, developmental, and endocrine effects (ATSDR, 2003, June Update). Despite the manufacture of PCBs being banned in most Arctic countries since 1977 (since the early 1990s in Russia), a number of current exposure sources do remain. It is well documented that the greatest human exposure to PCBs occurs through the consumption of contaminated fish. It is likely that PCB congeners are capable of being released into the general environment and thus, are able to contaminate local food by means of poorly maintained toxic waste sites, contaminated dwellings and through the unacceptably poor sanitation systems found in most native communities in the Russian Arctic.

As seen from concentrations of contaminants measured in maternal blood serum, indigenous pregnant women living in coastal areas of the Russian Arctic, show levels of exposure to a group of 'long-banned' pollutants, and in particular to HCB, DDT and PCBs, that are among the highest currently reported for all Arctic indigenous peoples (AMAP, 1997 and 2002).

It is likely that DDT and HCH blood contamination largely originate from common exposure sources which are not closely associated with the contamination of natural areas or wildlife. Based on the results of the targeted survey, extensive uncontrolled household use of materials which contain lead, and also use of insecticides and pesticides for rodent control, may significantly contribute to human PTS loads, through the secondary contamination of food which is stored and processed at home.

From the survey, it was found that in randomly selected wash-outs and wall scrapes taken from 28 houses occupied by indigenous families in the Nenets, Taymir and Chukchi Autonomous Okrugs, all major POPs were detected in 100% of cases. Levels were highest in Chukchi samples, where HCH was over 4 μg/m^2 and DDT was up to 4500 μg/m^2. Taymir wash-outs contained up to 38 μg/m^2 of total PCBs. DDE and DDD metabolites in the wash-outs and scrapes constituted 27% of total DDTs on average, (within a range of 10-70%), which suggests significant recent indoor contamination by chemicals containing DDT.

Between 65 % and 100% of home-made local foods, including both food which is prepared for cooking in the kitchen (i.e. trimmed and sliced) and ready-to-eat foodstuffs (salted, boiled or fermented) were contaminated by PCBs and DDT. Furthermore, 12 out of 13 domestic food samples from the Nenets AO communities, were contaminated by DDT at levels exceeding national food safety limits, while reindeer meat and fish samples taken from the natural environment at these locations were not found to be excessively contaminated by POPs. Data obtained during targeted surveys indicate that levels of indoor PCB contamination (of walls, kitchen facilities and appliances) correlate well to PCB levels measured in the blood of indigenous people living in houses surveyed. It is believed that intake of these substances by family members from the indoor environment takes place through the secondary contamination of food.

Based on concentrations measured in maternal blood serum, exposure of Russian Arctic indigenous peoples to PTS, and specifically to HCHs, HCB, DDT and PCBs, is one of the highest reported for all Arctic regions. The discovery of up to a 25-fold increase in *p,p'*-DDT serum concentrations in women from all of the study areas, may indicate a fresh source of exposure, bearing in mind that DDE concentrations of the women are at level comparable to other arctic populations (Hansen *et al.*, 2000; J. Oostdam *et al*, 1999).

The POP exposure intensity (body burden) of arctic indigenous women as measured in maternal and umbilical serum, in some cases exceeds that of residents of territories which are internationally recognized as disaster areas, for example the Aral Sea region. Here, due to long-term application of persistent pesticides, very high levels of environmental pollution exist, particularly for DDT and HCH (Muntean *et al.*, 2003), which occur in local foods at levels higher than maximum residue limits established by European Commission (EC, 1997, 1999, 2003). Thus, the geometric means of cord and maternal μ-HCH concentrations in the Chukotka population were found at levels 10-20% higher than those measured in Aral Sea women. DDE cord concentrations in the Kola population occur within ranges similar to those found in the Aral Sea population, while maternal and cord HCB concentrations measured in the coastal population of Chukotka, are likely to be some of the highest ever reported for both the Arctic and Aral Sea regions.

As some pesticides such as Mirex and toxaphenes have never been manufactured or imported into Russia (or into the former Soviet Union), blood serum concentration levels in the indigenous population in the study areas, provide an opportunity to obtain an approximate evaluation of the relative contribution made by global transfer of these substances to the POP exposure experienced by indigenous populations residing in the study area (Figure 10.1).

