

Chapter 1

Introduction

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1.1. Background for the Human Health Assessment

Since its establishment in 1991, the principal task for AMAP has been the preparation of assessments of the state of the Arctic environment with respect to a range of priority pollution issues including persistent organic pollutants (POPs), heavy metals (mercury, lead, and cadmium), radioactivity, and acidifying substances. The assessments have also covered pollution issues associated with petroleum hydrocarbons and the effects of climate change, ozone depletion, and ultraviolet-B (UV-B) radiation.

The AMAP assessments also address the implications of these pollution issues for the health of Arctic peoples including both indigenous and non-indigenous residents. The AMAP Human Health subprogramme is focused mainly on the potential health effects arising from exposure to POPs and heavy metals and, to a lesser degree, UV-B radiation. Radionuclides have been addressed in cooperation with the AMAP radioactivity assessment group (AMAP, 2003a). Acidification and petroleum hydrocarbons were regarded during the first phase of AMAP (1991–1996) as having no immediate impact on human health and were consequently not addressed in the health assessment that was prepared under AMAP Phase I.

The scope of the AMAP monitoring and assessment programme embraces sources of pollution, located both within the Arctic region and at lower latitudes, and the pathways of contaminant transport to and within the Arctic. The programme addresses concentration levels in abiotic and biotic compartments of the Arctic environment and ecosystems, temporal and spatial trends, the fate of pollutants in the environment, and their effects on Arctic ecosystems including effects of exposure on human populations in the Arctic. The information compiled during AMAP Phase I was published in the AMAP Assessment Report (AMAP, 1998). That assessment constitutes an invaluable documentation of the baseline situation during the 1990s, providing a basis for the continued activities under AMAP Phase II, which started in 1998.

1.1.1. Major conclusions from AMAP Phase I

The major conclusions from the first AMAP human health assessment (AMAP, 1997, 1998) were that several peoples or communities in the Arctic are highly exposed to environmental contaminants. Persistent contaminants derived from long-range transport or local sources accumulate in animals that are used as traditional foods. Thus, variation in human exposure depends on a combination of 1) varying environmental concentrations of contaminants, 2) local physical and biological pathways that make the contaminants available, and 3) the local dietary habits of the people.

- Exposure to POPs is the primary concern. People are most exposed to polychlorinated biphenyls (PCBs)

and certain pesticides due to biomagnification of these contaminants in marine food webs, which results in high concentrations in some marine mammals, birds, and, to a lesser extent, fish. The use of different foods determines contaminant intake. Some indigenous peoples are exposed to levels that exceed established tolerable daily/weekly intake levels. Transfer to the fetus *in utero* or to infants through breast milk can result in levels in newborns, which are two to ten times higher than in regions further south.

- Exposure to radionuclides is mainly through atmospheric transfer and deposition to terrestrial ecosystems. Particular soil and vegetation characteristics concentrate some radionuclides, enabling high concentrations to develop in plants and animals (reindeer/caribou, game, lichens). Arctic peoples are generally exposed to higher levels of radionuclides than people in temperate zones.
- Of the heavy metals, both cadmium and mercury tend to accumulate in the long marine food chains. Methylmercury, partly because it is fat soluble, is efficiently taken up following consumption and therefore poses the main potential risk. Like POPs, methylmercury can be transferred to the fetus and to breast-fed children, and in certain areas and within certain populations levels are high enough to indicate a need for public health measures. Although mercury levels can be high, interactions with selenium and nutrients may reduce the toxicity of this contaminant and thus also the risk to people.
- Humans in the Arctic are exposed to enhanced UV-B radiation, resulting from the release of ozone-depleting substances at lower latitudes. The main health concern relates to possible ocular damage and additional immunosuppressive effects and dermatological disorders.
- Controls on emissions have resulted in measurable reductions in inputs of some contaminants (e.g., lead, radionuclides, atmospheric sulfur, and possibly PCBs and DDT). There is considerable variation across the Arctic, however, and recycling of accumulated pools of long-lived contaminants in ocean and lake water and in sediments, can result in continued exposure long after controls have been enforced.

