ICARP II – Background Document

CONTAMINANTS

Developed by the AMAP Secretariat

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Introduction

One of the conclusions of the Second International Conference on Arctic Research Planning (ICARP II), held in Copenhagen, Denmark on 10-12 November 2005, was that contaminant issues are relevant within all ICARP II working group themes and should be addressed in all the ICARP II science plans. It was agreed that the considerable body of information compiled through the work of the Arctic Monitoring and Assessment Programme (AMAP) should provide the starting point for a consideration of contaminants in the ICARP II science plans.

This background document reflects gaps in knowledge and recommendations and priorities for arctic contaminants research identified through AMAP scientific assessment activities over the past 15 years.

Major progress has been made over the past two or three decades in extending knowledge regarding the presence and fate of contaminants in the Arctic – the pathways by which contaminants reach and are distributed within the Arctic, the spatial patterns of contamination and changes in contamination over time, and the effects of this contamination on ecosystems and arctic human populations. Much of this work has been carried out within the AMAP framework, and through national and international programs of contaminant monitoring and research that contribute to the various AMAP programs.

Despite this progress there are still many gaps in knowledge, and new findings have raised new questions. These gaps and questions are comprehensively described in the scientific background documents that form the basis for AMAP assessments of the pollution status of the Arctic.

The links that have been documented by AMAP over the last 15 years between contaminants and threats to the health and wellbeing of both animal populations and human populations in the Arctic (in particular some indigenous peoples groups) clearly demonstrate the relevance of this issue to residents and communities of the north. Recent attention given to the influence of climate change on contaminants and to the results of the Arctic Climate Impact Assessment (ACIA, 2004, 2005) show the connections to global processes that may, in the not too distant future, lead to significant changes for both the Arctic and other parts of the world, that are as yet poorly understood.

Focus and Relevance of the Research Theme

The focus of contaminant research in the Arctic is an understanding of the mechanisms by which contaminants are transported to and within the Arctic, and knowledge of the fate and implications of arctic contamination for the region's environment and ecosystems, including human populations within the Arctic. Our ability to assess the extent of arctic contamination, its development over time (temporal trends), and effects on biota at different levels of organization (from the molecular level to population and even possible ecosystem responses) depends on an adequate base of knowledge regarding (many) relevant scientific disciplines. Potential human health effects of contaminants are a key concern, in particular for indigenous peoples of the Arctic. Research (and monitoring) aimed at improving understanding of arctic pollution issues is an integral component in the development of sound science-based policy recommendations to reduce arctic contamination and its impacts. This key feedback in terms of policy relevance is facilitated largely through the Arctic Council, and the work of AMAP. Information on contamination of the Arctic played a key role in the development of international agreements such as the Stockholm Convention on Persistent Organic Pollutants, and the UN ECE Convention on Long-range Transboundary Air Pollution and its related protocols, and is also an important component in the reviews of the effectiveness and sufficiency of such agreements. Recently, increasing attention has been paid to the issue of arctic climate change, and the many ways in which future climate change has the potential to alter the pathways of contamination and the environmental fate and effects of contaminants in the Arctic – including possible feedbacks relevant for assessing contamination issues at lower latitudes.

Key Research Questions

In 1997, AMAP concluded that the current understanding of contaminant transport processes and the ability to quantify them is inadequate. In particular, determination of transport processes and their relative importance or magnitude within and between compartments (air, land, water, ice, sediments, and biota) is essential (see AMAP, 1997, 1998).

Specific gaps and needs identified in the 1997 AMAP assessment concerned:

- Contaminant inputs to the Arctic from various sources and pathways, including increased knowledge of local sources within the Arctic, which may as yet be unknown or insufficiently quantified.

- Poor understanding of pathways of transport and deposition of heavy metals, persistent organic pollutants (POPs), petroleum hydrocarbons and radionuclides, from land to rivers, estuaries, deltas and the continental shelf. In particular, determining contaminant focusing zones (i.e., zones of convergence of contaminant transport pathways) and understanding the processes of sequestration by sediments need further attention. The use of natural and anthropogenic tracers to mimic contaminants and distinguish sources has been underutilized.

