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Key recommendations and research priorities of the 2021 AMAP human health assessment

Cheryl Khoury[a] and Pál Weihe[b]

[a]Environmental Health Science and Research Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Canada; [b]Department of Occupational Medicine and Public Health, The Faroese Hospital System, Tórshavn, Faroe Islands

ABSTRACT
Over the last three decades, the Arctic Monitoring and Assessment Programme has published five human health assessments. These assessments have summarised the current state of the science regarding environmental contaminants and human health in the Arctic. The 2021 Human Health Assessment Report had a particular focus on dietary transitions, in addition to human biomonitoring levels and trends, health effects, risk assessment methodologies, risk communication and multi-disciplinary approaches to contaminants research. The recommendations and research priorities identified in the latest assessment are summarised here to assist decision- and policy-makers in understanding and addressing the impacts of contaminants on human populations in the Arctic.

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Introduction

The Arctic Monitoring Assessment Programme (AMAP) was established in 1991 as a Working Group of the Arctic Council. It is mandated to document, monitor and assess pollution and climate change issues and trends in the Arctic and to produce sound evidence-based assessments for use by policy- and decision-makers. Human Health Assessment reports summarise contaminant exposures and health effects associated with these exposures, in addition to risk assessment methodologies, risk communication activities and multi-disciplinary approaches to contaminants research in Arctic populations.

Diet is a primary source of human exposure to contaminants in the Arctic. This is the result of long-range transport of these pollutants by air and water currents from other parts of the world to northern latitudes. Once contaminants reach the Arctic many can persist and bioaccumulate in the food chain. Consumption of marine species and wildlife can contribute to higher levels of contaminants in humans. Contextualising the adverse effects of exposure to these contaminants is complicated by the fact that dietary sources of contaminants also have nutritional, spiritual and cultural importance. This is referred to as the Arctic Dilemma.

The terms “traditional food”, “country food”, “traditional country food”, “subsistence foods” and “local foods” are used to describe food such as hunted animals and plants gathered from the land. These terms may be interchangeable in some regions, but have distinct meanings in others. Even within regions, different definitions may be preferred by different groups. AMAP [1] uses all of theses phrases depending on the context of the results being described.

The 2021 Arctic Monitoring and Assessment Programme (AMAP) Human Health Assessment follows four previous assessments [2–5]. It includes an update on the science regarding contaminants and human health with a focus on dietary transitions in the Arctic. Here, we summarise the recommendations of this assessment and priorities for research, in the context of the findings of all five AMAP assessments by describing the relationship of these conclusions to those from previous AMAP assessments.

Recommendations[1]

Building on the recommendations of previous assessments and new evidence, the 2021 AMAP Human Health Assessment report made four key

CONTACT Cheryl Khoury Cheryl.khoury@hc-sc.gc.ca Environmental Health Science and Research Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Canada

[1]AMAP: Arctic Monitoring and Assessment Programme; POPs: persistent organic pollutants; PFAS: per-/polyfluoroalkyl substances; PFOS: perfluorooctane sulphonate; PFOA: perfluorooctanoic acid; PFHxs: perfluorohexane sulphonate; SAMINOR study: The Population-based Study on Health and Living Conditions in Regions with Sami and Norwegian Populations; HALDI study: health and living conditions in Sápmi, Sweden; HHAG: Human Health Assessment Group

recommendations. These are presented in this section, with a high-level summary and supporting examples. The reader is referred to the full report [1] for complete details.

Reduce or eliminate contaminants at the source

- Arctic States and all parties to the Stockholm and Minamata Conventions should strengthen and accelerate measures to eliminate POPs and human-made mercury emissions globally.
- Arctic States should take steps to reduce or eliminate chemicals of emerging Arctic concern such as non-regulated PFAS through national policies and international agreements.

