AMAP Report 99:3

Synopsis of the State of the Arctic Environment in the Context of the Development of an Arctic Council Action Plan for the Elimination of Pollution in the Arctic (ACAP)

1999

SYNOPSIS OF THE STATE OF THE ARCTIC ENVIRONMENT IN THE CONTEXT OF THE DEVELOPMENT OF AN ARCTIC COUNCIL ACTION PLAN FOR THE ELIMINATION OF POLLUTION IN THE ARCTIC (ACAP)

CONTEXT:

This document presents a synopsis of information from AMAP's assessment of the status of pollution in the Arctic that is considered most relevant for the initial stages of development of an action plan for elimination of pollution in the Arctic. Most of the material is taken from the two AMAP reports, «Arctic Pollution Issues - A State of the Arctic Environment Report» (SOAER) and «AMAP Assessment Report - Arctic Pollution Issues» (AAR). The SOAER was accepted by Ministers at Alta, in June 1997; the more detailed AAR provided the scientific validation for the statements made in the SOAER. Only data which had passed a quality assurance regime, or information which had been published in an international peer reviewed journal was utilized in the AAR. Where relevant, new information provided by the AMAP lead country experts has also been introduced, in particular in relation to recent changes in the status of development of international actions to reduce emissions of certain substances (e.g. new UN ECE protocols).

As such, this document complements and embraces the content an earlier report entitled «Brief Synopsis of the State of the Arctic Marine Environment in the Context of the Development of a Regional Plan of Action To Protect the Marine Environment from Land-Based Activities (RPA)». Whereas that document focussed on threats to the Arctic **marine environment** from **land-based sources**, this report concentrates on the threats to the Arctic terrestrial and freshwater environments and their ecosystems (including humans), and threats to the marine environment from all sources, i.e. including non-land-based sources.

The document produced in response to a request from Norway, the lead country for the development of the ACAP. It was prepared on the basis of material provided by AMAP lead country experts and has been approved by the AMAP Working Group.

TYPES OF SOURCES AND IMPLICATIONS FOR ACTION OPTIONS:

The AMAP Assessment identifies three basic categories of sources of pollution that effect the Arctic. The features that distinguish the different categories also, to a large extent, determine the types of approach that may be considered in relation to the development of the Action Plan, i.e. global, regional or national. The categories are as follows:

Sources outside of the Arctic: The AMAP Assessment identifies a number of Arctic pollution problems related to long-range transport of pollutants from source regions far distant from the Arctic. The Assessment also addressed global pollution issues such as climate change and increasing UV as a consequence of stratospheric ozone depletion. By their very nature, such issues imply that they can only be effectively addresed through international initiatives aimed at reducing pollution at the global (or at least hemispheric) scale. Several activities proposed for inclusion under the ACAP strategy that relate to pollution from sources outside of the Arctic are therefore directed at supporting or promoting ongoing activities under different international fora responsible for negotiating relevant emission reduction agreements.

Sources within the Arctic that have significant impacts at the regional scale: The AMAP Assessment also highlights certain pollution sources within the Arctic that are clearly associated with significant negative environmental impacts within the region, or having potential for such widescale (in some cases cross-border) impacts. Some of these sources involve multi-pollutant emissions, giving rise to combined effects or potential for combined effects. These two characteristics, significant regional impacts and multi-pollutant aspects, imply that such major sources within the region could justifiably be targetted under ACAP as matters deserving some degree of priority.

Sources within the Arctic that have significant impacts at the local scale: The AMAP assessment further identifies sources located within the Arctic that give rise to impacts that are largely local in their extent. Due to the incomplete information on many of these types of source, they can generally only be considered to represent examples of sources that are probably more widely distributed throughout the region. It is important that the examples highlighted in the AMAP Assessment are not considered to represent a definitive priority list of such types of sources, but rather that any proposed remedial activities within the context of ACAP first include a mapping exercise to identify other similar sources and establish priorities for addressing these. Studies such as that currently being coordinated by AMAP in relation to the multi-lateral project for the elimination of PCB sources and disposal of PCB wastes in the Russian Federation, and the AMAP/NEFCO exercises to identify environmentally sound projects for pollution reduction in North-west Russia are examples of the type of work that needs to be conducted.

The AMAP conclusions relevant to the development of ACAP that are highlighted in this document are placed within the context of one or more of the above categories.

ORGANIZATION OF THIS DOCUMENT:

The following two sections, 'General Considerations' and 'Human Health Considerations' present some of the general conclusions from the AMAP assessment that are pertinent to the development of the Action Plan, and its justification. The remainder of the document is arranged according to the individual pollution issues as they are addressed in the AMAP Assessment (POPs, Heavy metals, Radioactivity, Acidification, Petroleum hydrocarbons and PAHs, Climate change and UV). Each of these sections contains a series of statements that constitute the background for consideration of actions, followed by a series of conclusions relevant to the development of ACAP with indication of action level (national, regional, global, etc.). Readers who are not interested in the background information, most of which is taken from the already published AMAP assessment reports, may wish to direct their attention to the latter sections only - these are arranged in tables in bold typeface. The order in which the conclusions are presented in the tables does not imply any priority.

GENERAL CONSIDERATIONS:

In comparison with most other areas of the world, the Arctic remains a relatively clean environment. There are, however, 2 important categories of exception to this statement:

(1) Where combinations of physico-chemical and biological mechanisms have the potential to focus particular contaminants in certain geographical locations and/or species.

- Examples of levels attributable to geographic focusing due to atmospheric trajectories, oceanographic and ice transport, and of biomagnification are given in the POPs section below.

- Substances which under certain circumstances are elevated from low levels in seawater to high levels in top marine predators are generally those which are derived from far distant sources in the northern hemisphere and the world, which are rapidly transported and dispersed by atmospheric transport, subsequently deposited in the ocean or into watersheds, and which are then subject to biomagnification. These are primarily POPs and different species of mercury. Ministers have recognized since 1993 that multi-national action on a northern hemispheric and a global scale is necessary to address this category and in their Alta Declaration put their strong support behind the relevant international instruments and negotiations.

(2) Where pollution sources within the Arctic can be associated with geographically localized elevations in levels in the environment.

- In some cases, the levels attained may approach or exceed recognized levels of concern. It will be noted that examples relating to this category given in the pollutant family sections below are dominated by observations from the Russian Arctic.

In some areas discrete signals in the environment can be detected as, e.g., elevated concentrations of contaminants in the lower reaches of the Ob, but have not been positively linked to any given source(s).

As our coverage of monitoring data improves, further geographical areas of concern may be identified. In such cases, identification of the relevant sources will be the initial work item in any future actions.

The scope and depth of the AMAP assessment was limited by the availability of quality assured data. In the absence of data, some assumptions can be made on the likely behaviour of various contaminants once released to the environment, and the subsequent probability of levels being attained in the marine environment which may justify intervention. This depends largely on the geo-chemical partitioning characteristics of the substance concerned.

Geochemical and physicochemical characteristics of pollutants exert a significant influence on their transport and fate in the Arctic:

- Some pollutants are very particle active, are rapidly bound to sediment, and therefore do not travel far from source in aquatic systems (for example, Lead and Plutonium). However, they may be subject to long-range transport in association with fine atmospheric particles (for example, Lead).
- Others undergo physical and/or biological degradation (e.g. oil).
- Others are soluble (e.g. Caesium 137 and Cadmium) or volatile or semi-volatile (e.g. Caesium 137 and most POPs) and therefore travel far from source.
- Others biomagnify (e.g. Organic Mercury and most POPs).
- Some appear to be naturally elevated in many regions of the Arctic (e.g. Cadmium, Mercury and some hydrocarbons and PAHs)
- Some possess a combination of the partitioning properties outlined above (e.g. many POPs, Mercury).
- Some have a negligible impact on the marine environment, regardless of their rate of delivery (e.g. sulphate acidifying substances).

A number of the contaminants of concern bioaccumulate (i.e. are taken up by biota). Some of them, in particular certain POPs and Hg also biomagnify, such that levels increase many fold in biota higher up the food chains. The result of biomagnification may be the elevation of levels from close to background in seawater to levels in top predators (including humans) which approach recognized levels of concern.

The traditional use, by Arctic indigenous peoples, of certain plants and animals, in particular marine mammals, for food can have implications for both human health and also the cultural identity of the indigenous peoples themselves, if these resources are contaminated.

Arctic contamination derives from sources both within and outside of the Arctic. Efforts to address the latter need to be taken in the context of global initiatives to reduce emissions of pollutants. To retain a credible position in such global negotiations, the Arctic countries must take all possible steps to ensure that they also address pollution sources within their own terretoriries.

At certain times of the year, Arctic biota may tend to concentrate at restricted locations (e.g. open areas within the sea ice). The concentrations may make them particularly vulnerable to serious pollution incidents (such as oil spills).

Many of the individual substances or groups of contaminants considered do not act in isolation. They occur in the Arctic environment together with other contaminants and may exert combined effects on Actic environments or ecosystems, both combined effects with other pollutants and with other types of stressors (such as UV radiation, cold conditions, etc.).

HUMAN HEALTH CONSIDERATIONS:

It is evident from the wide variety of man-made chemicals, which have been id entified in the Arctic environment, including food species that human exposure to chemical pollutants is inescapable and high.

These contaminants have been transported to the Arctic from industrial and other activities elsewhere in the world. Human exposure in the arctic should be viewed both as an indicator at the global nature of pollution and as a call to action.