- Ocean transport processes for different contaminants, including ice transport and subsequent contaminant release in melting (focusing) zones.

- Improved understanding of the influence of arctic conditions, especially temperature and light, on the transformation and fate of contaminants.

- Understanding of the changes in contaminant concentrations, transformations, and interactions that occur within food web pathways, including dynamics of the transfer of radionuclides into traditional foods arising from both terrestrial and freshwater pathways.

- Information on contaminant levels and trends, which is still lacking for certain contaminants and media in certain areas.

- Long-term trends in levels of contaminants in different compartments, especially in biota.

- Better understanding of physiological and toxicological effects of contaminants on humans and species identified as most at risk, especially on development of offspring, and/or immunosuppression and endocrine disrupting properties.

- Detailed information on the diet and food consumption patterns of specific arctic populations, including necessary information on other factors (e.g., smoking) which can influence contaminant exposures, to allow better estimates of dietary intakes of contaminants and permit more reliable estimates of associated risks.

- Integration of physical and biological models with information on environmental measurements of sources and pathways, to aid the design and implementation of monitoring, research, and management, including mitigation.

- Assessment of the probability and impact of release from operations involving radionuclides, other than waste dumping at sea, and identification of appropriate management options.

- Knowledge about combined effects of contaminants on biota and humans, both at the individual and ecosystem level.

- Knowledge about combined effects between climate change and contaminant pathways, including improvements of models for assessments. Existing models on climate change and transport processes do not have the resolution and accuracy needed to fully assess environmental consequences of anthropogenic emissions to the Arctic.

The AMAP assessments of POPs, heavy metals, radioactivity, and contaminants and human health were updated in 2002 (AMAP, 2002) and a number of these questions were addressed, but most of these key questions remain relevant.

A new aspect of arctic contamination addressed in the AMAP 2002 assessments was the influence of climate change on contaminant transport to, within and from the Arctic.

The 2002 AMAP assessments also raised new questions, for example:

1. The assessments highlighted the possible effects of atmospheric mercury depletion events following polar sunrise in delivering mercury to the Arctic, but the extent of these inputs is still not known, some of the mercury is re-emitted to the atmosphere, and there is no complete answer as to whether there is any net input of mercury to arctic ecosystems as a result of this deposition.

2. Are there other significant transport pathways for contaminants such as mercury that have not yet been adequately identified and studied, in particular ocean pathways?

3. New POPs are continually entering the market. One of the surprises in arctic contaminants research over past decades is the extent to which POPs are to be found in almost all components of the arctic environment and its ecosystems. For many of these contaminants, reliable methods to analyze them at the low levels found in most arctic samples are relatively recent; for many POPs, analysis is still a major challenge. An increasing body of information is available regarding “legacy” (now banned or controlled) POPs in the Arctic, for example DDTs and PCBs, but knowledge regarding “new” POPs (current-use pesticides and new high-volume chemicals), for example brominated flame retardants, is still very limited.

4. The Arctic contains a large concentration of sources of radionuclides – which have been increasingly well documented over the past 15 years. Effects of radioactivity are typically addressed by considering risks to humans – what are the risks to the environment and other parts of the ecosystem from arctic radioactivity?

5. AMAP assessments documented early on that, despite generally low levels of contamination in abiotic environments, some arctic animals and human populations have extremely high exposure to harmful substances; a result mainly of biomagnification in arctic food webs and the special dietary characteristics of some arctic population groups. New programs of research are needed to consolidate this knowledge. One important aspect is the lack of understanding of the combined effects of (a cocktail of) contaminants and other environmental stressors on the health of arctic biota, including humans.

