

ARCTIC MONITORING AND ASSESSMENT PROGRAMME (AMAP); Strategy and results with focus on the human health assessment under the second phase of AMAP, 1998-2003

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In 1991, Ministers of the eight Arctic countries (Canada, Denmark, Iceland, Finland, Norway, Russia, Sweden and USA), adopted the Arctic Environmental Protection Strategy (AEPS). To implement part of this strategy, the Arctic Monitoring and Assessment Programme (AMAP) was established and requested by Ministers to “*examine levels of anthropogenic pollutants...from any sources...and to assess their effects in all relevant compartments of the Arctic environment*”. In 1996 the AEPS, including all its working groups, was reorganized under the newly formed Arctic Council.

THE MONITORING PROGRAMME

Between 1990 and 1992, experts from the eight Arctic countries designed the first detailed AMAP monitoring programme (1). Representatives from Arctic Indigenous Peoples organizations, (the Nordic Saami Council, Inuit Circumpolar Conference (ICC) and Russian Association of Indigenous Peoples of the North (RAIPON), were also involved in this work. The programme was specified in five sub-programmes, designed to follow contaminants from their sources, via transport pathways into all compartments of the Arctic environment and its ecosystems, and ultimately into top predators including humans, see Table 1.

Because the periods of foetal development and development in children during the early years of life are those associated with the greatest vulnerability to toxic substances, contaminant intakes by pregnant women and children are of great concern. In this context, the programme identified newborn and infants as a critical group for possible human health effects of contaminants, and analyses of both maternal and cord blood were included in the human health monitoring programme (Table 2) to document the exposure of the foetus during pregnancy. By taking samples from both indigenous

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peoples and the non-indigenous northern populations it would be possible to see if there were differences in their exposure to contaminants, and whether such differences could be traced back to lifestyle and/or diet. As a major contribution to the work to ensure comparable data on contaminants in humans around the circumpolar Arctic, a Canadian laboratory at the Institute Nationale de Santé Publique du Québec offered to analyse 50 human blood samples from each of the eight Arctic countries. These samples were analysed for levels of POPs, such as DDTs, PCBs, chlordanes, etc., and by the time that the first AMAP assessment reports were published (2,3), all Arctic countries except the USA had joined in this part of the human health programme. Other contaminants in human blood and placenta samples, such as mercury, lead and cadmium, and radionuclides, were analysed by national laboratories and reported to the human health assessment group.

A key feature of the implementation of AMAP is that the programme can be initiated in a step-by-step manner. This gave the eight Arctic countries the freedom to adapt or develop their national programmes based on AMAP's recommendations, and adjust them according to their own priorities and financial and scientific possibilities. As a part of its general strategy, the AMAP programme builds on

Table 1.
Part of the original AMAP monitoring programme for persistent organic pollutants (POPs).

Sub-Programme	Media	Persistent Organics								
		Planar CB	PCB	DDT DDE DDD	HCH	HCB	Chlor-dane	Toxa-phene	Dioxins Furans	Mirex
Atmospheric	air	-	E	E	E	R	E	E	R	R
Terrestrial	soil	ES	ES	ES	ES	ES	ES	ES	E	ES
	mammals	ES	ES	ES	ES	ES	ES	ES	ES	ES
Freshwater	sediment	R	E	E	E	E	E	R	R	R
	water	R	ES	ES	ES	ES	ES	ES	R	R
	biota	R	E	E	E	E	E	E	R	R
Marine	sediment	R	E	E	E	E	R	R	R	-
	biota	R	E	E	E	E	R	R	R	-
Human	blood	E	E	E	-	E	E	-	E	E

E-essential, ES-essential in sub regions, R- recommended

Table 2.
Part of the original AMAP monitoring programme for human health.

Media	Priority
Human blood, tissue and placenta	E
Human hair, urine and breast milk	R
E-essential, R-recommended	

ongoing (national and international) research and monitoring activities. Thus, from the outset, AMAP recognized that research (in addition to national monitoring work) would provide much of the relevant information necessary for assessing levels of contaminants and their effects in the Arctic, a region where logistical constraints impose major limitations on routine monitoring activities. In many other regional monitoring programmes, research is largely ignored. In order to address quality assurance issues, AMAP insisted all participating laboratories join appropriate international QA/QC programmes and, where relevant, adopt existing international recommendations for methodology and parameters to be analysed. By doing this AMAP was able to compare the levels of contaminants observed in the Arctic with levels published from other monitoring and research programmes being conducted at lower latitudes.

At the beginning of the 1990s, few international monitoring and assessment programmes included more than one ecological system, e.g. the marine or terrestrial environment, and possibilities to follow contaminants from their sources through the environment to their ultimate fate, was very limited. AMAP was thus one of the first international monitoring programmes to design and implement a monitoring programme covering all major ecological systems (atmospheric, marine, freshwater and terrestrial - and humans), and all major contaminant groups in one programme, and at the same time fully integrating its monitoring and assessment activities (4).