Given the results for Mirex in Table 10.1, it is assumed that most of the study populations in arctic Russia are exposed to levels of long-range transported persistent toxicants which are from 4 to 100 times less than the population resident in the coastal area of the Chukotka Peninsula.

Population	Geometric means of Mirex concentrations in serum, μg/L	Ratio of concentrations to that of coastal Chukotka, %
Chukotka coastal	0.12	100.0
Chukotka inland (Anadyr)	0.008	6.7
Taymir inland (Khatanga)	0.02	16.7
Taymir inland (Dudinka)	0.02	16.7
Taymir urban (Norilsk)	n.d.	>1
Kola (inland)	0.007	5.8
Pechora River Basin	0.03	25.0
Aral Sea urban	n.d	>1

Table 10.1. Serum concentrations of Mirex in study populations.
n.d. – not detected

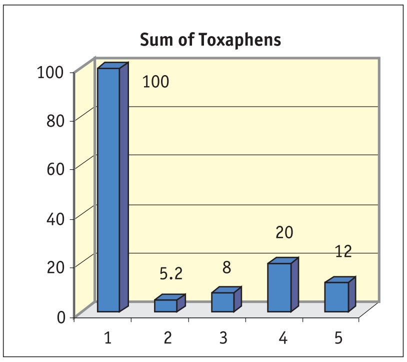
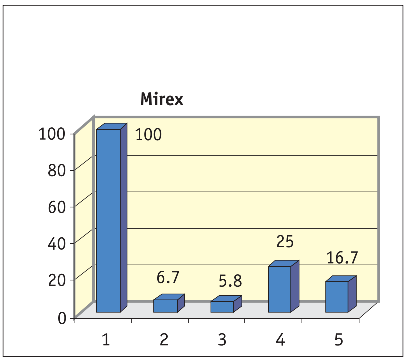


Figure 10.1
Proportion of serum samples containing Toxaphenes and Mirex in the study populations, %



1. Chukotka coastal
2. Chukotka inland
3. Kola
4. Pechora
5. Taimyr

Low-income indigenous families are at greater risk of exposure to POPs due to their significantly higher consumption of local foods, particularly fish and marine mammals of high fat content, which in many cases act as a major source of human exposure to environmental toxicants. Women with low incomes residing in the Chukchi AO, are also more likely than women with high incomes to be either underweight or obese. The prevalence of adverse outcomes of pregnancy increases steadily with a reduction in family monetary income per capita.

As a rule, blood concentrations of organic contaminants are positively correlated with each other, while this is not the case for inorganic contamnants. In pregnant women, a closer relationship is found between total PCBs and HCB (neither of which are pesticides), which presumes a common exposure source. Those organochlorines which are classified as pesticides, are also positively correlated with each other.

Significantly higher blood concentrations of PTS are found in males of indigenous populations compared to females. At a community level, the lowest serum concentrations of POPs are found in pregnant women, probably due to early hospitalization in delivery departments (and thus a change to a very different nutrition pattern). Long-term hospitalization preceding the expected birth is a common practice in prenatal health care in remote Russian Arctic areas.

At variance with commonly accepted views, cord blood concentrations of Pb and total Hg were frequently found to be higher than those measured in maternal blood and are poorly correlated. It is possible therefore, that babies could be at greater risk from inorganic pollutants accumulated by their mothers. In contrast, concentrations of total PCBs and most pesticides measured in maternal serum (expressed as unit of mass per unit of volume) are significantly higher when compared to their concentrations in cord blood and are closely correlated.

POP concentrations measured in blood serum are highly dependent on age. This phenomenon may reflect the impact of past exposure to POPs which, it is assumed, was much greater everywhere in the Arctic (AMAP, 1997).

The number of breast fed children has been also found to be a significant determinant of POP serum concentrations in women. Serum concentrations of lipophilic contaminants is reduced by an increase in parity.

In formal terms, only blood mean PCB and lead concentrations in the adult indigenous population exceed the internationally recognized levels of concern, designed to evoke preventive action. However, statistically significant associations have been found between blood concentrations of total PCBs (Arochlor 1260) and lead and a number of non-specific reproductive and developmental health effects such as prevalence of low birth weight, premature births, stillbirths and major structural malformations (Tables 10.2 and 10.3).