6. The climate in the Arctic is changing rapidly. It is also subject to (natural) variability on a range of time scales. The potential influences of climate change on contaminant pathways are many and complex, and could radically alter the types and patterns of contamination in the Arctic relative to those that have been documented to date. Such changes can confound temporal trend assessments, alter ecosystem exposure and effects, and possibly even make the Arctic a source for contaminants that may have accumulated there. Addressing such questions, in relation to future climate scenarios is a major objective of AMAP’s future work, and developing a coordinated program of research to support these activities is a high priority. One of the conclusions of the AMAP 2002 assessment was that “the inevitable surprises will highlight that the current understanding of complex environmental systems is

still very incomplete." How best can research effort be organized to provide information that will allow managers to prepare for such surprises?

It is difficult to address the subject of "contaminants" in terms of a single research agenda. Different fields of research address very different issues (e.g., transport pathways vs. biological effects), and different approaches are employed in attempts to answer key questions (laboratory studies vs. modeling vs. field campaigns vs. long-term monitoring, etc.). Some contaminants have natural sources others are only from anthropogenic sources; some are (or have been) used within the Arctic, many have not; some are still in use, whilst others are a legacy of past use. These factors, in addition to the physico-chemical and toxicological characteristics of individual contaminants, require that research must often be very specific in relation to the questions and contaminants concerned.

Linkages

Research linkages

The contaminants research considered here has linkages to a number of other national and international organizations engaged in research coordination (national research councils, European Union, International Council for the Exploration of the Sea, International Arctic Science Committee, etc.). Specific organization linkages for priority contaminant issues include:

Contaminant	Specific organization linkages
POPs	• EMEP (European Monitoring and Evaluation Programme), IPY (International Polar Year)
Metals	• EMEP, IPY
Human Health	• World Health Organization, International Union on Circumpolar Health, IPY
Radioactivity	• Overall risk and impact assessments: AMAP, European Union through its Northern Dimension Environmental Partnership, the G8-countries and the European Bank for Reconstruction and Development Projects • Environmental Impact Assessments: AMAP/Arctic Council and arctic countries with nuclear facilities in or close to the Arctic • Protection of the environment: AMAP, EPPR (Emergency Prevention, Preparedness and Response: Arctic Council/AEPS group), International Union of Radioecologists, International Commission on Radiological Protection • Basis for emergency preparedness: AMAP, EPPR, IAEA (International Action Plan for Strengthening the International Preparedness and Response System for Nuclear and Radiological Emergencies) • AMAP data dentre on radioactivity
Climate Change/UV and Contaminants	• Arctic Council (AMAP, CAFF), IASC, WMO, IPY

Stakeholders

Examples of stakeholders that will benefit from research into contaminants in the Arctic include: Arctic national governments and national authorities; indigenous peoples (Arctic Council Permanent Participants); local health authorities; international regulatory agencies (UNEP-Stockholm Convention, UN ECE-CLRTAP Protocols, International Atomic Energy Agency, OSPAR Commission, European Environment Agency); scientists, especially those engaged in multidisciplinary studies; international bodies/groups concerned with various arctic issues, biodiversity, sustainable development, etc. (Arctic Council, World Wide Fund for Nature, resource management organizations, United Nations Environment Programme, etc.).

ICARP Theme linkages (X: indicates linkage; notes in table are examples of key linkages)

ICARP II Science Plan	POPs	Metals (mercury)	Human health and contaminants	Radioactivity	Climate/UV and contaminants	Other contaminants/ issues
SP 1	X (food security, potential contamination of natural resources)	X (food security, potential contamination of natural resources)	X (food security and health, drinking water supply)	X (energy, military and risks to northern communities)	X	X (potential contamination from oil industry, shipping, mining, etc.)
SP2	X (POPs in traditional foods)	X (metals (mercury) in traditional foods)	X (contaminants in traditional foods)		X	
SP 3		X (riverine flux of metals through the coastal zone)		X (riverine flux of metals through the coastal zone)	X	
SP 4				X (radio-tracers)	X	
SP 5	X (inflow and outflow of POPs to/from Arctic Ocean)	X (inflow of metals to Arctic Ocean)		X (inflow of radionuclides to Arctic Ocean)	X	
SP 6	X (POPs effects on marine biota/ biodiversity?)	X (metals effects on marine biota/ biodiversity?)			X	
SP 7					X	
SP 8	X (POPs effects on terrestrial/ aquatic biota/ biodiversity?)				X	
SP 9					X	
SP 10			X (e.g. health effects of changes in diet and lifestyle)	X (vulnerability to accidents)	X	X (development and coping with potential contamination issues)
SP 11	X	X	X	X	X	X