The scientific knowledge is currently inadequate to address the potential adverse human health effects because the range and complexity of contaminants is such that a clear understanding of their effects individually and in the actual combination prevalent in food of Arctic peoples is not possible within an acceptable timeframe.

The characteristics persistent organic pollutants (POPs) and methyl mercury provide reason for concern due to their global presence and resistance to destruction in the environment and in living organisms which lead to their accumulation and successive magnification in the food chains, and a high intake in species including man, which feed at the top of the food chain. This is particularly true for some Arctic peoples whose diet includes a high proportion of tissues of top predatory marine species.

In animal experiments and in acute accidental exposures of humans a spectrum of toxic symptoms has been observed. Recently studies at the cellular and molecular levels have identified POPs as modulators of immune and hormone status and implicate their involvement in cancer, autoimmune diseases, fertility and fetal development. The exposure levels of POPs through the diet have not resulted in identifiable adverse health effects. However, the potential for as yet unidentified effects from the mixture of chemicals actually prevalent in the diet of some Arctic peoples is clearly present.

The integrity of the Arctic environment and the health of Arctic peoples are matters for social concern and action. It may most profitably be pursued by aggressive and sustained efforts to reduce the further transport of contaminants into the Arctic environment.

In spite of the potential health effects of pollutants it is at the moment premature and inadvisable to advocate a drastic dietary change as a means of limiting intake of contaminants, because of the known adverse effects of rapid transition from traditional diets. As a consequence the AMAP Human Health group recommended that Arctic Peoples should continue to eat their traditional food with recognition that there is a need for dietary advice so they can make informed choices concerning the food they eat. Furthermore it was recommended that breast-feeding should continue to be promoted.

Summary general conclusions relevant to the development of ACAP	Action level indication
1. To retain a credible position in such global negotiations, the Arctic countries must take all possible steps to ensure that they also address pollution sources within their own terretoriries.	National
2. As our coverage of monitoring data improves, further geographical areas of concern may be identified within the Arctic. In such cases, identification of the relevant sources will be the initial work item in any future actions.	-

SPECIFIC CONSIDERATION OF CONTAMINANT GROUPS

PERSISTENT ORGANIC POLLUTANTS (POPs):

Considerations, and main conclusions from AMAP's Assessment

POPs in the Arctic

All POPs considered under the AMAP assessment have been found in air, snow, water, sediments, and/or biota in the Arctic. In some cases, a number of Arctic species have POP levels high enough to cause effects. It is therefore vital to continue to promote measures to reduce levels of POPs in the environment.

In addition to the main groups of POPs considered by AMAP, PBDE, PCN, and chlorinated paraffins have been detected in biota from Svalbard and PCDEs in biota in northern Finland. PBDEs are of concern in view of expected future trends in production or release and potential toxic effects. Some of the less persistent chlorinated pesticides (endosulfan, methoxychlor, pentachlorophenol, trifluralin, atrazine, chlorpyrifos, and chlorothalonil) have also been found in Arctic air, snow, water, and plants. These are currently not included in the AMAP monitoring program. Although they are not expected to biomagnify in food webs, they may be accumulated by plants and phytoplankton at the base of the food web and little is known about the behavior of these chemicals at low temperatures.

Sources and transport of POPs

Current and past use of POPs in mid-latitudes of the northern hemisphere are the major source of many POPs in the Arctic environment. Global transport from current use areas at low latitudes is also important for some organochlorines (OCs). The initial transport mechanism from sources is usually via the atmosphere. Transport can also occur via ocean currents and via rivers following atmospheric deposition to watersheds or runoff of, e.g., agricultural chemicals containing POPs.

The highest concentrations of alpha-HCH in the worlds' oceans are found in the Canadian Arctic Archipelago, but this reflects the fact that old Arctic water isolated from atmospheric exchange is exiting the Arctic by this route rather than indicating current sources. Elevated levels of some POPs are seen around Svalbard, East Greenland and the Barents Sea, which is believed to reflect a focusing of atmospheric deposition, due to winter weather patterns; the meeting of warm Atlantic water with cold Arctic water at the polar front; and, possibly, the seasonal melting of sea ice in this area, thus releasing a winters accumulation of atmospheric deposition to the ice. Some of this ice may have originated from Russian shelves and contain incorporated sediment from those areas.

Some sources are also located within the Arctic. These will include production of dioxins, furans and HCB at municipal incineration sites and from burning of wastes in Arctic communities, smelter emissions, direct discharge of dioxins and furans from certain pulp and paper facilities to fresh and marine water bodies, loss of PCBs from electrical installations and building materials, and other past uses, industrial and community effluents, dumps, harbours, waste sites, military installations, etc. Such sources will exist in all circumpolar countries, however, they are often not well documented or studied.

Examples indicating sources located within the Arctic include:

- High HCH levels seen in Russian lake water (Taimyr Peninsula) and rivers, with gamma-/alpha-HCH ratios indicating fresh use of lindane.
- High PCB and DDT levels in a range of media sampled in Russia with some samples having higher relative amounts of *p,p'*-DDT, indicating possible fresh releases. Although some of these results need further verification, they indicate contamination with these compounds, possibly through current use or improper disposal.
- Significant PCB contamination observed in the immediate vicinity and within 20 km of abandoned and recently active military radar (DEW line) sites in the Canadian Arctic. PCB transfer to the terrestrial and aquatic food webs near the sites has been demonstrated, and from some of these sites PCB can be transported to the immediate marine environment. Military and civilian sites and dump sites that contain significant amounts of electrical equipment certainly exist in other circumpolar countries.
- PCB contamination observed in marine sediments outside of landfills on Svalbard and local PCDD/F contamination in the vicinity of a smelter near Kirkenes, Norway.
- Studies in the Archangelsk area show local contamination with dioxins and furans from pulp mills on the Northern Dvina and tributaries which extend to the White Sea.

In comparison with atmospheric deposition, local sources within the Arctic are likely to be relatively unimportant in contributing to total loadings of many of the main POPs to the Arctic, however their role in contributing to total loadings is not well known and needs further study. Sources within the Arctic can, however, have major local significance.

Levels of POPs within the Arctic

Levels of PCB and DDT were up to ten times higher in snow from the Taimyr Peninsula and Laptev Sea than in the Canadian Arctic.

High PCB levels are found in Russian seawaters. The PCB levels in Arctic seawater exceed some guidelines for protection of freshwater aquatic life.

Although information on levels of OCs in lake waters is very limited, relatively high levels of HCH, DDT, and PCB were found in some Russian lakes. Concentrations of PCBs in lake waters in Canada and Russia exceeded levels associated with negative biological effects.

Exceptionally high HCH levels are found in Russian river water, especially the Ob, although these observations need to be confirmed. Ratios of γ-HCH to α-HCH indicate use of lindane. PCB and DDT levels on suspended solids in the Ob and Yenisey Rivers are higher than found in river water near industrialized areas in North America.

OC levels are higher in freshwater sediments than marine sediments.

PCB levels in both freshwater and marine sediments generally do not exceed thresholds associated with biological effects, however, TEQ levels in most freshwater, marine, and estuarine sediments exceed some guidelines for protection of aquatic life.

Although levels of OCs in Arctic environments are generally lower than in temperate areas and levels of POPs in most Arctic species are generally lower than in comparable species in temperate areas, there are several significant exceptions.

High levels do occur due to a combination of: (1) biomagnification of OCs in long food webs, particularly those that are dominated by organisms with high lipid content, (2) some abiotic-biotic interfaces, for example ice edge communities, that may be particularly effective at transferring OCs into the food web, and (3) some species, and/or their prey, that import large contaminant burdens from their southern overwintering habitats.

Toxaphene is observed to be a major OC contaminant in air, seawater, fish, pinnipeds, and cetaceans in the Canadian Arctic. There is little information available on toxaphene levels outside of Canada.

Fauna in the terrestrial ecosystem, excluding migratory birds and birds which prey on them, are less contaminated with OCs than in freshwater and marine systems, mainly due to shorter food webs. Differences between, e.g., marine and terrestrial organisms, in the role played by lipids in insulation agasinst cold may also be a factor. The major concern in the terrestrial environment is for migratory birds of prey and fish eating mammals (e.g., mink, otter), which have higher OC levels.

Freshwater ecosystems contain higher levels of OCs than terrestrial ecosystems, mainly due to longer and more complex food webs. The major concern is high OC levels, particularly toxaphene and PCB, in fish at higher trophic levels.

The lack of substantial spatial patterns in concentrations in the marine environment is indicative of the overriding significance of northern hemispheric scale transportation and dispersal processes from distant sources. However, as indicated under the section on sources (above) signals indicating local sources can be detected.

Spatial trends within the Arctic

Most spatial trends that have been identified are in Canada, and reflect the large areas with differing in ecological characteristics, distances from pollution sources, and atmospheric deposition patterns. A general west to east increase in PCB and DDT levels in caribou and certain marine mammal species appears to extend to Greenland and Svalbard and possibly also to Svalbard, northern Norway, and even western Russia. HCH levels in certain species are higher in Canada than from sites farther east (Svalbard, northern Norway, and western Russia).

Results of PCB and DDT analyses in Arctic seabirds indicate that the Barents Sea may be more contaminated than the Canadian High Arctic, however the geographical extent of this trend cannot be determined due to lack of information from the Alaskan Arctic or the Chukchi/East Siberian Seas. Some data indicate that levels of some OCs in other biota on and around Svalbard, the southern Barents Sea, and eastern Greenland may also be higher than in biota measured in other areas.