It is crucial that international efforts to regulate chemicals in the environment continue and that these regulations are implemented effectively. Given the global sources of much of the pollution that reaches the Arctic, international cooperation on chemicals management is important in reducing exposures to populations in the Arctic. This can be achieved by reducing and controlling regional industrial emissions [2,5], controlling production and use of POPs [3] and supporting international conventions [2–5]. Global assessments of health and the environment can highlight linkages between health and the environment to support international regulatory efforts [3].

Previous recommendations aimed to strengthen international chemicals management. These included recommending that polybrominated compounds and fluorinated compounds be added to the Stockholm Convention and included in future routine monitoring [4]; recommending that a global agreement on mercury be established [4]; and recommending a precautionary approach to the chemicals management of contaminants of emerging concern [5]. As reported succinctly in AMAP [5], risk communication is not the solution to the contaminant crisis and continued chemicals risk management efforts at the international level are required to reduce levels of contaminants in the Arctic.

The value of monitoring programmes in documenting trends can be seen in the ways data from these programmes have been used as evidence for the need to establish and adopt global conventions (e.g. Stockholm Convention, Minamata Convention). There are now limits in place on more than 30 POPs under the Stockholm Convention. Since 2009, new POPs have been added including some perfluorinated compounds, such as PFOS and PFOA. Data suggesting increasing trends of some PFAS such as PFNA (Lemire and Blanchette pers comm 2019, as reported in AMAP [1]; [6]) may support further regulatory efforts of this class of chemicals. Evidence of the effects of mercury on humans and the environment in the Arctic played a significant role in the development of the Minamata Convention [7]. The time trends established through on-going work provide evidence of the need for, and evaluation of, international chemicals management, which is the only true solution to reducing exposure to contaminants in Arctic populations.

The collection of evidence for the reduction of contaminants and effectiveness evaluation of international conventions benefits from harmonised approaches. These can encourage high-quality data and comparability of results. The need to develop uniform methods to allow for comparisons of studies across the Arctic was identified in 1998 and confirmed in subsequent assessments [2–5]. Standard laboratory practices are not the only uniform methods required. One mechanism for achieving harmonised results is through the use of existing biobanks. The creation and management of tissue/specimen banks was promoted in early AMAP assessments [2,3]. In future studies, samples from multiple biobanks may be analysed using the same, or complimentary, methods to produce comparable human biomonitoring data across regions. Harmonised results may also be encouraged through the reporting of health outcomes using uniform indicators and similar reporting structures to help understand trends and make meaningful comparisons [4]. In 2015, it was recommended that guidance on harmonised study designs, statistical methodologies and reporting of results would make it possible to carry out strong meta-analyses and enhance the ability to compare results across all regions [5].

The use of harmonised approaches has been highlighted in the 2021 Assessment. While the establishment and maintenance of biobanks are huge undertakings, projects in many regions have biobanked samples. A successful example of the use of biobanks is the MercuNorth project, which relied on biobanks from several regions to establish baseline levels of mercury in Arctic populations [8]. Results provide evidence for the value of these long-term investments, as samples from pregnant women recruited from across the circumpolar Arctic into different studies were analysed by laboratories to provide comparable baseline levels of mercury in advance of ratification of the Minamata Convention. Participation by analytical laboratories in external quality assurance and control schemes provides confidence that comparisons between laboratories are valid and data are of a high quality. As contaminants of emerging Arctic concern are identified and included in monitoring programmes, the importance of harmonisation is even greater to ensure that emerging methodologies and new data are comparable.

Promote healthy food choices by promoting foods low in contaminants

- To get the best out of country, local and traditional foods and store-bought Western diets, governments can, for example, promote consumption of foods low in contaminants. Effective communication can increase the use of healthy country, local and traditional foods (e.g. fish and terrestrial animals such as reindeer/caribou, musk ox, and sheep) and reduce intake of foods that are likely to have high levels of contaminants or that are otherwise unhealthy.
- Vitamin D and iodine levels should be monitored in Arctic populations and the need for supplements and fortification should be evaluated.