Documentation

AMAP assessment reports prepared over the last ten years identify a number of gaps in knowledge and contain a number of recommendations for scientific research to address these gaps. This material can provide much of the basis for the ICARP II discussions. All the AMAP scientific assessment reports are available online from http://www.amap.no (follow links to >> Assessment Results >> Scientific Reports). References to relevant documents are presented in Annex 1 to this report.

Similarly, a number of workshops, such as the August 2005 international workshop on mercury research in polar regions, have produced reports containing recommendations that can help initiate the consideration of these issues within the ICARP II process.

Documentation for the AMAP Trends and Effects Programme (http://amap.no/documents/index.cfm?dirsub=%2FThe%20AMAP%20Trends%20and%20Effects%20 Programme%3A%201998%2D2003&sort=default) includes sections on recommended methodologies, the relationship between research studies and monitoring, and the use of research results in the interpretation of monitoring results, etc. and data handling issues, including data policies to protect the rights of researchers while at the same time ensuring access to research results.

Funding

It can be assumed that the majority of the funding required to support the research activities covered in this document will come from the national research councils and other agencies engaged in funding monitoring and research at the national level; in particular relevant agencies in the arctic countries, and in some (few) other countries with a special interest in arctic research.

IPY funding will play an important role in the coming five years, however it is critical that this represents new money – if IPY activities are funded through reallocation of existing funds, then while some parts of the arctic research community may benefit in the short-term, it is likely that other arctic researchers and established ongoing (long-term) observing, monitoring, and research efforts may be severely disrupted.

Within Europe, the allocation of funding through the EU Framework Programme has not been particularly favorable in relation to supporting research on contaminants as an arctic issue of concern. One example of the complications that have been encountered by arctic scientists applying for EU research funding is the process by which proposed projects may be rated according to their pan-European relevance. The Arctic is a relatively small part of Europe; only two EU member countries (Finland and Sweden) have arctic territories (Denmark is a member, but Greenland is not part of the EU). Despite the "Northern Dimension" strategy and cooperative agreements with other arctic countries (Norway, Iceland) in the environmental and research fields, the Arctic does not have a high interest for most European countries. It might be hoped that issues such as climate change and trans-boundary pollution will help highlight the critical linkages between the Arctic and regions to the south, and that this might stimulate increased funding for arctic research from these sources.

Funding needed for, in particular, arctic field research is substantial as can be gauged from the support allocated by Canada (Can$150 million) essentially to support the Canadian IPY effort. Some types of research (modeling, laboratory studies, etc.) may be less costly, but reliance on cheap alternatives (e.g., making use of "already available" data from remote sensing platforms) should be viewed as complementary and not an alternative to programs of field measurement and observation.

Greater emphasis should be placed on presenting the (relevance of) results of arctic research to a wider audience than has been done in the past, with a view to convincing those holding the purse-strings of the importance of arctic research, not just for the Arctic but for the world as a whole.

Increased potential for development in northern areas (oil and gas industry, shipping) also presents opportunities for encouraging industry-sponsored research in the region – if necessary with appropriate mechanisms to ensure the impartiality of such research. A very small part of the finances that will be spent to develop arctic resources would represent a very significant part of the research funding required to help ensure that economic development in the Arctic is done in a sustainable manner that minimizes risks for environmental contamination, etc.