Lack of circumpolar data limits our ability to understand sources, transport pathways, and mechanisms for focusing contaminants.

Temporal trends within the Arctic

A nine-fold decline in concentrations of HCH in Arctic air, based on measurements in the Bering/Chukchi Seas and at several locations in the Canadian Arctic Archipelago, has been observed. However, in the European Arctic at Svalbard, α-HCH concentrations have only declined two-fold and γ-HCH concentrations appear to have increased during the period 1984 to 1992. This may possibly be due to regional differences in inputs of HCH isomers.

Studies of freshwater sediment cores show recent declines in PCDD/F deposition following major increases after the 1940s. Sediment cores from lakes in the North American High Arctic show later onsets of PCB inputs (in the 1950s) compared with cores from subarctic and mid-latitude lakes, however there are no analyses of sediment cores from the Eurasian High Arctic which could confirm whether observations in the North American High Arctic reflect a generalized circumpolar phenomenon.

Retrospective time trends derived from a snow core from the Agassiz Ice Cap, Ellesmere Island, Canada showed no significant changes in OC levels with time. This may be due to different processes involved in scavenging and deposition of contaminants in snow and sediments.

Long-term, standardized, temporal trend data for the Arctic, based on annually collected, well-defined samples, are only available for fish and reindeer from the Swedish Arctic and subarctic, and, based on longer intervals between sampling, for seabird eggs in the Canadian Arctic. Based on these time series, PCB, PCDD/F, and DDT levels in biota declined between the 1970s and the 1980s, after many POPs were restricted or banned. Based on the more precise studies in Sweden, PCBs, DDT, PCDD/F, HCH, and HCB levels have not? declined in biota in recent years. The decline seems to be slower for PCB. This may indicate continued low-level leakage of PCB to the environment from unknown or poorly studied sources.

Despite being banned for open use in the circumpolar countries, evidence from temporal trend studies in biota and sediment cores indicates that PCB levels are not decreasing in the Arctic as quickly as other POPs. In part, this is probably due to continuing releases from old equipment (both improperly disposed of and still in use) and buildings where PCB containing materials were used.

Effects and health aspects attributable to POPs

Current concentrations of chemically related PCBs and dioxins/furans in several Arctic marine species (ringed seal, beluga, certain seabirds, harbour porpoise, walrus, polar bear, Arctic fox) are at or above known threshold effects associated with reproductive, immunosuppresive and neuro-behavioural effects in related species. Populations of northern peoples harvesting and consuming the lipid rich tissues of these species have the potential for exceeding dietary intake levels set by health authorities. Current OC levels in the prey of many top level predators may affect reproduction in these predators.

There is very little data on TBT levels. Imposex has been observed in Arctic invertebrates in some harbors probably due to TBT exposure and some invertebrates may be at risk for the reproductive effects of TBT.

For all species living in the Arctic in which lipids play an important role as energy reserves during starvation periods, there is a risk of redistribution of lipid-soluble OCs stored in the lipids. Detrimental effects of chemical contaminants may be enhanced by environmental stresses that occur regularly or occasionally in Arctic ecosystems. It is not known how Arctic animals respond to “below threshold” levels of contaminants which then relatively rapidly increase above thresholds. In polar bears, there is limited evidence that detrimental effects of OCs on reproduction will occur if females are stressed by starvation. Other stresses, such as occasional extreme weather, overhunting, habitat destruction, or human harassment may affect behavior, reproduction, and social structures. Physiological stress caused by toxicants may worsen the effects of such environmental stressors.

International efforts to reduce emissions and discharges of POPs to the environment

The Arctic Ocean receives input of water mainly from the Atlantic. These waters, especially those transported from the European shelf seas, can transport POPs. The North-East Atlantic, including its Arctic segment, is monitored and regulated according to Decisions under the OSPAR Convention, and earlier Decisions under the Oslo and Paris Conventions. A variety of actions have been agreed under the auspices of these Conventions to reduce emissions and discharges of POPs to the atmosphere and marine environment.

The UN Economic Commission for Europe (UN ECE) adopted, in 1998, a Protocol to control, reduce, or eliminate discharges, emissions and losses of POPs to the environment, in the ECE region as well as in the United States and Canada. Sixteen substances are currently listed in the POPs protocol, with a procedure for adding new substances as new information becomes available. All Arctic countries with the exception of the Russian Federation are signatories to the 1998 UN ECE POP Protocol, which has so far only been ratified by Canada.

The UN ECE POPs Protocol is a major regional initiative that will hopefully contribute to the development of global controls on POPs, in particular the agreements currently under negotiation under UNEP.

Summary conclusions on POPs relevant to the development of ACAP		Action level indication
1.	**The occurrence of all POPs considered under the AMAP assessment in air, snow, water, sediments, and/or biota in the Arctic, in some cases at levels in biota high enough to cause effects, confirms the need to continue to promote measures to reduce levels of POPs in the environment.**	-
2.	**Because most POPs rapidly and widely disperse from distant sources and efficiently biomagnify in freshwater and marine foodwebs, Arctic Ministers should be encouraged to continue to assign the priority they accorded at Alta and to address these substances through the hemispheric actions now agreed upon under the LRTAP Convention and about to be initiated in a global context under UNEP.**	Global/ Regional
3.	**Where local sources have been identified, and these may significantly contribute to levels in the environment where health or ecosystem effects may arise, specific actions could be initiated. This should recognize the fact that the identified sources do not constitute a comprehensive list of all such sources, and thus there is a need for further work to locate other comparable local sources of POPs, especially associated with, e.g. decommissioned military and radar installations.**	Regional/ National
4.	**Actions should be taken both to clean up contaminated sites, and to establish safe routines for handling of PCB oil, contaminated equipment, and to introduce use of alternative fluids. Although this applies to all Arctic countries, it is clear that Russia will be in a special situation due to the economic situation. Bi-lateral and joint projects should be initiated and supported by the Eight Arctic countries. A phasing-out of PCB with alternatives, and handling of PCB contaminated waste is a practical initiative that could be included under the Action Plan and would be consistent with the objectives and obligations of the recently adopted LRTAP Protocol on POPs.**	Regional/ National
5.	**Pulp mills on the Northern Dvina and tributaries which extend to the White Sea have been identified as sources of local contamination with dioxins and furans, however, they are not believed to be major sources to the offshore Arctic Ocean. Drinking water to Archangels city is taken 1 km downstream of the outlet from Archangels pulp and paper mill. Local dioxin/furan contamination has also been detected close to a smelter in Kirkenes, however this facility is now closed. Other such sources should be identified and considered for action under an Action Plan.**	Regional/ National
6.	**Measures currently being introduced by IMO that will extend the control on use of TBT antifoulants on ships and structures should be supported and adopted by the Arctic countries.**	Global

7.	**The environmental behavior, levels, and effects of the less persistent OCs, which are still in use in most circumpolar countries should receive increased attention.**	**-**
8.	**The observations of high HCH levels in Russian lake water and rivers, and high PCB and DDT levels in Russian samples should be verified and, if correct, actions must be taken to reduce inputs to the Arctic.**	National
9.	**Current sources within the circumpolar countries should be identified and remediated. Surveys of local sources of contamination by POPs within the Arctic are needed to quantify the emissions and leakage. Where emissions are high, actions should be taken to reduce or remediate them. Surveys of other such sites within the Arctic should be made to determine the circumpolar scope of the problem and remedial actions taken where high levels of contamination are found.**	National/ Regional
10.	**Despite being banned for open use in the circumpolar countries, evidence from temporal trend studies in biota and sediment cores indicates that PCB levels are not decreasing in the Arctic as quickly as other POPs. Due to the threat posed by PCBs in the Arctic, it is necessary to reduce the inputs of PCB into the environment both from the circumpolar countries as well as globally. International action is also needed to reduce global inputs of DDT and other persistent OCs that are still in use.**	National/ Regional/ Global

HEAVY METALS:

Considerations, and main conclusions from AMAP's Assessment

Heavy Metals in the Arctic

Heavy metals occur naturally in all Arctic environments and ecosystems, but with large concentration variations. They are also released to the environment by many different anthropogenic activities.

The main metals of concern are Hg, Cd and Pb, but other metals (e.g. Cu, Ni, Cr, Ag) may be of significance around local sources.

Cadmium and Hg are the most important metals in the Arctic biosphere because they tend to accumulate in the food chain to concentrations that might have health implications for individual animals or their human consumers.

Significant anthropogenic inputs of metals are detectable against the highly variable natural background. Such elevated concentrations are generally restricted to local scales (typically of the order of tens of kilometres or less from the source). However, decreasing south to north concentration gradients can also be observed over larger distances for some metals in soil and vegetation in sub-Arctic regions. These gradients reflect distance from the industrialized centres of Europe, North America and Asia.

The fate and biological availability of metals is highly dependent upon the geochemical partitioning characteristics outlined in the general considerations section above.

Metals are taken up by Arctic biota, and levels in biota often reflect both local geology and local anthropogenic activities. Metals can be accumulated by migratory species at their more contaminated over-wintering areas, from whence they are transported to the Arctic and can enter Arctic food webs.