SOME RESULTS FROM THE AMAP ASSESSMENT IN 1997

The main conclusions of the first AMAP assessment are summed up in the statement that:

“in comparison with most other areas of the world, the Arctic remains a relatively clean environment. However, for some pollutants, combinations of different factors give rise to concern in certain ecosystems and for some human populations. These circumstances sometimes occur on a local scale, but in some cases may be regional or circumpolar in extent.” (2).

The following text illustrates this situation and gives a short overview of the status with respect to sources of pollutants and their transport, levels and effects on Arctic ecosystems and humans as revealed by AMAP in 1997.

The major concern for the Arctic environment with respect to pollution comes from several groups of contaminants. Certain POPs, radionuclides, heavy metals, acidifying components and petroleum hydrocarbons are threatening different parts of the Arctic environment. Some of these are of circumpolar concern, while others are of regional and local character.

PERSISTENT ORGANIC POLLUTANTS (POPs)

POPs reaching the Arctic environment include pesticides, such as HCHs (including lindane), toxaphene, and DDT and its metabolites, mainly used in agricultural activities and practices. They also include industrial chemicals and by-products, such as PCBs, HCB, and anthropogenic and natural combustion products, e.g., dioxins/furans and polycyclic aromatic hydrocarbons (PAHs). Major sources of these chemicals are located at mid- and southern latitudes, both in Europe, North America and Asia. However, some sources also exist within the Arctic, mainly linked to military and industrial activities (e.g. PCB) and pest control or sanitary activities (e.g. DDT).

Although production and/or use of several of these substances has been banned or controlled in many countries, they are still produced and/or used in some countries, including industrialized countries, developing countries and countries with a transition economy (e.g. countries of the former Soviet Union).

POPs reach the Arctic mainly via atmospheric (Figure 1) and riverine pathways (Figure 2). In the atmosphere, there is evidence that volatile POPs travel in a series of 'hops', depositing from the atmosphere under cold conditions and then re-volatilizing when temperatures increase. The Polar regions form potential cold traps for these compounds.

Many POPs are lipophilic and after reaching the Arctic they enter the food webs. Fat and blubber are important energy reserves and insulating media for many Arctic animals, and POPs concentrate in these lipid rich deposits. A number of POPs can biomagnify in food chains, particularly marine food chains, so that they reach very high concentrations in top predators, including man.

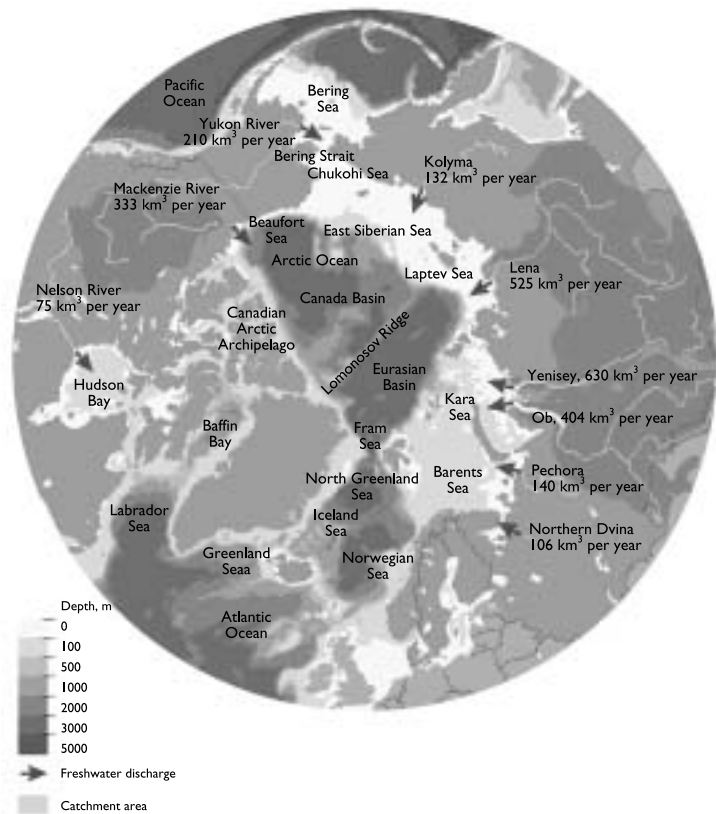
Studies in Canada and Greenland have shown that dietary intakes of POPs are generally higher in populations such as the Inuit living on Baffin Island or the west coast of Greenland who consume large amounts of marine mammals and fish. By comparison, the Sahtu Dene/Metis peoples who consume mainly caribou and freshwater fish have lower intakes. It is however vital to also remember that traditional foods contain many healthy nutrients that have substantial health benefits. They are important for both the spiritual and cultural well-being of Arctic indigenous peoples. Alternative foods are not always available, are invariably more expensive than traditional foods, and introduce new health consequences, such as increased risk of diabetes and heart disease.