Risk communication messaging should promote the nutritional value of foods while providing information on the risk of contaminants. Risk communication has always been identified as a necessary but challenging area. Early recommendations were to enhance the development of local information and advice for Indigenous peoples [2,3]. These recommendations were followed by further advice that regional health authorities should collaborate with communities to develop effective, culturally appropriate strategies to enhance messaging about the benefits of country foods, in addition to promoting the benefits of breast feeding and providing balanced advice that includes the benefits of country foods with the risks concerning contaminants [4,5]. In 2009, it was recommended that communication efforts should be evaluated with respect to their impact on the intended audience [4]. Since the first assessments, the need for relevant and up-to-date guidance values has been noted that would help to interpret and, in turn, communicate risk-benefits [2,3].

There are several examples in the 2021 Assessment Report that provide evidence that work is being done in these areas to improve risk communication messaging. For example, consumption guidance has been published for various food items, such as fish [9,10]; [11–13] and pilot whale [14]. There are also examples of messaging co-developed with communities (e.g. [15]) and evaluation studies that can help to inform future messaging (e.g. [16]) [17,18]). Some groups have worked to make meaningful data accessible to the appropriate audience, while attempting to minimise misuse of information (e.g. Local Environmental Observer LEO network) [19]. Positive research findings have been incorporated into messaging (e.g. advice given in Greenland that include information about the nutritional qualities of fish that are low in contaminants) [20]. However, trusted relationships are crucial to the success of communication. This trust is difficult to build and very easily damaged or destroyed. While risk communication is key to educating and empowering communities to make the best food choices, experience has shown that this is a very complex undertaking and is not a sustainable solution to ensure low levels of contaminant exposures in human populations. It is therefore crucial that regulations to lower contaminants in the environment are implemented effectively.

Studies of the interactions between nutrients and contaminants will help to provide balanced advice on reducing risks from contaminants with the nutritional benefits of country, local and traditional foods, and imported foods. In the second AMAP assessment it was recommended that studies on the nutrient content of traditional food items should be promoted [3]. Promoting improved access to country foods that have lower levels of contaminants and higher levels of nutrients was recommended [4], as well as the importance of studying the interactions between different contaminants and between contaminants and nutrients [4,5]. It was also noted that more research was needed on determinants of food choice and availability, including age and gender differences to inform dietary advice. Studies that include both biomonitoring and total diet components were highlighted as necessary to better characterise exposure estimates and provide dietary advice [4].

Dietary transitions across the circumpolar Arctic are described in AMAP [1]. In some areas, the dietary transition is well documented, such as in Greenland [13,21,22], the Faroe Islands [23–25], Iceland [26,27], Norway [28–30] and Sweden [31]. However, information is lacking in other areas, including Russia and the Sápmi area, the traditional homeland area of the Saami people.

In general, there has been a change towards more imported or store-bought foods. However, country food consumption has been consistent over the past 25 years in some areas (e.g. fish and terrestrial foods consumption in Northwest Territories, Canada) [18] and fish consumption in Chukotka, Russia ([32,33]). Whether positive effects (e.g. decline in mercury levels; increases in dietary fibre or decreases in trans fatty acid intake) [27,34,35]; or negative effects (e.g. increases in obesity and diabetes) [36–40]; are observed depends on which food components are adopted from a new diet and to what extent components of the local diet are changed and/or continue to be consumed. Documented declines in nutrients differ substantially by country. Reduced country food consumption has been linked to declines in Vitamin D [41], omega-3 fatty acids [34] and iodine [42] The links between country foods and nutrients is supported by the finding that vitamin D levels were higher in Russian ethnic groups with a more traditional lifestyle [43]. Understanding dietary transitions helps inform advice on the risk-benefits of country, local and traditional foods.