Also, statistical analysis of recorded health problems in connection with blood concentrations of some other pollutants (Hg, Cd and HCHs) indicates possible associations between pollutant levels and the prevalence of certain reproductive and developmental stages as well as with the prevalence of chronic diseases in older people.

Serum concentrations of total PCBs in maternal blood appear to be associated with alterations to the sex ratio. For concentrations of between 2 to 4 µg/L, the frequency of male offspring is found to be higher than the national average. In contrast, for maternal total PCB blood concentrations higher than 4.0 µg/L, there appears to be a strong effect on the prevalence in female offspring. Such a phenomenon has been widely discussed elsewhere in terms of paternal exposure to dioxin and dioxin-like substances (Davis *et al.* 1998; Ryan *et al*, 2002). Given that close correlations among adult members of a family are seen in blood levels of PCBs (see chapter 6) the exposure of fathers (as well as mothers) cannot be ruled out as a possible important risk factor in affecting sex ratios.

Metal	Level of exposure, µg/L	Susceptible populations	Observed effect (RR – relative risk of an effect)	Confounding	Statistical strength
Lead	> 30.0	Pregnant women	Premature birth RR= 2.77 Altered gender ratio RR=2.2	PCB, Cd	Moderate
		Women over 40 of age	Prevalence of chronic diseases RR=3.0	Alcohol	Moderate
Cadmium	> 1.0	Pregnant women	Premature birth RR=2.06	Pb, PCB	Weak
			Low birth weight RR=2.5	PCB, alcohol	Weak
Mercury	> 2.0	Pregnant women of Chukotka	Spontaneous abortions RR=3.1		Moderate

Table 10.2. Summary of possible health effects in indigenous populations associated with exposure of indigenous people to selected metals.

In contrast to information previously obtained from national and global statistics, female babies of indigenous mothers with elevated POP blood concentrations, are exposed to a higher risk of low birth weight and other adverse outcomes of pregnancy when compared to male babies. A similar association was reported for a number of cases where parents had been exposed to organochlorine chemicals.

PCB	Level of exposure, µg/L	Observed effect	Confounding	Statistical strength
Total PCB Arochlor 1260	> 2.0 > 5.0	Altered gender ratio of newborns, RR=3.3	Pb	Moderate
		Premature birth, RR=2.22 In female newborns: RR=2.6	HCH, Low family income, Alkohol	Weak
		Premature birth, RR=2.8	Alkohol, Low family income	Weak/moderate
		Stillbirth and birth defects among female newborns, RR=3.5		Weak
		Increase in prevalence of lifetime adverse outcomes of pregnancies, RR=2.4	Hg, Pb	Weak

Table 10.3. Summary of possible health effects associated with exposure of pregnant indigenous women to PCB.

Any criteria proposed for the limitation of POPs in human blood and tissues necessarily involve a large number of uncertainties, due to the lack of precise toxicological information on the effects of hazardous substances, especially when addressing the most sensitive sub-groups of people (e.g, infants, the elderly and the majority of indigenous people who lack good nutritional) .

10.2. Region-specific priorities for environmental health

A summary of regional environmental health priorities related to the project objectives is given in Table 10.4.

10.3. Evidence of causation

Because causation is a fundamental issue in the epidemiology of reproductive health and developmental disorders, the lines of evidence described in Table 10.2 need further discussion. To show that a causal relationship does exist, a number of tests or criteria have been developed (Hill, 1965; Wynne and Braunwald, 1998; Cotran *et al.*, 1999). These include consistency of results between studies involving different groups; the way in which the results of different studies fit each other (coherence); whether there is a relationship between given definite levels of exposure and the effect or population response ('dose-response relationships') etc. Since very limited information on PTS-induced human reproductive and developmental effects is available, it is not feasible to test the full set of suggested epidemiological criteria of causation.