It is possible to gauge the relative, but not absolute, risk associated with such dietary exposures by comparing estimated one-day intakes with currently held tolerable daily intakes. Baffin Inuit exhibit one-day intakes that exceed tolerable daily intakes (TDIs) for chlordane and toxaphene by nearly ten-fold. Exceedance of TDIs is of particular concern if an individual continues to exceed the limit for a significant period of their life. Existing TDI guidelines need to be im-



Figure 1. Atmospheric transport to the Arctic. Source AMAP 1997.

Figure 2.
River transport
to the Arctic.
Source AMAP 1997.



proved for Arctic residents based upon studies of interactions among individual contaminants present in Arctic foods, and between contaminants and nutrients.

RADIONUCLIDES

Radioactive contamination of the Arctic has occurred at two different scales:

a) widespread contamination due to three primary sources: global fallout from atmospheric nuclear weapons testing (1950-1980), releases from European nuclear reprocessing plants (especially Sellafield in the UK), and fallout following the Chernobyl accident in 1986.

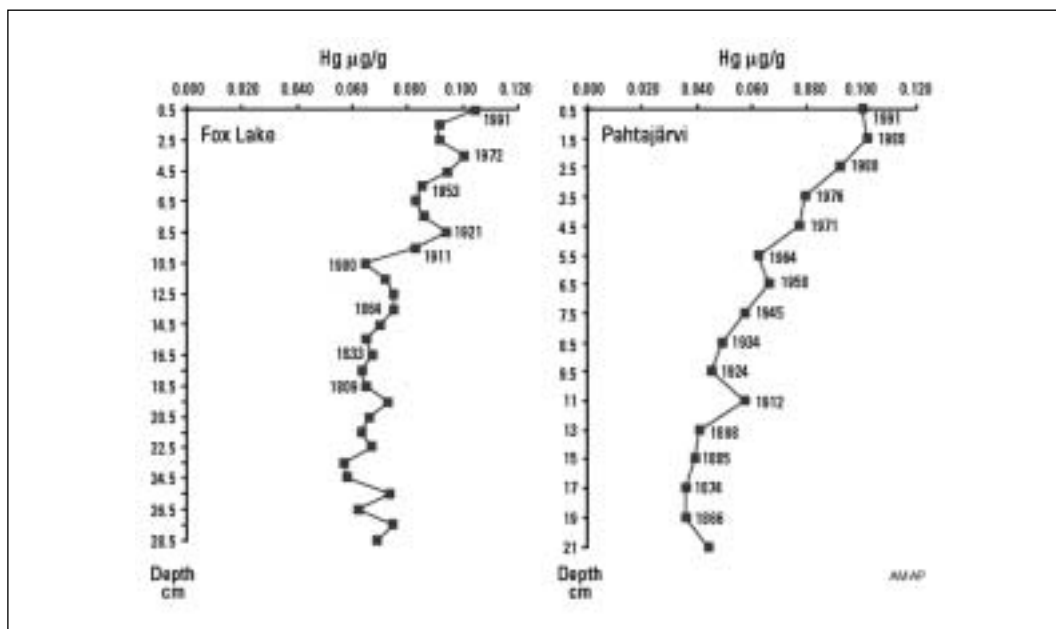
b) local contamination of smaller areas due to accidents (e.g., the crash of a B-52 bomber at Thule, Greenland in 1968), storage and dumping of nuclear waste, and the use of nuclear explosions (so-called PUNEs) for civilian purposes, such as river diversion projects in the former Soviet Union.

Within the Arctic, there is today an extremely high concentration of nuclear sources, both military and civilian. Military and civilian nuclear-powered vessels operate in the Arctic, nuclear weapons are located there, the Arctic is home to stored spent nuclear fuel, solid nuclear waste (e.g., from decommissioned nuclear submarines), liquid radioactive waste, nuclear power plants, etc. This situation, compounded by the fact that many of these sources do not have a satisfactory level of technical and environmental control, gives a significant potential for releases and leakages into the environment, and consequently for human exposure.

Radionuclides accumulate in food chains, but with large variations between terrestrial, freshwater and marine systems. The accumulation of ¹³⁷Cs is normally highest in terrestrial animals, such as reindeer/caribou, and some terrestrial vegetation, followed by freshwater fish, with the lowest uptake in marine organisms (fish and marine mammals). This situation, the opposite to that for POPs, plays an important role for the exposure of humans to radionuclides.

Reindeer/Caribou meat is an essential food source for northern peoples and this provides part of the explanation for the high intake of caesium by some Arctic inhabitants. For the Arctic population in general, transfer of radionuclides is five times higher than in temper-

Figure 3.
Mercury levels in
Arctic lake sediments.
Source AMAP 1997.



ate areas, while for special groups consuming large quantities of reindeer meat the transfer is more than 100 times higher. The levels of radionuclides within the Arctic area have decreased over the last decades. The highest whole body burdens of ^{137}Cs were up to 50.000 Bq/kg in the late 1960s.