Only few spatial or temporal trends are are clearly discernable in the existing data, largely due to lack of data (poor temporal or spatial coverage) or due to unresolvable artifacts in the data related to differences in sampling, analytical and reporting protocols.

Sources and transport of metals

The Arctic receives heavy metals from atmospheric deposition, via influx of waters from more southerly oceans, via river systems, and from local pollution. The relative importance of these sources differs between regions and between metals, however the most severe effects of metals on Arctic ecosystems are from local pollution.

During winter about two-thirds of the heavy metals in the air in the High Arctic are transported from regions with industrial activities on the Kola Peninsula, the Norilsk smelter complex, the Urals, and the

Pechora Basin. Five to ten percent of emissions from these sources are deposited in the High Arctic. The remaining one third of the heavy metals in the High Arctic air in winter is transported from industrial regions in Eurasia and North America. In summer local sources dominate in contamination of the High Arctic. The highest concentrations of atmospheric heavy metals in the Arctic air occur in the vicinity of smelter complexes on the Kola Peninsula and the Norilsk and result from emissions from these smelters.

Riverine transport of heavy metals towards the Arctic Basin is approximately half the atmospheric contribution for metals like Cd and Pb, while for others such as Zn the rivers are most important being a factor 5 higher than the atmospheric contribution. Such mass balance calculations of loadings will change considerably with the distance from the sources, and according to geochemical partitioning characteristics. In addition, source contributions are strongly seasonal.

In the Arctic, mining and metallurgical industries on the Kola Peninsula and in the Norilsk region are major contributors of metals to the aquatic environment. Local contamination around mines, such as Black Angel mine in Greenland and Strathcona Sound in northern Baffin Bay, is also a recognized problem. However, at point sources, such as mine sites and sources located in some Russian estuaries, background levels are only generally exceeded within distances of up to 30 km from the source.

Some of the biggest pulp and paper mills in Europe are situated along the Northern Dvina. Little treatment exists on the discharges to air and water which include quantities of chlorine and mercury.

Arctic metal concentrations relative to global background

Heavy metal concentrations in the air in the High Arctic are one order of magnitude lower than concentrations in other remote locations and about two orders of magnitude lower than the concentrations around major point sources in the Kola Peninsula. Air concentrations measured on the Kola Peninsula are comparable with the concentrations in the most polluted regions in Europe and North America.

Away from local sources, metal levels in soil and sediments, lake and river waters, and in the Arctic Ocean generally occur within the ranges of global background concentrations.

Cadmium levels in some terrestrial birds and mammals are high compared to global backgrounds, and so are Hg levels in some freshwater fish. Cadmium levels in marine organisms from large parts of the Arctic exceed global background. Mercury and Se levels in marine mammals are high, but not exceeding the highest global levels. Lead levels in large parts of the Arctic are at the lower end of global background.

The exposure pathways for lead to humans are not always clear, but air, food and drinking water are probably the major sources. Levels in maternal blood sampled in several Arctic countries are below guideline values, but the fact that they are similar to levels in southern populations in the northern hemisphere is indicative of the widespread contamination of the Arctic by lead as a result of long-range atmospheric transport. Also, although lead levels are generally decreasing, probably at least in part due to the introduction in most countriesof lead-free fuel, there are some exceptions in Arctic Russia.

Spatial trends within the Arctic

The concentrations in surface deposition around the sources, e.g. on the Kola Peninsula decrease rapidly by between one and two orders of magnitude within 10 to 100 km distance from the emission source. The concentrations within the large area of the High Arctic are uniformly distributed varying by a factor of 2 to 3.

The concentration of trace elements in soil and sediments is dependent on local geology, particle size, the amount of organic matter and anthropogenic influence. The background geographical distribution of Pb, Cd, Hg and Cu in soils and sediments is related to the geological provinces within the Arctic.

Large scale regional geographical differences in metal concentrations of benthic flora and fauna as well as in fish are not very apparent.

Regional differences in metal burdens in marine mammals for Pb, Cd and Hg strongly imply that tissue concentrations depend to some degree on regional geology and bio-geochemistry, however, anthropogenic sources are also responsible for widespread contamination of the Arctic as evidenced from temporal studies (see below).

Mercury levels in maternal blood of Arctic residents are highest among people who eat a lot of marine food, especially in the eastern Canadian Arctic and in Greenland and in some groups, blood levels are above acceptable values. The high exposure of some indigenous population groups in some Arctic countries to methylmercury is a matter of concern, which has raised the need for public health measures such as the development by local health authorities of dietary guidelines to help pregnant and nursing women avoid the most contaminated foods. At the same time it is vital that such advise take into account the substantial benefits of traditional foods, both from a nutritional and cultural perspective. Furthermore, the foods associated with high levels of mercury also tend to contain high levels of selenium. There is evidence that selenium may protect against the effects of some heavy metals, including mercury. Current WHO daily intake recommendations for mercury are exceeded by some Arctic populations and there is a strong case for developing specific recommendations for certain Arctic communities to take into account the types of factors mentioned above.

For Cd and Pb, there is no clear evidence of compromise of Arctic biological resources due to anthropogenic introductions.

For ringed seals, beluga whales and polar bears Cd levels have been shown to be highest in north-eastern Canada and north-western Greenland. Hg levels for the same group of animals has proven to be highest in the western part of the Canadian Arctic, decreasing towards the south and east. Geology, food constitution and growth processes linked to temperature are possible explanations for these differences.

Temporal trends within the Arctic

The concentration of heavy metals measured in sub-Arctic air has decreased during the last two decades. All the heavy metals show strong seasonal variation in the High Arctic. Mercury in Arctic sediments shows increasing temporal trends indicating a widespread regional process. Elevated mercury levels in upper layers of sediment cores from the central and eastern Canadian Arctic are indicative of anthropogenic enrichment over the last 50 years, however since not all sources are well known the changes in anthropogenic fluxes are uncertain and further investigations are needed before safe conclusions can be drawn.

Temporal trends data are scarce in Arctic biota. There is some evidence of Hg increase by a factor 2 to 3 of in some marine mammals within the last two decades. Only liver and in certain cases kidney tissue concentrations show such increases, however, and it is uncertain whether this is a real increase or reflects year to year variation. Hg concentrations in human and seal hair from the 15^{th} century are upto 9 times lower than in present day samples.

Observed biological effect and health aspects attributable to metals

The nickel-copper smelters on the Kola Peninsula and in the Norilsk region of Russia have severely polluted nearby terrestrial and freshwater systems. Deposition of metals (especially Ni and Cu) near the smelters has, in combination with emissions of acidifying substances, severely damaged soil and ground vegetation.

Health effects due to metals have so far not been investigated in Arctic biota. However, the Cd levels in some caribou, moose and ptarmigan from Yukon and in seabirds and marine mammals from Northwest Greenland may be high enough to cause kidney damage. It is likewise uncertain whether Hg poses a health problem to the highest exposed groups of marine mammals in the western Canadian Arctic and pilot whales from the Faroe Islands. However, there are indications in these areas that Se is present in concentrations that can protect against Hg poisoning.

Methyl-mercury can cross the placental barrier and there are some groups of people in the Arctic for whom mercury levels in mother's blood approach and exceed those thought to cause developmental effects in children. Umbilical cord-blood levels of methyl-mercury 2-10 times higher than in newborns from regions further south have been reported in the Arctic. It is possible that higher intake of Se by some Arctic populations is protecting against the high levels of mercury in some consumed food species.

Tissue burdens of metals relative to national standards

Relative to the concentration limits proposed by the Nordic Council of Ministers for Cd in kidney, liver and muscle tissue all caribou in Canada, most game birds, and marine mammals across the Arctic would exceed these limits. In almost all cases, Pb levels in marine organisms from the Arctic are well below food standard limits; however, this is not the case for hot spot areas such as mining areas and some Russian estuaries. No food standard limits are given for Se in food, but in some cases, human intake of

Se is estimated to be high.

International efforts to reduce heavy metal emissions to the environment

The Arctic Ocean receives input of water mainly from the Atlantic. These waters, especially those transported from the European shelf seas, can be enriched with heavy metals. The North-East Atlantic, including its Arctic segment, is monitored and regulated according to Decisions under the OSPAR Convention, and earlier Decisions under the Oslo and Paris Conventions. A variety of actions have been agreed under the auspices of these Conventions to reduce heavy metal emissions to the atmosphere and marine environment.

Under agreements made at the Third North Sea Conference (1990), many countries undertook to implement reduction of discharges of heavy metals to the North Sea.

The Organisation for Economic Co-operation and Development (OECD) is preparing a series of documents examining risk reduction measures for a variety of substances under the OECD Chemical Programme, including documents for heavy metals.

The UN Economic Commission for Europe (UN ECE) adopted, in 1998, a protocol on the reduction of heavy metal emissions in the ECE region as well as in the United States and Canada. Priority metals are Hg, Cd and Pb; secondary priorities under the development of these protocols include As, Cu, Cr, Ni, V, Se and Zn. All Arctic countries with the exception of the Russian Federation are signatories to the 1998 UN ECE Heavy Metals Protocol, to date the Protocol has only been ratified by Canada.

Pursuant to the requirements of the 1990 U.S. Clean Air Act Amendment, an interim toxic emission inventory has been developed for the continental United States. Environment Canada has initiated several projects on emission inventory development for heavy metals in Canada. The European Union has completed similar metal inventory activities for Europe. Global emission estimates for Hg and Pb have recently been revised to account for major changes in consumer patterns over the years.