Study population	Priority contaminants in the environment	Most contaminated local foods [1]	Priority contaminants in human body[2]	Associated Health effects
Coastal areas of the Chukchi AO	Food contamination by PCBs, Hg, toxaphenes	Sea mammal meat fermented in soil (Kopalchen), home-processed and salty dried sea fish, home-made brew (span)	PCBs, Pb, HCB, Hg	Reproductive and developmental, problems; chronic liver diseases
Inland areas of the Chukchi AO	High prevalence of use of household DDT/HCH chemicals	Salmon, home-processed fish		
Taymir AO	Highest use of lead ammunition	Birds, fish	Pb DDT (Norilsk)	
Nenets AO	Highest prevalence of lead paint use			
Kola peninsula	High use of household DDT/HCH chemicals; PCB food contamination	Salmon		Highest maternal/cord contaminant ratio of DDT

Table 10.4. Priority problems for different study regions in the Russian Arctic. [1] – at least one of PTS occurring in concentrations above the national limits; [2] – contaminants either occasionally exceeding international guidelines (level of concern) or are shown to associate with a certain effect

In the meantime, the identification of 38 cases in which the outcome of pregnancy was fatal, 62 cases of reduced birth weight (16 of which were extremely low), 27 cases of premature birth, 8 cases of serious birth defects and 31 spontaneous abortions, supported by life-style, occupational and other information on risk factors, as well as the measurement of a wide range of PTS in the environment, food, indoor materials and blood specimens collected as part of the cross-sectional study presented in this report, provides an opportunity to consider the causal role of exposure of individuals to specific environmental contaminants.

Current evidence supporting the classical causation indicators of plausability, consistency, coherence and analogy is judged to be acceptable for PCBs (Table 10.4), as well as for lead and total mercury exposures, as measured in human blood. It is not possible to properly assess the temporality and/or reversibility of previously reported findings, because the health effects suggested as being associated with PCB exposure, constituted limited population-based reports and were not the outcome of a systematic epidemiological study. However, it should be noted that the inherent weakness of cross-sectional study design and the limited number of pregnant women available for survey purposes (i.e. low power) diminishes the impact of the elevated relative risks and statistically significant p-values of the Chi-Square Test and of Fisher's Test presented in Table 10.2.

After adjustment for major confounders (i.e, smoking and alcohol consumption) the increased risk of adverse outcomes of pregnancies was clearly observable for concentrations of total PCBs in maternal serum over 2.0 μg/L, which is significantly lower than the level recommended as a level of concern (5-20 μg/L) and much lower than the level of effects (100 μg/L). The same is broadly true in terms of maternal lead concentrations, for which typical developmental disorders in newborns were manifest at levels of 30 μg/L, when internationally recommended guidelines are currently set at 100 μg/L. There are, however, two possible factors to be considered which are capable of affecting developmental disorders associated with PTS exposure. A first and frequently mentioned circumstance, is that the indigenous people of the Russian North are generally considered to be one of the most susceptible subpopulations due to factors such as malnutrition and an altered traditional diet that has become physiologically inadequate (Panin, 1989). A second uncertainty is that an adverse pregnancy outcome may not be solely the result of maternal exposure. Paternal exposure may also transfer risks to the off-spring. The study design used, however, did not allow the quantification of such risks.

The new evidences obtained suggest that the association between environmental exposure to PCBs, lead and mercury (as measured by blood levels which are considered to be relatively common for indigenous populations of the Russian Arctic) and health effects such as the prevalence of low birth weight, reduced gestational age, fatal outcomes of pregnancy and the prevalence of chronic diseases in women, supports a hypothesis of causation.

Statistical associations for the observed effects may be further improved by analysis of the remaining blood samples taken during the surveys, which are currently deep frozen (within the framework of the project, only 255 of the 348 maternal blood samples collected were randomly selected and analyzed). In a preliminary check of the 93 remaining sample donors, it was found that they include mothers recorded as having 14 cases of adverse pregnancy outcomes.

10.4. Application of the precautionary principle

Even though the lines of evidence for the causal role of PTS with respect to health effects are generally not complete and there are a number of uncertainties to accommodate before establishing reliable causation, it is important to note that the anticipated health effects associated with PTS exposure as experienced by vulnerable groups of indigenous populations are likely to be serious, and include birth defects and fatal outcomes of pregnancy. For this reason, it is suggested that two approaches are taken in addressing these uncertainties when considering recommendations and planning public health action.