Initiatives to increase awareness of the benefits of country foods, the best kinds of country foods to consume (low in contaminants, high in nutrients), the development of programmes to increase access to foods and education around food handling and preparation have been undertaken in Canada and Greenland [44,45]. Efforts to improve vitamin D levels have been made through supplementation of dairy products and margarine and use of cod liver oil [46,47]. Finland has also addressed iodine levels through fortification of cow fodder and table salt [48]. Results from on-going studies and analyses in different regions will provide additional information on diet and health for Indigenous Peoples in the Arctic [49,50,51].

Monitor and address food insecurity in Arctic communities

- Food insecurity is a growing problem in some Arctic Indigenous populations as diets transition toward expensive store-bought food and environmental factors such as climate change affect the availability of country, local and traditional foods. Governments and non-governmental organizations should take an active role in monitoring food insecurity in Arctic communities and collaboratively develop proactive approaches to address it, building on and learning from existing best practices and models.

The impact of contaminants on the health of human populations in the Arctic is influenced by food availability. Food security can be defined as physical and economic access to sufficient, safe and nutritious food that meets the dietary needs and food preferences for an active and health life [52]. Food insecurity can be described as poor food security. While AMAP has a role in documenting trends and issues related to contaminants, a discussion of contaminants cannot disregard food insecurity and how it intersects with exposure to, and health effects associated with, contaminants, as well as how risks are assessed, communicated and contextualized. The 2021 AMAP assessment makes clear that food security continues to be a high priority for many Arctic populations. [53–56]

Expand efforts to collect data on exposure, dietary transitions, and health impacts

- Arctic States and research funding bodies should work to fill information gaps, such as the need for more data on lifelong human health impacts in the Arctic related to exposure to contaminants, dietary transitions, and nutrition. There are also geographical gaps in Arctic data on contaminant levels and trends in humans: the need to expand monitoring and research is especially evident in Russia, where only a few dietary studies have evaluated Arctic Indigenous populations.
- Research should continue to focus on the effects of contaminants on pregnant women and women of childbearing age whose diets involve significant consumption of marine mammals. New, collaborative studies are required to study levels of chemicals of emerging Arctic concern, routes of exposure, health effects, lifestyle implications, and interactions with influences outside the field of contaminants for these specific groups. There should be more focus on mixtures of POPs to which people are exposed and their effects on reproductive health and the immune system.

On-going cohort and biomonitoring programmes are needed to support time trends, follow populations with elevated levels of contaminants, study health effects and identify contaminants of emerging Arctic concern. The importance of establishing temporal trends in contaminant levels was identified in 1998 [2] and reiterated in each subsequent AMAP assessment [3–5]. Even as declines in many POPs were observed, high exposure levels and new contaminants in some regions warranted continued monitoring in Arctic populations [4,5].

Since 2015, biomonitoring studies have documented exposure to POPs and metals, as well as other contaminants, some of which were identified in the Chemicals of Emerging Arctic Concern report [57]. While there is a rich database for some contaminants, more data are needed for other contaminants to establish regiothere are still limitednal and temporal trends. For example, the 2021 Assessment presents more data on PFAS than previous reports, but there are still limited temporal PFAS data available and gaps across regions [6,58–74].

The importance of health studies, in particular cohort studies, was acknowledged in the first AMAP assessment [2]. The importance of establishing on-going studies in the Arctic to better understand health effects and risk associated with current levels of exposure in the Arctic was recommended in subsequent assessments [3–5]. Cohort studies not only provide a means to study contaminant-related effects on sensitive endpoints, but they can also be used to study the effects of changing conditions on these associations (e.g. climate change, dietary transitions). These studies are expensive, resource intensive and invaluable to the study of contaminants in the Arctic. Results reported in the 2021 Assessment included studies of endpoints identified as knowledge gaps in earlier assessments, including genetic variability and health outcomes associated with contaminant exposures [75–86] and the effects of contaminants and diet on the cardiovascular system [87–93]. Furthermore, health effects research also included the effects of contaminant exposure on the central nervous system [94–98]; immune system [70,99–106], reproductive system [61,65,107–122] as well as endocrine disruption [123–144] and cancer incidence [145–151].