Summary conclusions on metals relevant to the development of ACAP	Action level indication
1. **The metals of primary concern in an Arctic context are Hg and Cd because they tend to accumulate in the food chain to concentrations that might have health implications for individual animals or the human consumers.**	-
2. **Lead contamination associated with long-range transport has generally exhibited a decreasing trend, consistent with reduced use of Pb as a petroleum additive in the industrialized regions of Europe, North America and Asia. In the Arctic, therefore, Pb is normally only of significance around local sources.**	-
3. **Consistent with the decrease in lead contamination, average adult blood levels have also declined and are only slightly higher in Arctic residents than in populations to the south (this elevation associated with high consumption of meat from marine mammals and smoking).**	-
4. **Recent data suggest that mercury levels may be decreasing in some Arctic populations, however, this may only reflect changes in food consumption patterns.**	-
5. **Widespread contamination of the Arctic environment occurs as a result of anthropogenic activities, in particular from sources in the industrialised regions of Europe, Asia and North America. Emissions from these areas are subject to long-range transport by the atmsophere or ocean currents. This is especially so in the case of Hg which exhibits characteristics similar to those of POPs. Arctic Ministers should be encoraged to continue to assign the priority they accorded at Alta and to address these substances through the hemispheric actions now agreed upon under the LRTAP Convention.**	Regional/ Global
6. **Similarly, Arctic Ministers should continue to support and promote the ongoing activities under the OSPAR Convention, North Sea Conference, and OECD, and other relevant internatinal organizations and initiatives, concerning reductions of heavy metal emissions and discharges to both the atmosphere and marine environments.**	Regional
7. **Metals also occur in all Arctic ecosystems as a result of natural sources, and take part in natural geochemical cycling processes. Metal levels in ecosystems away from local sources are generally similar to background levels, however, gradients of decreasing Pb contamination of terrestrial ecosystems can be observed with distance from industrialized areas to the south, reflecting long-range transport.**	-
8. **Regional differences in metal burdens in marine mammals for Pb, Cd and Hg strongly imply that tissue concentrations depend largely on regional geology and bio-geochemistry, and additionally on food consumption and behavioural patterns.**	-

9.	**A major source of mercury to the Arctic will be atmospheric emissions from coal burning power stations. This source is likely to increase in importance in the future as global energy demand increases. International agreement through, for example, the LRTAP Convention heavy metals protocol to reduce these emissions should be a priority.**	Global
10.	**Major Arctic river systems can be significantly contaminated with metals, and can transport, in particular Zn and to a lesser extent, Cd and Pb, to the Arctic from areas to the south. The flux of metals to the Arctic depends on season, the characteristics of the river system, and distance from the source. Away from local sources, metal levels in most smaller Arctic rivers tend to be similar to background levels.**	-
11.	**Metal-laden sediments transported to the coast by rivers are generally deposited on the shelf seas and only a minor proportion reach the open ocean. Natural sources of metals are important and in many cases are found to be the main source to the marine environment.**	-
12.	**Mining and metallurgical industries on the Kola Peninsula and in the Norilsk region are major contributors of metals to the local terrestrial and aquatic environment, and to elevated metal concentrations in air in these regions. The atmospheric emissions from these sources within the Arctic supplement the atmospheric loadings from Eurasian sources further south.**	National/ Regional
13.	**Local sources which may impact directly on the environmemt include mines and industrial activities. Industries are often located adjacent to water courses. Such sources may have significant local impacts at distances generally within 30 km of the source.**	National
14.	**Local sources with impacts restricted largely to a local scale also include untreated sewage sludge which is contaminating receiving waters. Other potential sites for remedial and preventative action from municipal and industrial waste disposal are Sveromorsk City, the region between Archanelsk and Severodvinsk on the White Sea, and facilities on the delta of the N. Dvina.**	National
15.	**Incineration plants such as those at Murmansk emit heavy metals (Pb, Zn, Hg, Cd) and other pollutants, largely in particulate form, leading to deposition in the nearby environment. Installation of appropriate technologies would be a potential project for remedial action for consideration under the Action Plan.**	National
16.	**Unlike Hg and Cd, Pb does not bioaccumulate. However, a direct route of human exposure is through contamination of game with lead pellets from shotguns used in hunting. This source can be eliminated through replacement with steel pellet ammunition.**	National
17.	**In relation to human health, WHO should be encouraged to revise its guidance on Tolerable Daily Intakes for Hg to take into account specific conditions of Arctic Peoples.**	Global

ACIDIFYING SUBSTANCES:

Considerations, and main conclusions from AMAP's Assessment

Sources and transport

The Arctic region is widely contaminated by low levels of acidifying substances, primarily as a result of atmospheric transport of emissions from industrialised areas of Europe, Asia and North America where sulphur and nitrogen compounds are emitted from sources associated with energy production, industry and transport.

Significant sources of sulphur within the Arctic include the metal smelters on the Kola Peninsula and at Norilsk. These sources have a significant local influence with very high levels of sulphur compounds observed in their immediate vicinity. The sources give rise to elevated concentrations of pollutants in ambient air, and elevated deposition of these pollutants, at distances of up to a few hundred kilometers from the source. Highly elevated levels, however, are generally observed only within distances of 20-50 kilometers from the sources.

The potential exists for increased emissions as a result of increased development of industrial activities both within the Arctic and in developing regions outside the Arctic (e.g., southeast Asia). If such increased emissions were to occur, they could elevate the general background concentrations of acidifying substances in the Arctic and result in increased deposition of such substances.

Atmospheric processes

The chemical reactions that produce sulphate aerosols contribute to the phenomena known as Arctic Haze. These aerosols have the potential to carry other contaminants and may also have an impact on regional and even global climate, although these mechanisms are as yet poorly understood. Most of the sulphates that form Arctic Haze originate from Eurasian sources.

In the High Arctic of Canada and in Alaska, air concentrations of sulphates and nitrates have not changed appreciably since the early 1980s. On Svalbard, however, there is a decreasing trend attributable to reductions in European sulphur emissions.

Effects and geographical areas of concern

Industries on the Kola Peninsula and Norilsk, and Eastern Finnmark (where emissions have recently ceased) emit a wide spectrum of major local pollutants, resulting in strong spatial gradients along atmospheric, terrestrial and freshwater pathways. Effects are locally catastrophic and subregionally damaging for areas adjacent to nickel smelters.

The acidifying emissions giving rise to the main concerns for environmental effects in the Arctic are those of sulphur and sulphur dioxide, rather than emissions of nitrogen and its related compounds. Acidification increases the bioavailability of some metals, which can act together with the acidification to affect flora and fauna. In the immediate vicinity of the smelters, the negative effects of heavy metals are added to the stress caused by acidifying substances.

There is evidence of acidification effects on the Kola Peninsula and in limited areas in the Norwegian eastern Finnmark and eastern parts of Inari in Finland. Direct damage to forest, fish and invertebrates has been documented and critical loads of acidifying substances are exceeded in this region. For the area surrounding the Norilsk smelter, total vegetation damage has been reported up to a distance of 80 kilometers southeast from the source.

Spring melt-water runoff can result in acidic pulses that can have significant impacts in small streams; impacts that are far greater than those associated with the annual average pH of the waters. The timing and intensity of these short-duration events depends on several environmental factors. In northern Fennoscandia there exist indications of effects of acid deposition on stream fauna and small lakes, probably related to acid pulses during snowmelt.

There are no indications of man-made acidification of surface waters in the North American Arctic, however acidification monitoring in many of these areas is very limited. However, throughout most of the Arctic region surface waters have naturally low buffering capacities.

Presently, therefore, acidification within the Arctic can be characterized mostly as a subregional problem. Outside of those regions affected directly by the smelters, there is no evidence of large-scale soil and water acidification in the Arctic today.

Future development and international action

Modelling results provide evidence that most of the environments and ecosystems presently under threat from long-range transported acidifying substances can still recover if these inputs are substantially reduced. However, some lakes in northern Fennoscandia are vulnerable even to fairly low rates of continued sulphur deposition. Thus, if actions proposed to reduce Northern Hemispheric sulphur emissions are not fully implemented within a reasonable timeframe then the regions of the Arctic presently affected will be further degraded and the extent of the affected area will increase.

International collaboration to address acidification problems on a Northern Hemispheric scale has been in existence for many years under the auspices of the LRTAP Convention. Steps are being taken in 1999 under this Convention to reduce the emissions of sulphur, nitrogen and volatile organic compounds in order to reduce the multiple effects of these substances in Europe (acidification, eutrophication, ground level ozone production).