Causation Indicator	Description	References
Temporality	No evidence	
Plausibility	Similar effect of PCBs has been demonstrated in a large number of animal experiments. Holzman strain of rats treated with commercial PCB mixtures showed that developmental toxicity can occur in the absence of overt signs of maternal toxicity as evidenced by reduced fetal weight and viability.	Spencer, 1982
	Reduced birth weight and postnatal growth reported in Wistar rats administered with PCB;	Hany *et al.*, 1999
	Impaired ability to conceive and decreased fetal survival are well-documented in female monkeys following repeated oral exposures to Arochlor.	Arnolds *et al.*, 1997, 1998
Consistency	Identical symptoms were observed in women consuming contaminated fish. Lower birth weight, smaller head circumference, and shorter gestational age were positively correlated with consumption of fish and levels of total PCBs in cord serum; however, when the two populations were divided according to the cord serum levels, the great majority in the low-level group were fish-eaters, suggesting that fish consumption rates were poor indicators of PCB exposure. Fish consumption during pregnancy only did not predict either birth size or gestational age.	Michigan study Fein *et al.*, 1984b
	PCB 153 in maternal blood used as a biomarker of exposure to PCBs, found an increase in the risk of a low birth weight at maternal blood PCB 153 concentrations of 300 and 400 ng/g (ppb, lipid basis).	Swedish cohort study. Rylander *et al.*, 1998
	Dutch general population cohort, prenatal exposure to PCBs (PCBs in cord blood) was associated with a reduced birth weight, but not with head circumference or height at 10 days of age.	Patandin *et al.*, 1998
	Parental exposure to dioxin and dioxin- like chemicals are manifested by increase of female offspring.	Devis et al., 1998; Mocarelli *et al.*, 2000; Ryan *et al.*, 2002
	Danish case-control study showed a strong association between low fertility and an excess of females compared to males among offspring.	Møller, 1998.
	The Yusho accident female victims who consumed PCB-contaminated oil had 2 stillbirths out of 11.	Masuda, 1994
Statistical Strength	An association between the prevalence of low birth weight, shorter gestational age of newborn, all fatal outcomes of pregnancies (adjusted for alcohol consumption) and total PCB concentrations in maternal serum over 2.0 μg/L (Arochlor 1260 over 5.0 μg/L) is from weak to moderate.	This report.
Specificity	Being of high sensitivity, the reproductive and developmental effects associated with PCB exposure are not considered to be specific ones.	This report
Dose-response	Dose-response relationship has been demonstrated through elevating serum concentrations of total PCB or Arochlor 1260 steadily, followed by increasing prevalence of reproductive and developmental effects including altered sex-ratio.	This report
Coherence	The known endocrine disrupting effects of PCBs, both the oestrogen-like and oestrogen receptor binding activity, might result in fetal damage and impact on its growth.	Arnold *et al.*,1998 Kester *et al*, 2000
	Prenatal exposure of mothers to a background level of PCB was shown to affect thyroid hormone metabolism related to developmental disorders	Koopman-Esseboom *et al.*, 1994
Reversibility	No evidence	
Analogy	Health effects in wildlife includes the following: mortality in piscivorous birds; reproductive impairment in monkeys, minks, ring doves, and American kestrels; immunotoxicity in monkeys and birds; endocrine and neurobehavioral effects in birds;	EPA, 1978
	Mink that were fed by fish contaminated with PCBs showed reproductive toxicity.	Hornshaw *et al.*, 1983
	A variety of other health effects have since been evaluated in wildlife, some of which may be relevant to human health.	AMAP, 2002
Study design	Cross-sectional study; Inherent weakness to establish causation	Hill, 1965; Beaglehole *et al.*, 1993

Table 10.5. Rules of causation applied to the prevalence of low birth weight and reduced gestational age of newborns in arctic indigenous women; experience of higher environmental exposure to PCBs is definite, with maternal serum concentrations exceeding 2.0 μg/L (or 300ng/g lipids).

From the project perspective, it is believed that a precautionary principle (PP) which addresses the avoidance of potential harm, should be applied in two basic situations encountered in the environment or workplace.

A. When there is a lack of regulation and lack of human data, but sufficient animal data.

B. When concern arises about an existing regulation in the light of new evidence of an adverse effect becoming available.