Multidisciplinary efforts and cooperation between researchers and organisations with different mandates are required to address the complexities of contaminants research and to study contaminants within a holistic perspective. In 1998, multi-disciplinary cooperation was recommended to combine expertise from multiple disciplines such as biomarker research, epidemiology and monitoring programmes [2]. A recommendation of 2002 AMAP report [3] was to pursue a more holistic health impact assessment of the influences of environmental pollution on the health of Arctic peoples and the associated risk factors affecting them, coordinated with related public health work initiated through the AMAP Sustainable Development Working Group. Later, it was suggested that specific studies could support our understanding of genetic variability and susceptibility among Arctic populations, the toxicology of emerging substances (e.g. polybrominated compounds, perfluorinated compounds), the relationship between mercury and cardiovascular disease in Arctic populations, as well as research on climate change impacts on contaminants [4]. This was followed by a Climate Change and POPs assessment which included input from human health experts [152]. The need for climate-contaminant work was reiterated in the 2015 AMAP assessment [5] along with the need to understand contaminants in wildlife and the availability of country foods as a result of climate change.

The 2021 Assessment describes the need to recognise the interaction between contaminants and other stressors. In 2015 [5] results of the ArcRisk study (Arctic Health: Impacts on health in the Arctic and Europe owing to climate-induced changes in contaminant cycling 2009–14) were reported. These included that the impact of climate change on exposure risk will depend on the properties of any given contaminant and climate-mediated changes in food availability and resource exploitation may influence human exposure to contaminants more than direct climate mediated effects. The study authors also highlighted the need for more data to model and characterise sources and exposures to contaminants, as well as the need for epidemiological research that is accompanied by detailed reporting of results. More information on the outcomes of this project were presented in the 2021 Assessment [153,154]. With respect to dietary transitions, the influence of climate change will depend on the types of food being consumed. Dietary transitions away from traditional and local foods may overshadow other climate-mediated effects on human exposures to contaminants.

There is growing recognition of the usefulness of the One Health paradigm (e.g [155–157]). Greater uptake of this paradigm will improve the ability of residents, public health agencies, and wildlife resource managers to deal with existing environmental threats, and early recognition of emerging threats. Epidemiological zoonotic/human disease models are needed, as well as new approaches to integrate existing and future data. The models will enable estimates of the risk and magnitude of human and wildlife health impacts and changes in disease and contaminant exposure in response to different climate change scenarios. Trends in population migration from smaller to larger communities and urban centres may be accompanied by changes in exposure to contaminants and zoonotic diseases. Understanding contaminants in a holistic context will help to address interconnected environmental health risks.

Research priorities

Following from the key findings and knowledge gaps presented in the 2021 AMAP Assessment [1], priorities for future research were proposed. These are outlined in Table 1. Specific activities are grouped by the following themes: international cooperation on chemicals management, harmonised approaches, risk communication messaging, interactions between nutrients and contaminants, cohort studies and biomonitoring programmes, and multidisciplinary efforts and cooperations.

Table 1. Priorities for future research of the impact of contaminants on human populations in the Arctic.