Summary conclusions on acidifying substances relevant to the development of ACAP		Action level indication
1.	**Acidification of Arctic ecosystems is, at present, a subregional problem. It occurs mainly around the smelters on the Kola Peninsula and at Norilsk in Russia.**	National/ Regional
2.	**The documented impacts of acidifying substances on the terrestrial and freshwater environments around the smelters on the Kola Peninsula and Norilsk is evidence of the serious pollution problems associated with these sources.**	National/ Regional
3.	**Several of the observed effects on soils and ground vegetation are linked to the combined effects of acidification and metal pollution.**	-
4.	**Arctic Ministers should be encouraged to continue to assign the priority they accorded at Nuuk and at Alta and to address these substances through the hemispheric actions now agreed upon under the LRTAP Convention, by encouraging ratification and implementation of existing protocols (in particular the protocol on further reductions of sulphur emissions) and expeditious completion of additional protocols (in particular the protocols being negotiated on nitrogen oxides and related substances based on multi-pollutant/multi-effects approaches).**	Regional/ Global
5.	**The major sources located within the Arctic (around the smelters on the Kola Peninsula and at Norilsk in Russia) should be addressed by the Action Plan in terms of measures to implement best available technology and clean technology solutions to reduce emissions from these plants.**	National/ Regional

RADIOACTIVITY:

Considerations, and main conclusions from AMAP's Assessment

General issues

The overall conclusion of the AMAP assessment of radioactive contamination in the Arctic is that the most significant threats to human health and the environment posed by human and industrial activities in the Arctic are associated with the potential for accidents in the civilian and military nuclear sectors. Of greatest concern are the consequences of potential accidents in nuclear power plant reactors, during the handling and storage of nuclear weapons, in the decommissioning of nuclear submarines, and in the disposal of spent nuclear fuel from vessels.

In the Arctic, terrestrial pathways of human exposure to radioactive contamination are far more important than marine pathways. The vulnerability of Arctic populations, especially indigenous people, to radiocaesium deposition is much greater than for temperate populations due to the importance of terrestrial, semi-natural exposure pathways.

Sources

Large-scale contamination of the Arctic with artificial radionuclides is derived from three primary sources: global fallout from atmospheric nuclear weapons testing; releases from European nuclear fuel reprocessing plants; and fallout from the Chernobyl reactor accident.

Some localised areas of the Arctic are also contaminated with radionuclides from other sources such as nuclear device explosions, spent fuel storage sites, and radioactive wastes dumped at sea. In the case of radioactive wastes dumped at sea and releases from underground and underwater nuclear explosions, the radionuclides remain mainly localised. Radionuclides released from Russian fuel reprocessing plants and in liquid radioactive wastes dumped in the Arctic marine environment have been distributed more widely.

Releases of radionuclides from the Thule B-52 accident, the sunken *Komsomolets* nuclear submarine and radioactive wastes dumped in the Arctic marine environment have not resulted in any significant increases in human exposures or risks to human health of Arctic residents. There is minimal likelihood of significant radiological consequences associated with any future releases of radionuclides from dumped radioactive wastes or from the sunken submarine *Komsomolets.*

Levels in the Arctic

Radionuclide activity concentrations in air and precipitation have closely reflected the rates of emission of radionuclides into the atmospheric from above-ground nuclear weapons tests. Radionuclides are accumulated in terrestrial ecosystems and water bodies, and the rates of decline in contamination levels of biota in both types of ecosystem is slower than that in the atmosphere.

In general, radionuclide contamination levels in terrestrial biota have consistently been higher than those in the marine environment. The highest radiocaesium activity concentrations in the terrestrial environment have usually been found in components of natural or semi-natural ecosystems, especially lichen and mushrooms, due to the high rate of interception or uptake of radiocaesium by these organisms. These high contamination levels are then transferred up the foodchain and are especially reflected in the meat of Arctic reindeer or caribou, which largely depend on lichen for winter fodder.

Population groups with high intakes of reindeer meat exist in all Arctic countries. Some of these groups showed high body burdens of ^{137}Cs in the late 1960s, although such observations have declined, in part due to changes in food consumption patterns.

In the marine environment, the highest levels of radiocaesium contamination were found in the North European seas in the late 1970s and early 1980s due to releases from the Sellafield reprocessing plant. Radionuclide activity concentrations in marine biota have consistently been low in the Arctic compared to the levels found in terrestrial biota.

Spatial and temporal trends within the Arctic

The highest time-integrated radiation exposures to members of average populations of the eight Arctic countries from global fallout occurred in Canada and the lowest in Greenland. The variations in individual dose distribution are not primarily due to geographical heterogeneity in radionuclide fallout. Rather, they result from variations in diet among arctic residents. Residents of Arctic Canada comprise a high proportion of indigenous people relying comparatively heavily on caribou as a source of food. In contrast, the population of Greenland is confined to coastal areas and has a diet containing a comparatively large proportion of marine foodstuffs having low radionuclide contamination.

The total number, geographical distribution and dietary composition of indigenous peoples within different Arctic regions is an important factor affecting potential individual and collective doses arising from a nuclear accident in the Arctic. Currently, little analysis has been carried out of the effect of the spatial distribution of the indigenous people, variations in diet among ethnic groups and variations in transfer rates to major food items.

In most Arctic areas, levels of radionuclide contamination in terrestrial biota reached a maximum in the second half of the 1960s due to global fallout from nuclear weapons tests. The geographical distribution of fallout reflects the patterns of precipitation for much of the Arctic. Fennoscandia and western Russia were also affected by fallout from the Chernobyl accident. In parts of Norway and Sweden, peak radiocaesium activity concentrations in terrestrial biota due to Chernobyl fallout attained values similar to those during the period of atmospheric nuclear weapons testing.

Following the cessation of widespread atmospheric weapons testing in the early 1960s, other sources, such as releases from European nuclear fuel reprocessing plants, increased in relative importance. A second, but lower, peak in fission product radionuclides occurred in the Arctic marine environment in the early 1980s as a consequence of the peak in the rates of radionuclide discharge from Sellafield in the mid 1970s. Since the Chernobyl fallout, the levels of radionuclides have been in general, but not ubiquitous, decline

Exposure of population and environment

The doses to Man in the Arctic from natural and anthropogenic radiation derive from both external and internal sources. The major contribution to the average population is the dose from inhalation of naturally-occurring radon. Lifetime doses to present generations of the Arctic average population due to anthropogenic radionuclides vary between 2 and 15 mSv or about 5 % of the dose from natural sources.

Arctic residents whose diets comprise a large proportion of traditional terrestrial and freshwater foodstuffs receive the highest radiation exposures to both natural and artificial radionuclides in the Arctic. This is particularly so for specific population groups, for instance those in Arctic Canada, having extreme consumption rates of reindeer meat. Doses to members of both the average population and selected indigenous population groups in the Arctic depend on the rates of consumption of locally-derived terrestrial and freshwater foodstuffs, including reindeer/caribou, freshwater fish, goat cheese, berries, mushrooms and lamb. In contrast, Arctic residents having diets largely comprising marine foodstuffs receive comparatively low radiation exposures because of the lower levels of contamination of marine organisms.

The major contribution to radiation doses of Arctic residents delivered by artificial radionuclides originates from previous nuclear weapons explosions in the atmosphere giving rise to global fallout. However, in some geographically limited, but populated, areas of the Arctic (Fennoscandia and western Russia), a substantial dose contribution has been made by additional fallout from the Chernobyl reactor accident. This contribution to the dose to Norwegian and Swedish Arctic residents was, and continues to be, reduced through the application of justified countermeasures.

The vulnerability of Arctic terrestrial ecosystems results in a fivefold higher exposure to radioactive contamination compared to that in temperate areas. Because of the unique ecology of the Arctic, the comparative importance of both radionuclides and exposure pathways differs from those in temperate areas. For Arctic residents, exposures to artificial radionuclides are dominated by ^{137}Cs derived from a wide variety of traditional foods of terrestrial and freshwater origin but most importantly reindeer/caribou meat. For reindeer-herders and those consuming comparatively large quantities of caribou/reindeer meat, the dominant pathway of natural radiation exposure is the intake of ^{210}Po through caribou/reindeer meat consumption. Whereas in temperate areas, following accidents, the immediate exposures to radioiodine are of primary concern, in the Arctic the low rate of milk production reduces the significance of this pathway.

Selected indigenous Arctic population groups can have individual radiation exposures 50-100 times larger than those of the members of the average populations. Individual doses within these selected groups are distributed among the Arctic countries in a similar manner to those of the average populations.

Potential releases of radioactivity in the Arctic

The greatest threats to human health and the environment posed by human and industrial activities in the Arctic are associated with the potential for accidents in the civilian and military nuclear sectors. Of most concern is the potential for accidents in nuclear power plant reactors, during the handling and storage of nuclear weapons, in the decommissioning of nuclear submarines and the disposal of spent nuclear fuel from vessels. The risks posed by radioactive wastes dumped in the marine environment of the Russian Arctic and by radioelectric thermal generators deployed in the arctic environment are relatively minor.

Because of the limited understanding of the rates and modes of transport of radionuclides within terrestrial environments, especially the effects of episodic events, it is not yet possible to judge the risks posed by the possible remobilization of radionuclides previously released from nuclear reprocessing activities that are currently accumulated in the basins of northern Russian river systems. Neither has it been possible to quantitatively assess, with confidence, the risks posed by potential reactor accidents in the Arctic, both military and civil, potential accidents in nuclear reprocessing operations, or potential accidents in the handling and storage of nuclear weapons.

There is a need for more detailed probabilistic safety assessments of civilian nuclear power plant installations. It is essential that account is also taken of medium and long-term internal doses via terrestrial Arctic pathways. Continuing attention should be paid to the modes and rates of radionuclide mobilisation in major river catchments of Siberia, including groundwater.