A number of basic factors or criteria associated with the application of the PP have gained both national and international requirements:

1. The size of the population affected;
2. The higher susceptibility of certain subgroups (e.g. children, pregnant women, individuals with poor health or malnutrition);
3. The seriousness of the anticipated effects (e.g. irreparable or irreversible impairments which significantly compromise human health);
4. The transparency and disclosure of potential risks (‘right to know’ of the public);
5. The consideration of inputs other than scientific evidence (e.g. a high level of public anxiety);
6. The implementation of temporary precautionary exposure levels;
7. The implementation of interim measures to reduce exposure to levels as low as possible/reasonable;
8. The need to apply PP on a case-by-case basis; a single conceptional framework not necessarily being suited to all situations;
9. When failure to apply precautions may engender liability in the future.

The establishment of exposure limits in Russia, constitutes, in many cases, an application of the precautionary principle. However, in the absence of such limits and guidelines for blood concentrations of PTS and also of limits for foodstuffs, it is clear that the potential seriousness of the anticipated effects and their general consistency with current knowledge regarding the specific toxicity of the PTS in question, argues for the application of the precautionary principle (at least on a ’case-by-case’ basis) as some babies may be at excessive risk from pollutants taken up by their mothers.

Overall conclusions and recommendations

The main conclusion of the first AMAP assessment (AMAP, 1997) clearly stated that the well-known benefits of breast milk and traditional food definitely outweighed the risks to human health risks from contaminants. The social, cultural, spiritual and physical health of Arctic indigenous peoples, depends on the collection and consumption of country foods. The consumption of local fish, meat, wild greens and berries is important in providing the necessary dietary intake of most nutrients, vitamins, essential elements and minerals. Based on these conclusions, the AMAP assessment recommended that:

- Consumption of traditional food continues, with recognition that there is a need for dietary advice to Arctic peoples so they can make informed choices concerning the foods they eat;
- Breast milk should continue to be promoted.

These basic conclusions and recommendations have received full acknowledgement and support within the framework of this project. At the same time, a number of important findings made during the period of project implementation have promoted the development of conclusions and recommendations specific for Arctic Russia, and for the objectives of the project.

1. A close partnership has been successfully achieved between researchers and indigenous organizations and communities in accordance with internationally recognized practices, as well as effective co-operation in developing remedial actions to reduce health risks resulting from the contamination of the environment and traditional food sources. The project has been implemented with the active participation of the Russian Association of the Indigenous Peoples of the North, Siberia and Far East (RAIPON) and its regional branches. RAIPON representatives acted as equal partners with the scientific teams in all project activities and phases, including the development of project recommendations. Achieving the project objectives would not have been possible without close collaboration with the Russian executive authorities, and particularly the administrations of the regions where the project was undertaken.

2. Project implementation has enhanced the position of the Russian Federation in international negotiations to reduce the use of PTS, and empowered RAIPON to participate actively and fully in these negotiations. The signing of the Stockholm Convention on Persistent Organic Pollutants by the Russian Federation, the active role played by RAIPON, in line with other International Organizations of the Arctic Indigenous Peoples, and the full-scale participation of Russian federal executive agencies and RAIPON in the development and implementation of the Arctic Council Action Plan to eliminate pollution in the Arctic are good, but not the only, indicators of attaining relevant project objectives.

3. The existing system in Russia for statistical reporting of environmental releases do not cover most persistent toxic substances, and in particular, those covered by the Stockholm Convention on Persistent Organic Pollutants.
   In this respect, it is recommended that new forms of state statistical reports on industrial atmospheric emissions, waste water discharges and solid wastes, be developed and approved, which should be adequate for the requirements of the Stockholm Convention on Persistent Organic Pollutants and other international treaties and agreements aimed at the limitation of environmental and human health effects of persistent toxic substances. In this, it is recommended that experience gained in the development and use of registers for emissions of contaminants and transport be used.

4. From experience gained during project implementation, existing data and information on PTS pollution sources available to federal and local environmental and human health authorities does not adequately reflect the actual situation in the Russian Arctic regions. Studies and surveys within the project framework have documented the environmental impact of unknown local PTS sources. In particular, there is evidence of relatively fresh environmental releases of contaminants such as DDT and PCB.
   Taking into account the objectives aimed at implementation of the Environmental Doctrine of the Russian Federation and the Fundamentals of the State Policy in Chemical Safety, it is recommended that a source inventory system be developed and implemented in the Arctic administrative territories inhabited by the indigenous peoples, that covers both former and current releases of PTS from all economic activities.