References

ACIA, 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press, 139p.

ACIA, 2005. Arctic Climate Impact Assessment. Cambridge University Press, 1042p.

AMAP, 1997. Arctic Pollution Issues: A State of the Arctic Environment Report. Arctic Monitoring and Assessment Programme, Oslo, 188p.

AMAP, 1998. The AMAP Assessment Report: Arctic Pollution Issues. Arctic Monitoring and Assessment Programme, Oslo, xii+859p.

AMAP, 2002. Arctic Pollution 2002. Arctic Monitoring and Assessment Programme, Oslo, xi+111p.

AMAP, 2003. AMAP Assessment 2002: Human Health in the Arctic. Arctic Monitoring and Assessment Programme, Oslo, xiii+137p.

AMAP, 2004a. AMAP Assessment 2002: Persistent Organic Pollutants (POPs) in the Arctic. Arctic Monitoring and Assessment Programme, Oslo, xvi+310p.

AMAP, 2004b. AMAP Assessment 2002: Radioactivity in the Arctic. Arctic Monitoring and Assessment Programme, Oslo, xi+100p.

AMAP, 2004c. AMAP Assessment 2002: Heavy Metals in the Arctic. Arctic Monitoring and Assessment Programme, Oslo, xvi+265p.

AMAP, 2006. AMAP Assessment 2006: Acidifying Pollutants, Arctic Haze, and Acidification in the Arctic. Arctic Monitoring and Assessment Programme, Oslo, xiii+117p.

Macdonald, R.W, T. Harner, J. Fyfe, H. Loeng and T. Weingartner, 2003. AMAP Assessment 2002: The Influence of Global Change on Contaminant Pathways to, within, and from the Arctic. Arctic Monitoring and Assessment Programme, Oslo, xi+65p.

Annex 1 – Priorities for Research within (Priority) Contaminant Subject Areas

Persistent Organic Pollutants in the Arctic

- Research to improve knowledge of pathways for abiotic and biotic transport and transfer of persistent organic pollutants (POPs) to/within the Arctic – long range transport in air and water, bioaccumulation, and biomagnification pathways.

- More concerted effects studies in animals at high trophic levels. This includes the need for laboratory, semi-field, and field studies to establish links to POPs and mercury levels.

- Spatial and temporal trend data on POPs – particularly for new chemicals and for areas not represented previously (for example Russia, with low spatial and little temporal data).

- Modeling of POPs transport to the Arctic, and bioaccumulation of POPs in arctic food webs and in humans. Better understanding of what physico-chemical properties are problematic for the Arctic in order to identify chemicals that have arctic transport potential.

For more information on POPs in the Arctic, see:

AMAP 1998 Scientific Assessment (AMAP, 1998)	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%20Report:%20Arctic%20Pollution%20Issues&sort=default
AMAP 2002 Assessment: Persistent Organic Pollutants (AMAP, 2004a)	http://amap.no/documents/index.cfm?dirsub=%2FAMAP%20Assessment%202002%3A%20Persistent%20Organic%20Pollutants%20in%20the%20Arctic&sort=default

Heavy Metals, including Mercury in the Arctic

- Process research is required to support monitoring – the two aspects are complementary and not alternatives. In particular, process research should be oriented toward supporting interpretation of long-term trend monitoring data in various arctic biotic and abiotic media (including the influence of climate change and variability on trend detection).

- Research to determine interactions between the atmosphere, sea ice, snow pack, and chemical, physical, biological, marine ecosystem exchanges and their impacts in relation to mercury. More interdisciplinary studies and whole system research projects are required.

- Research to establish the relationship and possible impacts between the behavior of mercury in the Arctic and climate change at coastal sites and regions, for example changes in methylation rate related to climate change.

- Identifying the source of methyl-mercury, including a greater focus on methyl-mercury in monitoring studies.

- Greater emphasis on research to understand the oceanic transport of mercury.