The Arctic is thus more vulnerable to radioactive contamination than temperate areas. The AMAP assessment included calculations of the transfer of radionuclides in the food chain and estimates of the average dose to the members of selected groups in the Arctic, as well as the collective dose to the Arctic population as a whole. This calculation shows that the dose from weapons testing fallout will contribute to about 750 additional cases of fatal cancer in the Arctic as a whole.

HEAVY METALS

Heavy metal contamination of the Arctic comes from both natural and anthropogenic sources, the latter including both local sources and sources far distant from the Arctic. Industrial sources in Eurasia and North America account for more than half of the air pollution measured in the Arctic, with maximum input in winter. The nickel smelters on the Kola Peninsula and at Norilsk are major sources for atmospheric, terrestrial and freshwater pollution within their regions and these two sites account for two-thirds of some heavy metals in High Arctic air. In addition, mining activities are contaminating or have contaminated local areas and river drainage systems, e.g. in Russia, Greenland and Canada.

A circumpolar problem seems to be linked to mercury. Gaseous mercury has a long residence time in the atmosphere, which allows it to be transported to the Arctic from sources around the globe. Mercury levels have increased over much of the Arctic during the past hundred years, see Fig. 3. The major source of anthropogenic emissions of mercury is coal combustion, in particular in coal-fired power plants. It has been estimated that in China, 75% of the total energy production comes from approximately 60,000 coal-fired power plants. Waste incineration is a major source of anthropogenic mercury emissions that are not well documented. Mercury emissions from Europe and North America have declined over the past 20 years. However, these decreases appear to be offset by increased emissions from Asia. Mercury accumulates in biota and reaches humans through the diet, in particular through consumption of marine mammals and fish.

Analyses of human hair and seal fur from Greenland today show 3 times higher levels of mercury than those found in hair from 500-year-old mummies and their seal skin clothing. This increase most probably reflects the increase in anthropogenic environmental contamination rather than a change in natural geological sources.

Anthropogenic emissions of other metals, such as cadmium, lead and zinc, also increased with industrialisation in Europe and North America. Emissions of lead in particular rose with its use as an additive in gasoline. Recent declines in anthropogenic emissions of these metals have been documented in Europe, in the case of lead, largely associated with the introduction of unleaded gasoline.

Recent new discoveries have revealed that the Arctic may act as a sink for part of the global pool of atmospheric mercury, due to a particular set of circumstances that occur at polar sunrise. As a result, it has been estimated that ca. 150-300 tonnes of mercury are deposited in the Arctic each year, compared with the previous estimates of ca. 80 tonnes per year. Mercury is deposited from the atmosphere in reactive forms, some of which is retained in snow and at snowmelt can enter aquatic systems. This runoff occurs during periods of high biological productivity in the Arctic and some of the mercury is taken up by aquatic organisms, into the marine and freshwater food webs (5).

In some areas, consumption of, in particular, marine mammals increases the intake of mercury by humans (6). The highest levels of mercury in maternal blood were found among those who eat large amounts of marine food, especially in Greenland and eastern Canada. The daily intake of mercury by some Inuit in Greenland and eastern Canada that have a traditional way of living, is eight times the TDI level set by the World Health Organization (WHO). However, these diets also provide important nutrients, and the high levels of selenium, also found in sea mammals and Inuit from Greenland and eastern Canada, may counteract the potential negative effect of mercury (2).

Table 3.

AMAP Human Health Effect Monitoring Programme

E – Essential; R – Recommended

The AMAP Human Health Effect Monitoring Programme is designed to examine the effects on reproduction and development of dietary exposure to POPs and heavy metal within the Arctic. One requirement is that a suite of studies are carried out in parallel, including dietary questionnaires and indicators, and contaminant measurements carried out by laboratories with documented QA/QC.