1.1.2. Major gaps in knowledge identified under AMAP Phase I

In the AMAP Assessment Report (AMAP, 1998) a number of gaps in understanding were identified regarding sources, pathways, and transformations of pollutants in the environment. The following needs were identified specifically for the Human Health subprogramme:

- better understanding of physiological and toxicological effects of contaminants on human populations and species identified as most at risk, especially on devel-

opment of offspring, and/or immunosuppression and endocrine disrupting properties;

- detailed information on the diet and food consumption patterns of specific Arctic populations, including necessary information on other overall health factors (e.g., smoking) which can influence contaminant exposure, to allow better estimates of dietary intakes of contaminants and permit more reliable estimates of associated risks; and
- knowledge about combined effects of contaminants on biota and humans, both at the individual and ecosystem level.

In an interim report to Ministers delivered in 2000 (AMAP, 2000), the gaps in knowledge were discussed in more detail and recommendations for research were made, which also emphasized issues associated with the:

- identification of new POPs of concern; and
- the development of quantitative models for human exposure and health outcome.

1.1.3. Health related recommendations arising from AMAP Phase I

Weighing the well-known benefits of breast milk and traditional foods against the suspected, but not yet fully understood, effects of contaminants, the recommendations arising from AMAP Phase I were that:

- consumption of traditional/country food should continue to be encouraged, with recognition that there is a need for dietary advice to Arctic peoples so that they can make informed choices concerning the food they eat; and that
- breast feeding should continue to be promoted.

To ensure the interest and active involvement of Arctic indigenous peoples and other Arctic residents it was recommended that the Arctic countries should:

- ensure the use and integration of indigenous knowledge in environmental research and policy and should promote community participation in research and policy development;
- establish a long-term communication programme to provide public information about environmental contaminants studied by AMAP, to allow access to sound and regularly updated information in an understandable language; and
- provide contaminant information for population groups with different educational levels in order to raise general environmental and scientific literacy among Arctic residents, including indigenous peoples.

In the interim report to Ministers in 2000 (AMAP, 2000) the AMAP Human Health Expert Group reviewed the conclusions from its Phase I assessment (AMAP, 1997, 1998) and found them still to be valid. However, new data and significant progress in laboratory and population studies presented in the interim report gave rise to some additional conclusions and recommendations.

- Data on exposure sources of hexachlorocyclohexane

(HCH) and DDT/DDE, in market foods, water supplies, air, and industrial/agricultural workplaces in Arctic Russia should be carefully examined to identify the primary cause of elevated levels of these contaminants in human tissues.

- Because lead shot, lead shot micro-fragments, and dissolved lead found in subsistence game can be a significant source of human lead exposure it was recommended that this problem should be extensively evaluated in regions where lead shot is used for subsistence hunting.
- All countries should undertake an evaluation of their current data on dioxins, furans and co-planar PCBs and should determine the relative contribution of these chemicals to the total TCDD toxic equivalencies.
- Levels of toxaphene in human tissues should be determined in all Arctic countries and reported utilizing compound-specific chemical analyses. Data showing levels of brominated flame retardants (e.g., PBDEs) equal to those of the dominant PCBs should be followed up.
- The relationship between immune system function and POPs exposure should be more fully evaluated.
- Existing studies on mercury exposure should be evaluated for subtle effects on infant neurodevelopment and blood pressure.
- The Phase II AMAP Human Health subprogramme, with its emphasis on human health effects and monitoring of spatial and temporal trends according a specified programme of activities, should be implemented in all the key sampling areas in order to improve the scientific background for local advice to Arctic peoples.

Increasingly strong evidence is found in the Arctic, as elsewhere in the world, concerning the positive benefits of breast feeding for infant development, especially for the psycho-social development of children and the development of their immune system. Nutritional studies also demonstrate the benefits of consuming traditional food. Consequently, the main recommendation from the AMAP Phase I assessment that traditional food consumption and breast feeding are to be encouraged in the circumpolar Arctic region was repeated.

1.1.4. Human health assessment under AMAP Phase II

At the fourth Arctic Environmental Protection Strategy (AEPS) Ministerial Conference in Alta, Norway, in June 1997 Ministers endorsed the continuation of activities under AMAP for monitoring, data collection, and exchange of data on the impacts and assessment of the effects of contaminants and their pathways, increased UV-B radiation due to stratospheric ozone depletion, and climate change on Arctic ecosystems. Ministers also agreed that special emphasis is required on human health impacts and the effects of multiple stressors (AEPS, 1997).