Summary conclusions on radioactivity relevant to the development of ACAP	Action level indication
1. The greatest radiological threats to human health and the environment in the Arctic are associated with the potential for nuclear accidents and failures in the containment of the large quantities of radioactive materials in storage such as high-level liquid and solid wastes.	-
2. Issues of major concern in relation to the potential for effects on the Arctic environment and its inhabitants are: • **accidents at nuclear power plants sited within, or close to, the Arctic;** • **accidents in military operations, including the handling and storage of nuclear weapons, decommissioning and refuelling of nuclear powered vessels and radioactive waste storage and disposal;** • **accidents during civilian vessel operations including refuelling;** • **migration of radionuclides from major uncontained sources in the drainage basins of the Ob and Yenisei Rivers; and** **releases from contained sources situated in the terrestrial environment.**	-
3. The risk of accidents in the handling and disposal of radioactive waste, especially spent nuclear fuel, from military vessels has probably been increased by the accelerated rate of submarine decommissioning partly imposed by recent disarmament agreements. These activities have imposed additional technical, infrastructural and financial demands on the processes of waste management that were already inadequate to meet the requirements of normal operations.	-
4. There are deficiencies both in the assessments of some previous accidents and of the probabilities and consequences of accidents in contemporary activities. These need to be rectified to enable more authoritative and comprehensive evaluations to be made of the risks posed to human health and the environment by such accidents. Major effort has been devoted to determining, with high degrees of confidence and precision, the consequences of radioactive waste dumping at sea. These assessments have clearly shown that there is little associated risk to human health or the environment. However, the risks associated with other major activities, which have considerable potential for widespread and serious consequences (such as the operation of nuclear-powered vessels and of nuclear reactors in the Arctic and the handling and carriage of nuclear weapons), have been inadequately addressed. Ideally, a risk assessment for all potential sources should be undertaken, not only those of contemporary political and economic concern. The priority and detail with	-

	which assessments of practices are conducted should be commensurate with the probability and severity of consequences to Man and the environment.	
5.	**Contemporary international guidance on radiation protection, nuclear safety, radioactive waste management and emergency preparedness should be rigorously adhered to by all Arctic states to minimise the probabilities and consequences of accidents.**	National
6.	**More authoritative and comprehensive evaluations should be made of the risks posed to human health and the environment by accidents in nuclear power installations. Assessments of the risks of releases of radionuclides and the radiological consequences for Man and the environment should be performed for all existing nuclear installations in, and near, the Arctic, including Probabilistic Safety Analyses for nuclear power reactors, preferably at Level 3.**	National
7.	**International recommendations regarding the improvement of nuclear and radiation safety in the nuclear industry, which cover reactor refuelling, decommissioning, and associated spent fuel storage and disposal operations, should be extended to, and implemented in, nuclear fleet operations.**	National/ Regional
8.	**Additional information should be obtained regarding: the habits and diets of Arctic residents; the transfer rates of radionuclides to terrestrial and freshwater foodstuffs; and spatial and temporal variations in production and consumption patterns of locally-produced foodstuffs. Such information would enable more precise estimates of radiological exposures and risks to arctic inhabitants to be obtained and provide a basis for deciding on intervention measures in the event of nuclear accidents.**	-
9.	**Attention should continue to be directed to reducing operational releases from nuclear fuel reprocessing plants.**	National/ Regional
10.	**Actions to assist the restoration and clean-up of contaminated lakes, reservoirs and riverbeds close to Mayak reprocessing plant may be warranted under ACAP.**	National/ Regional
11.	**Projects should be considered under the Action Plan to address issues including handling and transport of radioactive waste and spent nuclear fuel along the coast of Murmansk and Archangels Oblast; improving regional storage for radioactive waste and spent nuclear fuel in Murmansk and Archangels Oblast, and development of alternative techniques for decommissioning of nuclear submarines.**	National/ Regional

PETROLEUM HYDROCARBONS AND PAHs:

Considerations, and main conclusions from AMAP's Assessment

Sources of petroleum hydrocarbons and PAHs

The major anthropogenic source of hydrocarbon contamination in the Arctic is oil and gas development. Releases from shipping and burning of fossil fuels are additional sources within the Arctic. Accidental spills and chronic releases from poorly maintained pipelines, from ships, and during transfers at oil storage depots pose the greatest threats from petroleum hydrocarbons.

Petroleum hydrocarbons are also transported from the heavily industrialized areas outside of the Arctic by air currents, ocean currents, and rivers. The main pathway is probably via the atmosphere. Based on models, it has been estimated that atmospheric transport annually adds about 40 000 tonnes of hydrocarbons to the Arctic marine environment.

Natural oil seeps from the Mackenzie River contribute the largest quantities of hydrocarbons to the Beaufort Sea region. Oil seeps have also been detected in eight areas of the United States Arctic, several of which are located along the Beaufort Sea coast.

PAHs are widespread in the Arctic environment. They come from a variety of sources, both natural and anthropogenic, the latter including oil and gas development, incineration, and burning of fossil fuels.

The relationship between different PAH compounds can be used to identify their main sources. Alaskan marine sediments point to petroleum hydrocarbons, while PAHs in the Barents Sea show a greater contribution from combustion sources. The Canadian Beaufort Sea has a mixture of the two sources, which is also the case for Russia’s marine environment. Sediments near Spitsbergen are enriched in PAHs compared with the Russian sediments, which probably reflects contamination from coal particles and petroleum products.

Levels of petroleum hydrocarbons and PAHs in the Arctic

Hydrocarbons can be detected in marine environments throughout the Arctic. Except for areas affected by local chronic sources and spills, anthropogenic input to the Arctic marine environment to date is relatively low and is of little if any ecological significance.

Concentrations in the marine waters of the Russian Arctic are generally much higher than those found in North American waters. One explanation might be differences in analytical technique, but oil pollution carried by the large Russian rivers probably contributes.

There is evidence of high levels of petroleum hydrocarbons in some freshwater environments, in particular river systems that pass through oil and gas exploration and production areas. This is especially true in the lower part of the Ob River. The pollution can result from chronic releases or accidental spills, but also derives from industrial centres and cities located on rivers, and in some cases natural oil seeps.

Riverine transport of petroleum hydrocarbons results in elevated levels of petroleum hydrocarbones in marine areas just off of river mouths, however, even where local freshwater or terrestrial contamination is severe, riverine and other physical and biological processes tend to limit the contribution reaching the marine environment. For example, during the Komi oil spill, only a minor portion of the spilled oil reached the mouth of the Pechora River.

Contamination of terrestrial environments tends to be limited to local areas in connection with accidental spills or chronic releases, such as pipeline ruptures.

Effects of petroleum hydrocarbons and PAHs in the Arctic

The Arctic environment is more vulnerable to oil spills than warmer environments because oil and PAHs break down more slowly under cold, dark conditions. Arctic flora and fauna also require longer times to recover from the effects of oil related damage. Arctic conditions also make it much more difficult to apply remedial measures, especially if the spill occurs in a remote location.

PAHs tend to associate with particles and thus accumulate in sediments. PAHs levels in both freshwater and marine sediments in several areas of the Arctic are elevated relative to global background. This probably reflects a combinations of long-range transport and local industrial and natural sources in the watershed. The Beaufort Sea is an area with particularly high levels, however these are believed to be related to natural sources including atmospheric deposits from forest fires, and the Mackenzie River, which flows through regions with known fossil fuel deposits and natural hydrocarbon seepage. With a few exceptions, PAH levels are below those thought to cause effects on biota.

PAHs are also transported long distances on atmospheric particles, also from sources outside of the Arctic. In cities, PAHs are major components of air pollution, especially in cities on the Kola Peninsula and Arkhangelsk area where PAH levels regularly exceed maximum allowable concentrations.

Wood-burning as a source of domestic heating can give rise to high indoor levels of PAHs with potential for negative effects on human health.

Fish can bioaccumulate PAHs, however these substances do not biomagnify in the food web and levels in Arctic biota are generally similar to those for background locations outside otf the Arctic.

Future developments and international actions

There are a number of legal instruments to prevent oil pollution both offshore and onshore. Some are aimed at shipping while others specifically address oil and gas exploitation.

Further planned development of Arctic oil and gas reserves implies the potential for increased petroleum hydrocarbon contamination in the future.

Summary conclusions on petroleum hydrocarbons and PAHs relevant to the development of ACAP	Action level indication
1. Petroleum hydrocarbon contamination in the circumpolar Arctic environment is always expected to be subregional or local in extent.	-
2. The Artic marine environment is threated from both land-based and offshore activities. In relation to subregional petroleum hydrocarbon contamination of the Arctic marine environment resulting from land-based activities, the threats are essentially potential in nature and related to possible unintentional releases from existing facilities and future development of oil and gas resources (including related oil transportation infrastructure) in the coastal zone or watersheds of north flowing rivers. Offshore oil and gas development activities and shipping (i.e. non-land-based activities) as a source of petroleum hydrocarbons should be covered. Existing guidelines such as those adopted under OSPAR on reporting of discharges from offshore oil installations, and IMO regulations regarding discharges from shipping should be implemented and if necessary strengthened as the basis for Arctic environmental protection measures.	National/ Regional
3. Proactive measures aimed at ensuring that future development of oil and gas resources in the Arctic take due account of appropriate environmental protection measures (EIA, BAT, BEP, etc.), together with targetted remedial and preventative measures at sites with existing problems, are probably the most effective means available to the Action Plan.	National/ Regional
4. Environmental observations in the lower part of the Ob River and in the Pechora suggest that initial attention could be directed towards facilities located within these watersheds.	National
5. Facilities for receiving and treating liquid or solid waste from ships, and the general provision of wastewater treatment facilities are issues that should be addressed for a number of communities at the coast or on major rivers. These represent substantial multi-pollutant local sources, including petroleum hydrocarbons.	National
6. Incineration plants, such as those at Murmansk, and smelters, such as those on the Kola Peninsula and at Norilsk, emit PAHs (including benzo(a) pyrene) and other pollutants, often associated with particles, leading to deposition in the nearby environment. Installation of appropriate technologies at such sites would be a potential project for remedial action for consideration under the Action Plan.	National/ Regional

CLIMATE CHANGE AND UV:

Considerations, and main conclusions from AMAP's Assessment

General considerations

The Arctic has many unique attributes which make it particularly susceptible to climate change, ozone depletion, and UV enhancement.