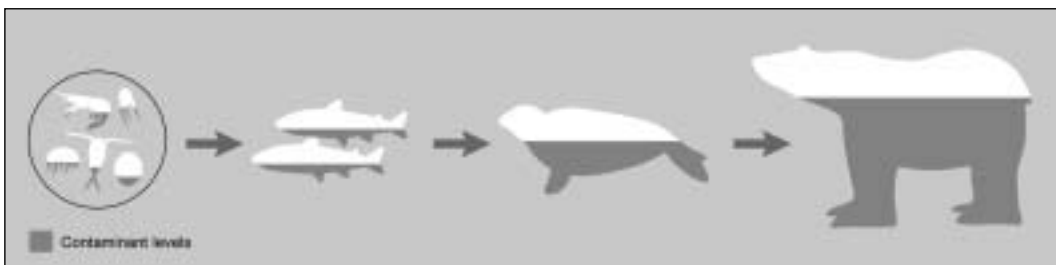
Bio-Physical Indicators		Epidemiological Effect Markers		Molecular/Genetic Effect Markers
Health Statistics	E R	Morbidity/Mortality data Cancer incidence		
Genetic susceptibility studies	R		R	Gene polymorphisms Gene expression (mRNA)
Fertility studies	R		R	Receptor/hormone toxicology, measurements performed in steroid hormone cleared blood samples
Time to pregnancy (TTP)	R	Time or number of menstrual cycles it takes a couple to conceive from discontinuation of contraception	R	Estrogenic-, androgenic- and dioxin-like activities and in vitro hormone receptor bindings
Semen quality and quantity	R	Sperm count/volume Sperm quality/mobility		
Sex hormones (in blood from male partners providing semen samples and their spouses)	R		R	FSH, Inhibin-B, LH, testosterone, estradiol, sex hormone binding globulin, osteocalcin, pyridolins
Pregnancy outcome				
General indices	E	Abortion (spontaneous) Gestational age Birth weight/length Sex (single/multiple) Placenta weight	R	Estrogenic-, androgenic- and dioxin-like activities Cytochrome P450 modulations, DNA adducts
Developmental anomalies	R	Maldescent testis Hypospadias Epispadias Ano-genital distance and other indices		
Developmental effects	R	Breast milk (POPs, fatty acids)		
Immunological effects	R	Hospitalization Vaccination response	R R	Antibody (HIB), Vitamin A and Cytokines, Complement system Dioxin-like activities
Neurological effects	R R	Milestones + age Pre-school tests: neurophysiological tests neuropsychological tests audiogram and visual tests	R R	Thyroid hormone Estrogenic-, androgenic- and dioxin-like activities GSHRd, GSHPx, Ubiquinol 10/Ubiquinone 10, Ox-LDL, F2-isoprostanes

BIOMAGNIFICATION

Due to the processes of bioaccumulation and biomagnification, POPs can reach very high concentrations in top predators in the Arctic, even when levels in air, soil and water are generally low (Figure 4). The same is true for mercury, which is semi-volatile and behaves in the environment in a manner similar to many POPs. Biomagnification is a process that occurs in food chains where animals consume other animals for food, but at the same time consume all the contaminants that their prey have accumulated. Since many POPs are not broken down or excreted, concentrations increase with each step from prey to predator. Biomagnification of POPs is particularly strong in Arctic marine food chains leading to high levels of POPs in top predators such as seals and polar bears, and ultimately man. The role of fat reserves in allowing many Arctic animals to survive the cold climate, and its importance in the diet of top predators including humans, further promotes the biomagnification of lipid-soluble POPs.

Studies have shown that POPs can affect the immune system and lead to developmental, behavioural and reproductive effects in a number of species including birds, fish and mammals. Current levels of POPs found in some species in some areas are approaching or even exceeding thresholds associated with these types of effects. The concern for Arctic ecosystems is that effects at the individual level may ultimately lead to effects at the population or community level. Temporal trend data show that levels of some POPs in the Arctic environment are decreasing, but only very slowly. Other data show levels of, for example, mercury to be increasing in some areas. In many cases it is not possible to see a trend from the sparse data available, even though uses have been restricted for some time.

Figure 4.
Biomagnification.
Source Canadian Northern
Contaminant programme.



THE AMAP HUMAN HEALTH PROGRAMME FOR THE PERIOD 1998-2003

At the fourth AEPS ministerial meeting in Alta, Norway in June 1997 the Ministers agreed that a special emphasis should be placed on human health impacts, and in particular on the effects of multiple stressors.

In order to address the updated requests from Ministers, the AMAP Human Health Expert Group (HHEG) reviewed and revised the original human health monitoring sub-programme that was implemented under the first phases of AMAP (1993 – 1997).

As a result, an expanded core-programme of human health (contaminants) monitoring activities to address temporal- and spatial-trend detection for the second phase of AMAP was developed and agreed upon at an HHEG meeting in Reykjavik in September 1998. A new component for human health (effects) monitoring was also discussed and finally agreed at the HHEG meeting in Rovaniemi in January 2000, Table 3. The updated phase 2 AMAP Trends and Effects Programme was approved by the AMAP Working Group (7).

The updated AMAP human health sub-programme focuses on exposure and the effects of different contaminants, individually or in combination. In this context, the relevance of human exposure to new xenobiotics being identified in the Arctic environment is emphasized. The activities in the AMAP human health group have, during phase 2 of AMAP, concentrated on two activities according to the mandate given: 1) continued monitoring of contaminants in human media from Arctic populations and 2) studies on combined effects of environmental stressors.

MAJOR ACHIEVEMENTS DURING PHASE 2 OF AMAP

The human blood monitoring activities have been extended to be almost circumpolar in coverage and a considerable amount of new data on human exposure levels has been obtained, which has created a better basis for assessment of exposure levels, also on a regional basis.

At the same time, dietary surveys have been carried out to provide more detailed information on dietary habits, which, in combination with better data on contaminant concentrations in food items, has improved the possibilities to make realistic estimates of dietary exposure to contaminants for a number of (indigenous and non-indigenous) population groups.