- Research to identify the species of mercury that are involved in mercury depletion events and the fate of these species in the environment.

- Research to address the question of how mercury enters the arctic environment. What parameters are important for the uptake of mercury in the arctic environment?

- Improved understanding of risk factors in relation to human health impacts of mercury exposure, also including benefits of traditional diets, etc.

- Research to investigate the linkages between mercury and cardiovascular disease, including studies on mercury speciation in food items, understanding metabolic interactions between mercury and other pollutants and nutrients, monitoring mercury in tissues of wildlife that are consumed, and identifying key communities and the social and economic changes that they are undergoing, etc.

- Addressing issues relating to natural versus anthropogenic sources of mercury, including the influence of climate change.

- Establishing a mercury mass balance for the Arctic.

- Further studies into the increase in platinum, palladium, and rhodium in ice and snow samples from Greenland, and the environmental and human health effects of these metals.

For more information on heavy metals, including mercury, in the Arctic, see:

AMAP 1998 Scientific Assessment (AMAP, 1998)	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%20Report:%20Arctic%20Pollution%20Issues&sort=default
AMAP 2002 Assessment: Heavy Metals (AMAP, 2004c)	http://amap.no/documents/index.cfm?dirsub=%2FAMAP%20Assessment%202002%3A%20Heavy%20Metals%20in%20the%20Arctic%20%28Pre%2Dprint%20files%29&sort=default
Interdisciplinary workshop for research on mercury in polar regions. Toronto, August 29–31, 2005.	TO BE ADDED TO THE AMAP WEBSITE SHORTLY

C. Contaminants and Human Health in the Arctic

- Registration of disease patterns in relation to climate changes.

- Studies on genetic susceptibility to xenobiotic compounds.

- Continued monitoring in hot-spots of contaminant exposure in relation to climate change.

- Identification of alternative sources for human exposure to xenobiotic compounds.

- Research on how nutrients modify contaminant effects.

- Intensified contaminant related health effect studies (blood pressure, serum lipid profile, thyroid status, glucose intolerance, xenohormone effects).

- Risk Benefit studies (traditional food vs. contaminants; traditional food vs. store bought food).

- Development of risk communication strategies.

For more information on contaminants and human health in the Arctic, see:

AMAP 1998 Scientific Assessment (AMAP, 1998)	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%20Report:%20Arctic%20Pollution%20Issues&sort=default
AMAP 2002 Assessment: Contaminants and Human Health (AMAP, 2003)	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%202002:%20Human%20Health%20in%20the%20Arctic&sort=default
Workshop on persistent organic pollutants (POPs) in the Arctic: Human health and environmental concerns	http://amap.no/documents/index.cfm?action=getfile&dirsub=&filename=wsphh%2Drep%2Epdf&sort=default

Radioactivity in the Arctic

- Research relating to management of risks associated with nuclear reactors and the handling of radioactive waste including: development of improved tools (including consideration of the uncertainties) to conduct risk and impact assessments (including accident scenarios); improvements in hazard and consequence assessment and emergency planning; and promotion of exchange of scientific information regarding sources of radioactivity affecting the Arctic and surrounding areas).

- Research relating to the development of a framework for the protection of the arctic environment.

- Research to improve knowledge of the behavior of radionuclides in the environment, and understanding of environmental transport processes within the Arctic, for example a detailed study of the remobilization of radionuclides from sediment and its potential long-term effects on the Arctic.

For more information on radioactivity in the Arctic, see:

AMAP 1998 Scientific Assessment (AMAP, 1998)	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%20Report:%20Arctic%20Pollution%20Issues&sort=default
AMAP 2002 Assessment: Radioactivity (AMAP, 2004b)	http://amap.no/documents/index.cfm?dirsub=%2FAMAP%20Assessment%202002%3A%20Radioactivity%20in%20the%20Arctic&sort=default

Climate Change/ Ultraviolet Radiation and Contaminants in the Arctic

- Ice is a dominant, multi-compartment medium in the Arctic but its role in modulating contaminant fate is poorly understood. There is a need for a better understanding of this issue in the light of climate change effects on ice cover. Studies are required on ice changes along the coastal margin, and their role in contaminant transport, changes in shipping routes, and increased oil exploration and transport and the associated risks.