In order to address the updated requests from Ministers, the AMAP Human Health Expert Group reviewed

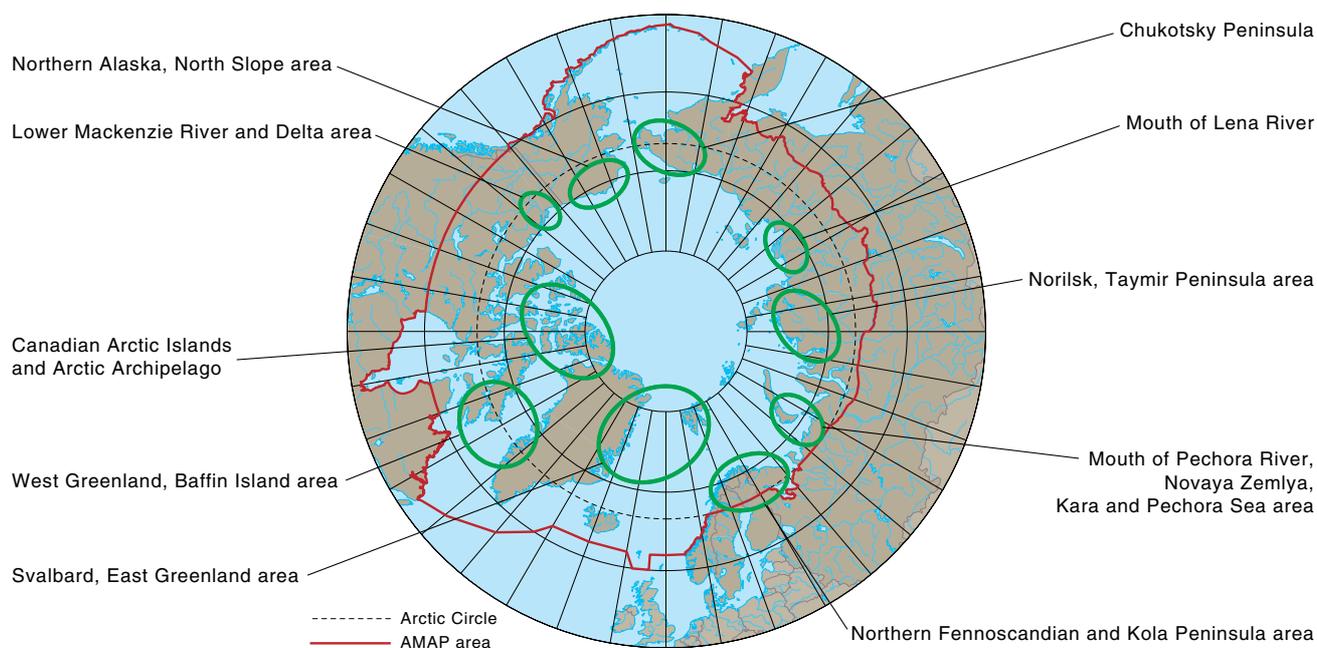


Figure 1-1. Map of 'key areas' for studies under AMAP Phase II.

and revised the original AMAP human health monitoring subprogramme that had been implemented between 1993 and 1997. An expanded core-programme of human health monitoring activities for temporal- and spatial-trend monitoring for AMAP Phase II was developed and agreed upon at the meeting of the AMAP Human Health Expert Group in Reykjavik in September 1998. A programme for human health effects monitoring was also discussed and finally agreed at the meeting of the AMAP Human Health Expert Group in Rovaniemi in January 2000. Details of the AMAP Phase II Human Health subprogramme are presented in sections B and C of the AMAP Trends and Effects Programme: 1998–2003 (AMAP, 1999).