The second major achievement has been the development and introduction in several areas of a human health effects programme. The effects programme (Table 3) is not yet implemented in all key sampling areas (Figure 5), but hopefully this process will continue and be expanded in the coming years.

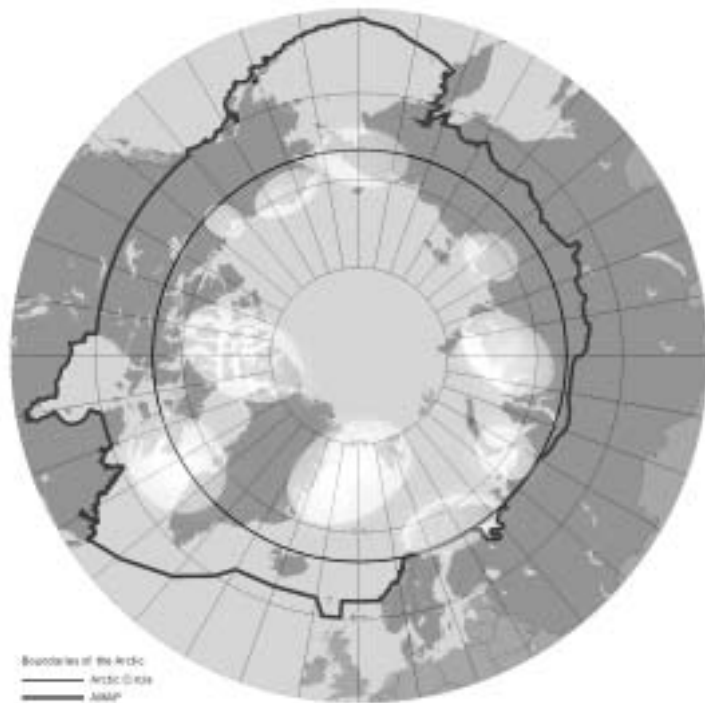
A third achievement has been the establishment of an analytical quality and control group to advise the HHEG. All laboratories producing data for the AMAP Human Health Assessment are required to participate in the intercalibration programmes run by this group.

RESULTS PRESENTED IN THE 2002 ARCTIC POLLUTION REPORT

Monitoring of exposure. Monitoring of POPs (14 PCBs, 11 pesticides) heavy metals (mercury, cadmium and lead) and the essential micro-nutrient selenium has continued. In addition, biochemical indicators of diet (plasma-fatty acids) and of smoking (plasma-cotinine) have also been measured in some areas.

The extended data sets obtained during phase 2 have confirmed the result from phase 1 that the main route of human exposure to

Figure 5.
AMAP Key monitoring areas.



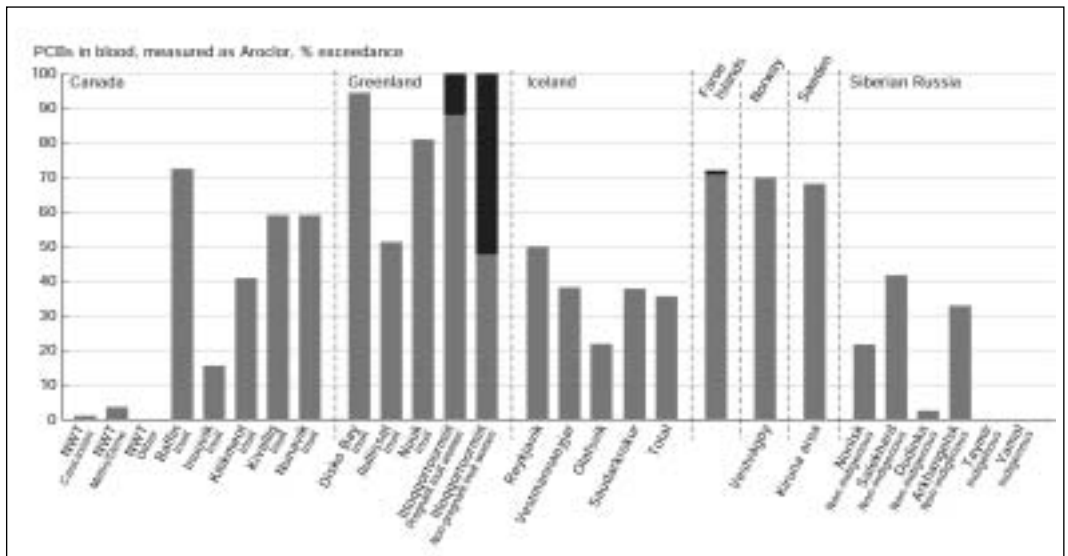
(many) contaminants is through the diet, and that consumption of traditional food is the main source of human exposure for many population groups in the Arctic. In several communities in certain areas of the Arctic, dietary intakes of PCBs, chlordanes, and mercury exceed established national and international guidelines (Fig 6 & 7).

So far it has not been possible to establish reliable time trends regarding POP levels in humans, largely due to the short period of observation.