The climate of the Arctic affects both the inhabitants of the Arctic and the global climate system. Anthropogenically-driven climate change is likely to be most severe in the Arctic because of the strong feedback mechanisms. The Arctic climate has undergone rapid changes in the past; recent changes have been linked to anthropogenic forcing.

Changes in sea ice coverage and thickness are the primary driving forces in the polar amplification of global warming forecast by many climate models. Yet there are few continuous and ongoing measurements of the surface energy balance, of the ice thickness distribution, or of the structure of the upper ocean. In the past, the drifting ice stations of the Former Soviet Union provided many key measurements, but that series of manned camps has ended and none from any nation are likely to replace them.

Due largely to the complex interactions of the various components of the Arctic, climate models in existence do not agree well with current measurements, nor do they agree with each other with respect to predictions when applied to the Arctic. Sea ice dynamics and trace gas balance, particularly over land, are very important aspects of the climate system in the Arctic, yet very little is known about changes taking place in either of these components. Prediction of Arctic climate is, therefore, not reliable at this time.

In the last 20 years, ozone concentrations in the Arctic have been changing more than those at mid-latitudes, with observed trends of in excess of 10% per decade. Of particular concern is the occurrence of short-term episodes of extreme ozone depletion. There are indications that the occurrence of these episodes is increasing, yet their full cause is not well understood. Because ozone depletion in the Arctic is linked to stratospheric cooling, future climate change is expected to have a strong influence on future ozone levels. The reductions of CFC’s agreed under the Montreal Protocol alone may not be enough to restore the Arctic ozone layer to pre-1980s levels.

UV radiation in the Arctic is significant because of the large amount of diffuse radiation. In the Arctic, UV is difficult to measure and difficult to estimate from satellite information, yet existing UV ground-monitoring stations in the Arctic are very unevenly distributed, so that the present spatial coverage of UV monitoring is insufficient. The increase of UV during the observed ozone depletion events is particularly important because these events often occur in spring-time when snow cover is decreasing and ecosystems are extremely sensitive.

Climate change and UV effects on ecosystems (including humans)

Although there is a general understanding of possible climate changes to the Arctic, because of the lack of ecosystem monitoring and the complexity of the feedback mechanisms in the Arctic little is known about the specific effects of climate change on marine or terrestrial ecosystems or on individual species, or about widespread effects of climate change which have occurred already. Changes in sea ice, snow, and permafrost extent will determine the available habitat for plants and animals in the Arctic. Climate changes are likely to take place faster than Arctic ecosystems are likely to be able to respond.

The effects of UV radiation on Arctic ecosystems are not well understood with many assumptions being based on UV studies carried out in the Antarctic or at mid-latitudes. Observed UV effects appear to be tied to such factors as water stress and other environmental factors that are also influenced by climate change. The springtime changes in ozone concentrations could expose primary production in the Arctic Ocean as well as the terrestrial ecosystems to harmful UV radiation because of the timing and intensity of the changes; changes in primary production would impact higher trophic levels.

The effects of climatic warming on the Arctic ecosystems are likely to be large and to have a noticeable impact on present human ways of life. Climate change, through its effect on physical properties of the land and ocean, could greatly impact infrastructure, especially transportation and large structures; this could make the Arctic more accessible to development. Agriculture, forestry, and fisheries will likely be altered. While these changes may include economic benefits, they are likely to permanently impact traditional ways of life. Sea level rise could displace many permanent communities.

Effects of UV radiation on human health in the Arctic is larger than previously suspected. The strong seasonal cycle often exposes populations to high UV levels in the early spring when they have not yet developed protective pigmentation. UV has been linked to dermatological, ocular, and immunosuppression effects, all of which can have severe impacts on the health of Arctic people. The low sun angle and high reflectivity of snow make UV even more hazardous for Arctic populations than previously thought. Because of the high cost of administering health care in the Arctic, UV effects due to decreasing ozone are likely to have high economic impact.

International agreements

The Montreal Protocol on Substances That Deplete the Ozone Layer and its amendments have set standards to reduce the production of CFCs and other ozone depleting substances; however, these agreements do not directly address measures that may need to be taken to assure the protection of the Arctic stratospheric ozone layer.

Compliance with the Montreal Protocol is a concern. Several countries have already indicated that they will not be able to reach their agreed phase-out goals. Illegal trade in the controlled substances may also undermine the goals of the Montreal Protocol and amendments.

Agreements on reductions in emissions of greenhouse gasses that are responsible for global climate change are negotiated under the auspices of the United Nations Framework Convention on Climate Change. These negotiations include provision to promote sustainable management of greenhouse gas sinks (natural ecosystems which can remove greenhouse gases from the atmosphere). Appropriate greenhouse gas emission targets are critical to the Arctic environment because of its high sensitivity to climate change, however, existing (e.g., Kyoto) agreements may not be sufficient to protect the Arctic.

The Intergovernmental Panel on Climate Change (IPCC) assessments summarizing the present understanding of the science of climate change and the impacts of climate change have focused on modeling and model predictions for future levels. The IPCC documents have illuminated serious problems in the existing models for Arctic climate. Because of the unique qualities of the Arctic environment and its interactive processes, many general results are not applicable to the Arctic. Focused effort, on the part of the IPCC, to examine the Arctic's responsivity to climate change through available data from the Arctic would be appropriate and useful to understanding global climate change.

Summary conclusions on climate change and ozone/UV relevant to the development of ACAP	Action level indication
1. As a result of global climate change, surface temperatures over large parts of the Arctic have increased over the last 30 years (e.g., Alaska and East Siberia), in other areas (e.g. Spitsbergen, Scandinavia) no significant changes have been observed, and in the Greenland, Hudson Bay area temperatures have declined slightly.	-
2. Despite the significance of likely future changes in the Arctic and the existing high degree of uncertainty in predictions for the Arctic region, little scientific effort is going into improving our understanding of the implications for the Arctic of climate change. IPCC and WMO should be requested to take up these issues for the Arctic, in particular with respect to improving the ability of climate change models to accurately predict changes in the Arctic.	Global
3. Although the Arctic countries contribute significantly to current WMO and IPCC assessments, the interests of the Arctic countries are under-represented, particularly in light of the severe changes taking place in the Arctic. In future WMO and IPCC assessments, Arctic issues should be placed at a higher level of importance including addressing such issues as the influence of climate change on Arctic ozone levels, and the resultant effects of increased UV radiation on human health and the biosphere.	Global
4. Arctic countries are often considered to be likely beneficiaries with respect to climate change (e.g., warming increasing agricultural area and production), however, such conclusions do not take into account the effects of further increases in UV radiation or the possibly devastating effects on vulnerable ecosystems and Arctic communities. Climate change effects on ecosystems need to be examined in terms of an integrated assessment, taking into account relevant environmental factors such as acidification, UV and pollutants, as well as the effects of climate change on competing species within an ecosystem.	Global
5. Whereas the Arctic lower troposphere shows an increasing temperature trend (ca. +0.05 degrees C per decade) as a result of global warming, temperatures in the lower stratosphere have decreased (ca. -1 degrees C per decade). Under Arctic conditions, this stratospheric cooling is causing significantly increased ozone destruction. Current understanding of the quantitative estimates of the effect are poor, however the problem seems to have been underestimated.	-
6. Ozone depletions in the Arctic have been greater than those observed anywhere outside of the Antarctic. The losses have been particularly severe in the springtime when biological activity is most sensitive.	-

	Measurements have confirmed very strong increases in UV radiation in the Arctic as a result of ozone depletion. Depletion in the spring has been roughly 200 Dobson units over the past decade. Under current legislation the most optimistic expected recovery of ozone is estimated to be only 20 Dobson units over the next fifty years.	
7.	**Arctic ozone depletion is governed by concentrations of CFCs (chloroflurocarbons) and other ozone depleting substances, temperature and dynamics. Because of the nature of Arctic ozone depletion, current international legislation is not likely to be sufficient to protect the Arctic ozone layer. Two international efforts are involved in these issues globally: the Montreal Protocol and the Intergovernmental Panel on Climate Change(IPCC). The Montreal Protocol has made it clear that they will not tackle the difficult aspects of changing temperatures and dynamics which are relevant to Arctic ozone depletion. It is likely that the efforts by the Montreal Protocol and its amendments will be sufficient to protect the ozone layer in the mid-latitudes but not in the Arctic. So far, IPCC has not taken up the issue of the effects of climate change on Arctic ozone and UV levels.**	**-**
8.	**Examination of the direct effect of UV radiation on human health requires immediate attention, particularly with respect to ocular damage and additionally to immunosupression effects and dermatological disorders. Similarly, the effects of UV and climate change on Arctic peoples and on the plants, mammals, and fish they harvest for food, on grazing animals, and on the physical environment need to be better understood.**	**-**