The AMAP Human Health subprogramme focuses on exposure and the effects of different contaminants, both individually and in combination. In this context, the relevance of human exposure to new xenobiotic compounds being identified in the Arctic environment is of concern. The Human Health subprogramme is supported by information from other components of the AMAP Trends and Effects Programme, particularly those parts of the programme that are concerned with monitoring levels of POPs, metals and radioactivity in species consumed as food. To ensure effective integration between the human health studies and the other components, human health activities under AMAP Phase II have been concentrated in specified 'key areas' (Figure 1-1). In addition to the activities in these key areas, supplementary studies have been carried out in other settlement areas of indigenous and local populations of special interest.

Supporting studies are essential additional activities under the AMAP Trends and Effects Programme (see AMAP 1999, section D). These, largely research-based, activities provide detailed information that is necessary to allow a more meaningful interpretation of the results of the monitoring programme. Some of the main supporting studies of relevance to the human health assess-

ment concern dietary surveys. These studies help to provide the basis for contaminant intake estimation and for dietary advice to Arctic peoples so that they can make informed choices concerning the food they eat. Supporting research is needed to provide local health authorities with scientifically documented indications concerning possible needs for regulatory intervention.

1.2. The concept of combined effects

Environmental exposure of human populations to a single chemical pollutant is rare (generally only occurring in accidental or occupational scenarios); environmental exposures are almost always to mixtures of substances. As a result, the interactive toxicity of the combined exposure is of utmost importance from a public health point of view. While the effects of individual pollutants and mixtures can be studied in controlled tests in research laboratories, it is very difficult to examine the effects of single substances on human populations. Epidemiological studies usually provide information on combined effects. This is true even where it is intended to study single compound effects by eliminating confounding factors. As the overall exposure situation usually varies from one population to another, this mix of contaminants may explain the often-contradictory findings from epidemiological studies endeavoring to report on effects of single components.

Animal studies and *in vitro* tests have demonstrated that exposure to a mixture of chemicals can produce additive, synergistic, or antagonistic effects. This is most likely also to be the case with humans. The sum effect of exposure to chemicals is also influenced and modified by genetics, nutritional status, and lifestyle.

Environmental factors may influence health in both a positive and a negative way. From a public health perspective, a major toxicological issue is the possibility of unusual toxicity due to interactions of a multitude of toxic chemicals and physical stressors at levels that are

normally considered harmless for individuals. In this connection, the occurrence of chemically induced hormesis should be mentioned. Chemical hormesis refers to the occurrence of a biphasic dose-response relationship in which higher doses cause an inhibitory effect and lower doses cause a stimulatory effect (Calabrese *et al.*, 1987). The phenomenon has been reported widely in the biological literature during the last twenty years, but has in general been neglected in toxicology. Hormesis has been reported in both plants and animals, with a wide variety of exposures, e.g., to radionuclides, heavy metals and POPs. Of great interest is the finding that the hormetic mechanisms that determine the threshold for physical or chemical toxicity can be mitigated by other chemical and physical agents, resulting in highly accentuated toxicity. This should be taken into account especially when making risk assessments at low levels of exposure to combinations of chemicals. Recognition of the existence of cellular and tissue hormesis provides a mechanistic basis to evaluate thresholds of toxic effects, enabling consideration of specific identifiable adverse health effects of low levels of exposure to chemicals in the environment (Mehendale, 1994).

The combined effect of the actual chemical mixture is a result of interactive processes between the chemical and physical stressors and biological receptors. Interactions can be anticipated between:

- individual contaminants in a mixture
- a mixture of contaminants and radiation (ionizing and UV)
- a mixture of contaminants and nutrients
- radiation and nutrients

The sum effect of these interactions may be observed at different levels:

- molecular
- cellular
- organ
- individual
- population

Prerequisites for understanding the combined effects of environmental stressors are the development of mechanistic effect models for individual contaminants and for the mixtures of contaminants prevalent in the environment, and the conduct of studies of genetic polymorphism in populations in order to describe individual genetic susceptibility to adverse effects from contaminants.

Some individuals are more sensitive to xenobiotic compounds than others, and this may in part be due to differences in metabolic capacity. Based upon *in vitro* and *in vivo* studies, e.g., transgenic animal studies on the pharmacokinetic properties of various contaminants, a risk profile for a particular exposure situation may be designed for both high and low exposure scenarios.