Effects of exposure. Effects of exposure to contaminants can be studied either in epidemiological studies or by molecular biological studies. All effects observed in humans in both types of studies will be a result of the combined exposure to a variety of contaminants. The AMAP effect-monitoring programme for human health includes various levels of effects, ranging from health statistics to biomarker identification at the molecular level (Table 3).

In the Arctic only few epidemiological studies have been conducted. There is, however, evidence of subtle developmental effects in children following exposure to mercury (8) and PCBs (9) due to their neurotoxic effects. Methylmercury exposure has been linked to increased risk for development of cardiovascular disease (10). Also evidence of impaired immune-defence in children has recently appeared (11).

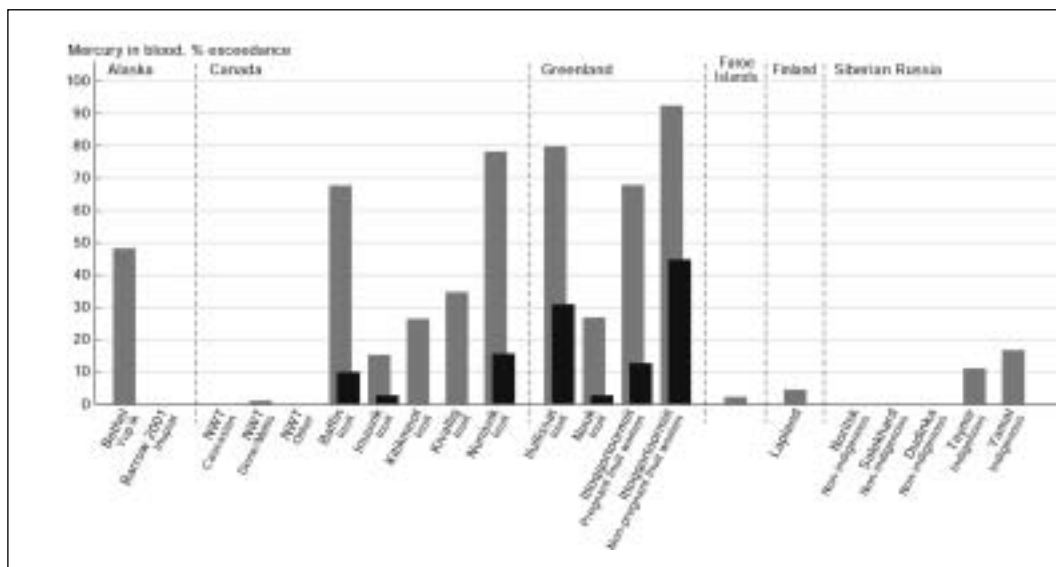
Figure 6. PCB in human blood compared to national guidelines. Dark shading indicates the percentage of samples greater than or equal to the 100 µg/litre (action level); light shading indicates the percentage of samples greater than 5 µg/litre and less than 100 µg/litre. Source AMAP 2002.



A new epidemiological study has been carried out in Greenland using cell cultures and molecular analyses. In the human serum samples, dioxin activities were measured and the serum extracts containing the accumulated POPs affected normal hormone processes. This biomarker of effects could be related to the concentration of certain PCB congeners and pesticides. Regarding the PCBs, the effects are related to specific congeners (12). As the active congeners often occur in relatively low concentrations the need to perform risk analysis on a congener specific basis is stressed. This is the first documentation of a hormone disrupting effect of the actual level and mixture of contaminants in a population in the Arctic. Based on experiences from wild life and laboratory animal studies these biomarker effect studies are of great concern. However, the consequences of observations in a human population should be viewed in the perspective of generations.

Figure 7. Mercury in human blood compared to national guidelines. Dark shading indicates the percentage of samples exceeding the Health Canada mercury guideline; light shading indicates the percentage of samples exceeding the US EPA 1999 mercury guideline. Source AMAP 2002.

Statistical analyses of data on contaminants in relation to lifestyle factors have revealed a connection between blood concentrations of organochlorine contaminants and smoking status. This clearly indicates that contaminant retention is not only a question of exposure, but is influenced by other factors such as life style.



The efforts to identify causal agents are complicated and confounded by new contaminants now being identified in the Arctic environment, but so far not included in the human monitoring programme.

THE TRADITIONAL DIET

In 1998, the health chapter of the AMAP Assessment Report (3) introduced the concept of the 'Arctic Dilemma' (i.e. vigorously supporting the consumption of traditional foods with their known nutritional benefits, while recognizing that these same foods are the primary source of environmental contaminants). Data in the new report strengthen this concept. The weight of evidence for harmful effects of POPs and some metals (in particular mercury) has been augmented through epidemiological investigation and biomarker studies. Yet knowledge of the nutritional value of traditional foods and the linkages they have to social, cultural, and spiritual integrity are also enhanced. Overall, the evidence is still compelling that traditional food is more nutritious than market food, reduces risk factors for several disease conditions such as heart disease, obesity, and diabetes, and can bind communities together in ways that market food does not. It is also clear that in some areas of the Arctic there is a need for some groups, such as women who are fertile or pregnant, to substitute their intake of the most contaminated food items with less contaminated but similarly nutritious items in order to minimize the risks for their babies. The AMAP HHEG affirms that despite the presence of contaminants in some marine animals and human milk, consumption of traditional food is highly recommended to be continued and that breastfeeding is the best and safest form of infant nutrition, critical for proper development of the infant immune system, and should continue.