5. PCBs can be considered as one of the most serious environmental and human health risk factors for the areas covered by the project , which cannot be adequately explained by long-range transport and existing information on local sources. According to the Russian PCB inventory, 53,000 out of 180,000 tonnes of PCB produced in the former USSR, were used for the production of paints, varnish, lubricants and other products, i.e, they have been used in open systems. Although this type of PCB use could not be taken into account by the inventory, it is likely that some of the PCB- related problems mentioned above also resulted from contamination from such sources.
   Within the framework of the Russian National Action Plan on implementation of the Stockholm Convention, it is recommended that a special section on the rehabilitation of PCB-contaminated sites, including land and housing be developed and implemented. With respect to this issue, spe-

cial attention should be paid to land and settlements inhabited by Arctic indigenous peoples, taking into account their lifestyle and social vulnerability.

6. A significant proportion of total global PTS in the Arctic environment, is determined by their long-range transport. For example, the pesticide, Mirex has not been produced and used in either the USSR orRussia. However, levels of Mirex in the blood of the indigenous population residing in the Russian Arctic, particularly in coastal Chukotka, are found at clearly detectable levels, albeit lower than in some other parts of the Arctic, such as Arctic Canada. At the same time, the validity of long-range atmospheric transport and deposition estimates is limited by the scarcity of data on remote sources, and a lack of comprehensive source inventories.
   It is recommended that the Government of the Russian Federation, in cooperation with the other member countries of the Arctic Council, take active measures in the international arena to ensure the reduction, and in the future, the full elimination of environmental and human health threats from global PTS. In particular, it is recommended that the Russian Federation ratifies the Stockholm Convention on Persistent Organic Pollutants, and joins the Aarhus Persistent Organic Pollutants and Heavy Metals Protocols of the UN-ECE Convention on Long-range Transboundary Air Pollution.

7. Environmental aspects of human health, particularly those associated with PTS exposure of indigenous peoples, are closely linked to the economic and social status of indigenous families. In this respect, a significant reduction in the effects of PTS on human health cannot be successfully achieved without improvement in the economic and social conditions of the Russian Arctic indigenous peoples.
   It is recommended that, the National Plan of Economic and Social Development of the Northern Territories of the Russian Federation, which, it is envisaged, is to be developed or reconsidered following the Meetings of the State Council Board of the Russian Federation and of the President of the Russian Federation with the representatives of the northern territories of the Russian Federation in Salekhard, 28-29 April, 2004; should fully address improvements to the social and economic conditions of the Russian Arctic indigenous peoples. This action should be undertaken with the full involvement of the indigenous peoples.

8. In general, PTS levels in the natural environment and biota of the Russian Arctic are at moderate levels compared to other Arctic regions. This presents a means to significantly reduce PTS intake by indigenous peoples without intervening in their basic traditional lifestyle and cultural identity, through the implementation of protection and remedial actions, including improvement of sanitary conditions in the indigenous settlements and by implementation of household and dietary recommendations developed as a result of the findings of this report.
   As a follow-up to this project, it is recommended that the Russian federal executive human health and environmental authorities, in close collaboration with the Russian Association of Indigenous Peoples of the North, Siberia and Far East and regional and local administrations, develop a set of practical activities aimed at achieving, in full acknowledgement and respect of the traditional lifestyle and cultural identity of the Russian Arctic indigenous peoples, a significant reduction in their PTS intake. These measures, which should be an integral part of the National Plan of Social and Economic Development of the Russian Northern Territories, should include actions required at the federal, regional and local levels, taking into account the circumstances of each area. More specific regionally-based recommendations, addressed to the indigenous peoples should be presented in special publications in Russian.