In addition, identification of reliable and applicable biomarkers of effects is needed in order to estimate the validity of assumptions of effect. Although toxicology and biomarker research provide the theoretical background for the understanding of combined effects, their applicability for actual exposure situations among Arctic populations requires additional information. Evaluation of the combined effect of pollutants in the Arctic

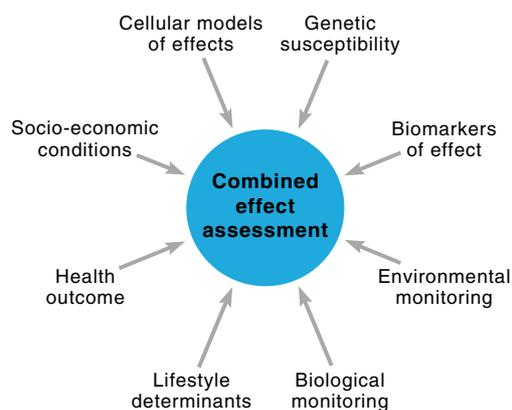


Figure 1-2. Disciplines involved in combined effects studies.

must be based on extensive environmental and biological monitoring, and on nutritional, epidemiological, and socio-economic data.

The disciplines needed for a thorough evaluation of combined effects are represented in Figure 1-2.

1.2.1. Combined effect assessment

Assessment of combined effects requires information from a range of different types of study.

1. **Cellular models of effect.** Toxicological studies of single compounds and mixtures at the molecular and cellular level.

2. **Genetic susceptibility.** Genetic polymorphism in relation to genetic epidemiology.

3. **Biomarkers of effect.** Identification of relevant and validated biomarkers of exposure and their *in vivo* relation to effects at specific exposure levels (effects monitoring).

4. **Environmental monitoring.** Identification and ranking of sources of exposure and geographical variation. Identification of risk areas, temporal trends, and estimation of possible (daily intake) exposures.

5. **Biological monitoring.** Repeated determination of contaminant concentrations in biological index media to determine individual and population exposure level and internal dose. Identification of risk groups, and establishment of time trends.

6. **Lifestyle determinants.** Identification of lifestyle factors that may influence contaminant effects, e.g., nutrition, obesity, smoking, alcohol/drug consumption and occupation.

7. **Health outcome.** Surveillance of health outcomes in priority categories such as: birth defects, reproductive disorders, cancer, immune function disorders, kidney function disorders, liver function disorders, lung and respiratory diseases, and neurological disorders.

8. **Socio-economic conditions.** Description of general living conditions in countries, regions, and ethnic groups. Nutritional status, sanitary conditions, drinking water quality, air quality, housing conditions, use of traditional and imported foods, community integrity, availability of health care and education, and economic status, etc.

1.3. The scope of the AMAP Phase II Human Health Assessment Report

From a public health perspective, the human environment is the sum of physical, chemical, biological, social, and cultural factors that influence people's health.

This report concentrates on the concept of the combined effects of environmental contaminants, as requested in the AMAP Ministerial mandate. It addresses the modifying influences, both positive and negative, of other environmental factors that affect the human condition and underline the need for a global assessment of the linkages between health and the environment. This approach to a holistic assessment of the health–environment interaction is a huge task.

From both a scientific and ethical perspective, the following issues need to be considered:

- the sum effect of environmental contaminants on human health;
- the possibilities for examination of health impacts from the environment;
- the relevance of existing tolerable daily intake (TDI) values for Arctic peoples;

- the adequacy of existing information on the populations most at risk; and
- mitigation, the ways people can reduce their exposures.

This report re-evaluates the relationship between environmental contaminants and health status for people in the Arctic by integrating what is currently known about multiple stressors. The assessment builds on data generated and experience gained during AMAP Phase I, but is mainly based on new data from studies conducted during AMAP Phase II, and other recent scientific work.

Within the limitations imposed by the (understandably) inadequate information base and still significant gaps in knowledge, this report will attempt to summarize the present state of knowledge in the field of environmental medicine in the Arctic. Hopefully it will constitute a further step toward a better understanding of the relationship and linkages between health and environment in the Arctic, and provide an improved background/baseline for further information gathering. The key objective of the AMAP human health assessments is improved health status among Arctic peoples (Figure 1-3).