- Develop fully coupled atmosphere-ice-ocean-ecosystem models to predict how natural systems will respond to contaminants (in terms of new releases or bans on use) and vice versa.

- Need for spatial and temporal trends in levels of contaminants and variability in the systems they enter to understand if trends are due to changes in contaminant inputs, changes in pathways due to climate change or both – collaboration will be required between environmental contaminant scientists and climate scientists.

- Studies of climatic factors affecting contaminant transport, most importantly changes associated with ice and precipitation and with ecosystem structure (changes in food webs).

- Adaptation. Waste sites that are located on permafrost will be vulnerable if permafrost thaws.

- Biodiversity. Invasion of more southerly species, changes in distribution for arctic species, population declines/extinction of species needing ice cover for survival (hunting, reproduction, etc.), all leading to changes in food web structure.

- Mercury. Knowledge of mercury pathways is incomplete (atmospheric transport, deposition during polar sunrise, biogeochemical cycling in ice-covered environment, bioavailability to primary producers and accumulation in food webs). Need for understanding of processes implicated in mercury depletion events. Atmospheric transport and deposition are related to climate change. Increased mercury release associated with thawing permafrost.

- POPs. Transport is affected by climate change, and subtle effects in organisms caused by POPs can be exacerbated by nutritional stress brought on by ecosystem and ice climate changes. Key species are marine mammals and key areas are the Kara Sea, Franz Josef Land, and Svalbard.

- Food security and human health. Changes in migration routes of marine mammals leading to change in food availability. Changes in food webs leading to increases/decreases in environmental contaminant levels and human exposure.

- Radioactivity. Studies of radioactivity in sea ice are required to identify the origin of the ice and the distribution of radionuclides by this route.

- Radioactivity. Studies on the potential impact of climate change on the transport of radionuclides to the Arctic from sources outside the region, and the way in which the distribution of radionuclides already present in the Arctic may be influenced by a change in climate, are of particular interest.

For more information on climate change/ ultraviolet radiation and contaminants, see:

AMAP 1998 Scientific Assessment (AMAP, 1998)	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%20Report:%20Arctic%20Pollution%20Issues&sort=default
AMAP 2002 Assessment: Climate Influence on Contaminant Pathways (Macdonald et al., 2003)	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%202002:%20The%20Influence%20of%20Global%20Change%20on%20Contaminant%20Pathways&sort=default
ACIA Follow-up Workshop	TO BE ADDED TO THE AMAP WEBSITE SHORTLY
Chapter 5 (UV and Ozone). Arctic Climate Impact Assessment (ACIA, 2005)	TO BE ADDED TO THE AMAP WEBSITE SHORTLY

Other Contaminant related Issues

For more information on other contaminant related issues, see:

AMAP 1998 Scientific Assessment Report	http://amap.no/documents/index.cfm?dirsub=/AMAP%20Assessment%20Report:%20Arctic%20Pollution%20Issues&sort=default
AMAP workshop on combined effects	http://amap.no/documents/index.cfm?action=getfile&dirsub=&filename=ceme%2Drep%2Epdf&sort=default
AMAP Workshop on modeling and emissions	http://amap.no/documents/index.cfm?action=getfile&dirsub=&filename=wsmod%2Drep%2Epdf&sort=default
ACIA workshop on modeling and scenarios	http://acia.uaf.edu/PDFs/Stockholm_final.pdf
AMAP Assessment 2006: Acidifying pollutants, arctic haze, and acidification in the Arctic (AMAP, 2006)	In press.
2006 AMAP assessment: [oil and gas assessment]OGA	