9. The levels of human exposure to PTS in the Russian Arctic, specifically to HCB and HCH, and, in some cases, also to DDT and PCB, is one of the highest reported for all of the Arctic regions. In some cases, exposure has been shown to exceed levels assessed for residents of territories, which are internationally recognised as disaster areas, such as the Aral Sea region, due to long-term use of persistent pesticides. In the areas of the Russian Arctic studied, practically every indigenous family consumes a significant amount of traditional food. Families with low incomes rely to a greater extent on the local, fat-rich traditional diet. As a consequence, low-income indigenous families are at greater risk of exposure to POPs.
   It is recommended that the human health authorities and administrations of the territories of the Russian Arctic inhabited by indigenous peoples, in close collaboration with the regional branches of RAIPON and in full acknowledgement of the importance of the traditional diet for nutrition and preservation of the national and cultural identity of the indigenous peoples, as part of their lifestyle, develop appropriate targeted measures to reduce PTS intake with traditional food, based on specific recommendations, the improvement of social and economic conditions and the raising of awareness about existing problems.

10. The highest PTS exposures and associated health risks are documented for the coastal areas of Chukotka, where the traditional diet of the indigenous population is largely based on marine mammals and fish. This corresponds to previous information obtained concerning the Greenlandic and coastal Canadian indigenous populations.
   It is recommended that, in the development of practical follow-up measures, special attention should be paid to the situation in the Chukchi AO, taking into account both, the social and economic status of the indigenous peoples in this region of Russia, and the health risks associated with PTS intake. On the basis of data obtained within the framework of the project, the coastal areas of the Chukchi AO are of main concern with respect to human health risks.

11. Indoor and occupational sources of PTS, including contamination of dwellings, are likely to be a significant contributor to blood contamination among indigenous peoples of the Russian Arctic. It was found that all of the houses of indigenous people studied during the targeted surveys, were contaminated by POPs, mostly by PCB and DDT. Levels of indoor PCB contamination correlate to levels of PCB measured in the blood of indigenous families living in these houses.
It is recommended that remedial action to remove PTS contamination from the houses of indigenous families, should be an important and urgent action, aimed at e improving the social and economic status of indigenous communities.

12. It was found that the labelling of chemicals produced and retailed for household protection against insects and rodents, often does not correspond to their actual chemical composition, and that these chemicals sometimes contain toxic substances in high concentrations, particularly DDT and PCB.
It is recommended that proposals for amendments to the Federal Law "On safe handling of pesticides and agrochemicals" be developed, to ensure implementation of strict and efficient control measures over the production and trade of pesticides and other chemicals for private use, particularly those used for protection against insects and rodents, which would ensure a complete ban on the use of PTS in these chemicals.

13. In a number of cases, home-made local food contains higher levels of PTS contamination than raw products obtained from the natural environment. It has been shown that additional contamination of food by PTS can take place when food is stored, processed, and/or cooked in a contaminated household environment.
It is recommended that the local human health authorities, in close collaboration with regional branches of RAIPON, work out an efficient action plan to improve sanitary conditions in indigenous houses. These measures should be integrated with communication with indigenous families and efforts to raise awareness about the health risks associated with contamination of home-processed food.

14. POP concentrations measured in blood serum are highly dependent on age. This phenomenon may reflect past exposure to POPs. The number of breast fed children has also been found to be a significant determinant of POPs serum concentrations in women. Serum concentrations of lipophilic contaminants are reduced by an increase in parity. Statistically significant associations have been found between blood concentrations of total PCBs (Arochlor 1260), lead and a number of non-specific reproductive and developmental health effects such as the prevalence of low birth weight, premature births, stillbirths and major structural malformations. Serum concentrations of total PCBs in maternal blood also appear to be associated with impacts on newborn sex ratios. In contrast with both national and global statistics, female babies of indigenous mothers with elevated POP blood concentrations, have a higher risk of low birth weight and other adverse outcomes of pregnancy when compared to male babies.
It is recommended that the Russian human health authorities implement internationally recognized levels of concern for PTS blood concentrations. It is further recommended that dietary safety advice based on the benefits of traditional food are made an important component of prenatal care and of family planning strategies for the indigenous communities at risk.

15. A close correlation between PTS levels in blood and breast milk has been documented for indigenous women of the Chukchi AO.
It is recommended that the international and Russian national health and environmental protection authorities develop recommendations for the assessment of human PTS intake, based on levels of these contaminants in blood and breast milk, taking into account the advantages and drawbacks of using these indicators for different groups within the population.

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