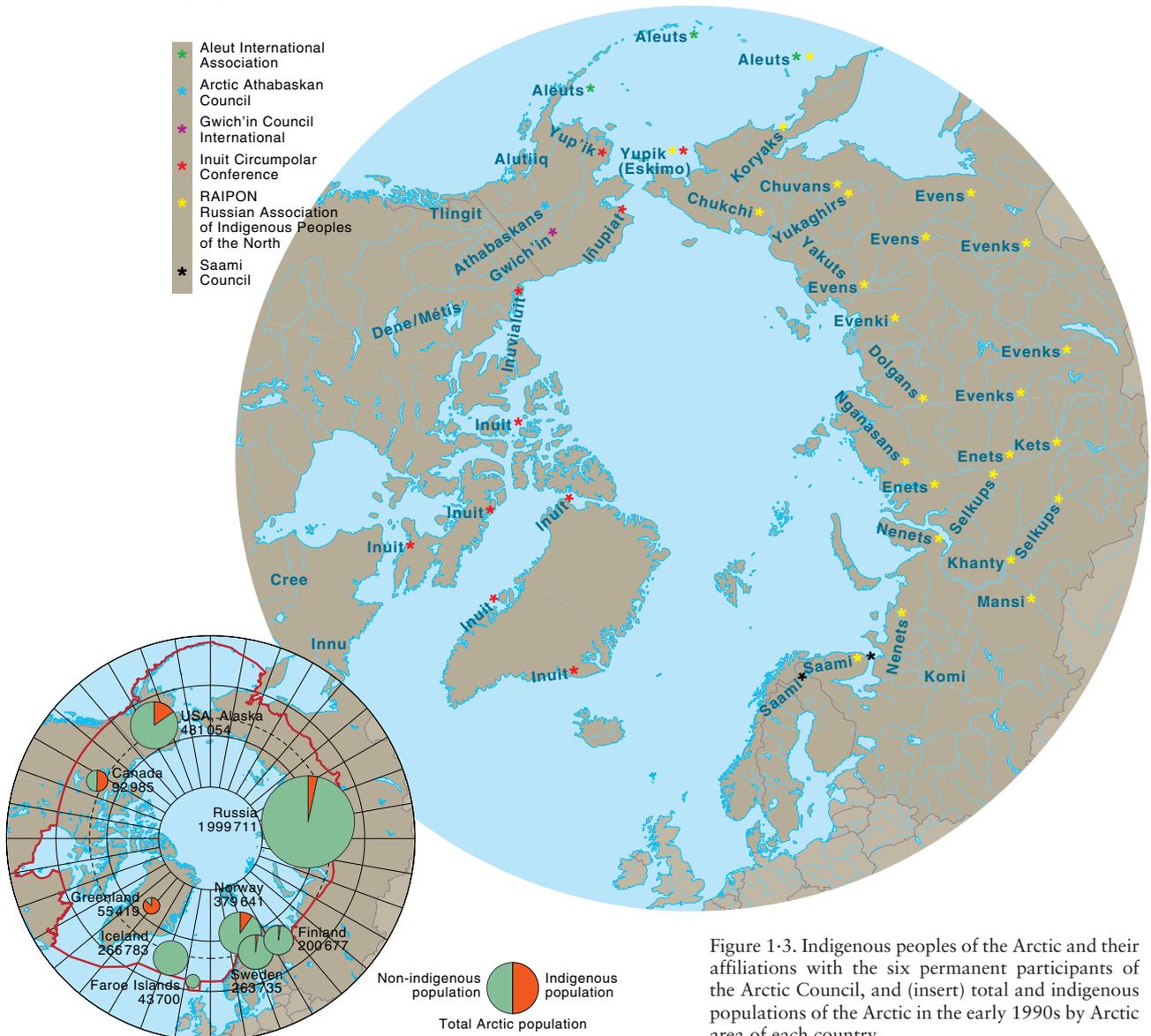


Figure 1-3. Indigenous peoples of the Arctic and their affiliations with the six permanent participants of the Arctic Council, and (insert) total and indigenous populations of the Arctic in the early 1990s by Arctic area of each country