MAIN CONCLUSIONS

The conclusions from phase 1 of AMAP are in general found still to be valid. There is considerably more knowledge of the effects of environmental factors on the health of Arctic populations in general than existed five years ago when the last AMAP Assessment Report (3) was published.

During AMAP phase 2 evidence has appeared to show that subtle effects at a sub-clinical level are present in some highly exposed Arctic populations (5). Consequently the current human exposure to

the existing level and mixture of contaminants influence the health of humans in a negative way. In consideration of the potential effects on future generations, efforts to reduce the entry of persistent substances into the Arctic ecosystems should be accelerated. The process initiated through AMAP phase 1 and 2 should be continued and expanded to involve all relevant disciplines with the goal of pursuing a more holistic assessment of the health of Arctic Peoples.

FUTURE DEVELOPMENTS

The Arctic region and its peoples are extremely sensitive to global environmental pollution. The levels of POPs in Arctic peoples and their traditional food supply vary considerably throughout the circumpolar region and there remains a need for local risk reduction strategies in some regions of the Arctic where current levels of POPs are above levels of concern. In general, it has been most effective for local public health authorities working in concert with the community at risk and experts from a variety of disciplines to develop risk reduction strategies that address the risks and benefits components of each specific concern. However, the global nature of persistent organic pollutants and metals, and their capacity to travel from the mid-latitudes to the poles also requires international, regional and national risk management approaches to control their manufacture, use, transportation, storage and disposal.

During the past five years, three major international agreements have been concluded aimed at reducing emissions of substances that have contaminated the Arctic, and in some cases pose a threat to the health of Arctic residents. The first two were the Protocols on POPs and Heavy Metals to the UN ECE Convention on Long-range Transboundary Air Pollution. A more recent one is the global Stockholm Convention on POPs. The evidence of pollution in the Arctic, and in particular the threats posed to Arctic indigenous peoples through dietary exposure to chemicals not used in the Arctic provided compelling justification that was effectively used during the negotiation of these agreements. However, these agreements will only come into force when they have been ratified by enough countries. This ratification process is vital if Arctic populations are to see a decrease in levels in their foods of some of the contaminants of most concern.

As a part of the Stockholm Convention agreements, additional monitoring may be required to document the effectiveness of the Convention and to confirm whether countries take the measures that they have agreed to. A global long-term monitoring network for POPs covered by the convention is one component, a monitoring programme including POPs not (yet) covered by the Convention is another. Since the Arctic seems to act as a sink for a number of POPs, the Arctic component of such a monitoring network will be important. The existing AMAP programme and its network of stations (atmospheric, freshwater, marine and terrestrial, and for human health) means that AMAP would be able to contribute to these new goals, and AMAP has already been invited to participate in discussion on follow-up monitoring linked to the Stockholm Convention.

AMAP may have an important role, not only in providing the information that can lead to the recognition of contaminant problems and the justification for actions, but also in the follow-up to these actions. It should be remembered that the international agreements made so far achieve nothing unless they are fully effectively implemented.

Mercury is increasing in part of the Arctic, new POPs (e.g. brominated products) have been observed in part of the Arctic, climate change and variability will mean that past information may no longer apply in the future. There are many new challenges for the human health sub-programme of AMAP and the Arctic cooperation, and the active involvement of the Arctic indigenous peoples is vital in addressing these challenges.

POSSIBLE SCENARIO

Based on current global trends and activities to manage risks, there are likely to be minor decreases in POPs in Arctic populations in Greenland, the Faeroe Islands, eastern Russia, western Alaska, and eastern Canada by 2010 and minor increases in mercury levels in Greenland and eastern Canada. There are likely to be major decreases in both POPs and mercury levels in these same populations by 2030. Levels of most POPs and metals in populations in Iceland, Norway, Sweden, Finland and the rest of Russia are already reasonably low and are only likely to decline marginally by 2030. These predictions will be heavily influenced by prompt ratification and implementation of the Stockholm Convention and other multinational environmental agreements.

Within the limitations imposed by the (understandably) inadequate information base and still significant gaps in knowledge, the phase 2 AMAP report on human health summarizes the present state of knowledge in the field of environmental medicine in the Arctic. Hopefully it will constitute a further step towards a better understanding of the relationship and linkages between health and environment in the Arctic, and provide an improved background/baseline for further information gathering. The key objective of the AMAP human health assessment is improved health status among Arctic peoples.

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