Research Priority	Activities to address priority
International cooperation on chemicals management	• Advocate for reducing or eliminating contaminants at the source • Support the Stockholm and Minamata Conventions • Contribute to the identification of chemicals of concern to human health in the Arctic
Harmonized approaches	• Participation in QA/QC programs as a requirement of all labs submitting data to AMAP assessments • Guidance on harmonised study designs, statistical methodologies and results reporting, including harmonised methods for assessing dietary intake, food security, health outcomes, and northern food environments to enable comparisons that are more accurate across populations and over time and that consider season, gender- and age-based differences in consumption. • The creation and maintenance of biobanks for as many projects as is possible. • A systematic update on the general health status of Arctic inhabitants.
Risk communication messaging	• Balanced messaging that appropriately presents the risks and benefits of local, traditional and country foods. • Promote increased consumption of species low in contaminants to increase dietary consumption of nutrients. • Evaluation studies, including follow-up on policy recommendations to evaluate reception and awareness of the communication to ensure the success of the messages, and studies of the effectiveness of social media in risk communication. As well, the evaluation of the combinations of medium and messenger for a variety of health messages is important to improve understanding of optimal communication strategies for different communities. • Data on health communication and risk perception to compare results to those from other regions and across Arctic countries that would help identify best practices, including cultural appropriateness that could be used and adapted to specific regional and community needs. • Collaborative communication projects done with affected communities that take into consideration aspects such as social, economic, and cultural factors to ensure that they are culturally appropriate. • The development of tools (e.g. guidance values) and models to help reduce uncertainties in the estimates of health risks from exposure to contaminants.
Interactions between nutrients and contaminants	• Understanding modern dietary changes and reasons behind dietary choices. Dietary intakes should be continuously followed in Arctic populations, especially in Russia, where there is a lack of dietary studies. • Risk-benefit analyses to compare traditional foods with store-bought Western foods while considering health, economics, local contexts, cultural resilience, and sustainability. • Study of the effects of low nutrient levels on health status. • Studies of the influence of sex, age, socio-economic status and geographical location on dietary intakes and dietary transition patterns. • Promotion of knowledge of the healthiest local and country foods. • Studies of the interactions of chemicals and nutrients and the benefits and risks associated with country foods. • Monitoring of Vitamin D and iodine levels in Arctic populations, and consideration of the need for dietary enrichment. • Partnerships among academics and Arctic Indigenous communities and organisations conducting dietary research using an approach based on co-production of knowledge.
Cohort studies and and biomonitoring programs	• Regularly conducted biomonitoring studies (e.g. every 5 years) to obtain data to support time trends, with the inclusion of contaminants of emerging concern, particularly new PFAS. • Support for, and expansion, of the use of cohort studies, which are important for making links between exposures and health outcomes in Arctic populations. • Studies to identify the mechanisms through which exposure can lead to health impacts, to support the findings of epidemiological studies. • A continued focus on exposure and health effects studies of pregnant women and women of child-bearing age whose diets involve significant consumption of marine mammals. This should include identification of prenatal and postnatal windows of vulnerability – the periods in which the foetus and infant are most vulnerable to impacts from exposure. • Research on mixtures of POPs and their effects on reproductive health and cardiovascular outcomes and the immune system.
Multidisciplinary efforts and cooperation	• Collaborations with experts in zoonoses and climate change using a holistic approach like the One Health model. • Acknowledgement of the importance of Indigenous knowledge and equitable engagement of Indigenous Peoples. • An improved understanding of the health impacts of contaminants on wildlife, including possible immunosuppressive effects that could lead to increased active zoonotic infections in exposed wildlife and increased risk to human consumers. The warming Arctic climate and permafrost thaw may influence contaminant exposure as well as an increase in the spread of zoonotic infectious diseases in the Arctic. • Research on critical questions related to lifetime contaminant accumulation, lifetime exposure to zoonotic pathogens, and the health consequences to wildlife and human consumers. • Collaborative studies to investigate lifestyle implications (e.g. smoking), and interactions with influences (e.g. climate change) outside the field of contaminants. • Work to integrate research with other disciplines through support for other AMAP expert groups.

Conclusions

AMAP Human Health Assessment reports include comprehensive coverage of available data from across the Arctic. They include reporting on not just contaminant levels, but health effects, dietary transitions and the ways in which contaminants are assessed, communicated and placed in context of overall health and well-being.

Central to the 2021 Assessment was a review of dietary transitions. Many Arctic populations are experiencing a transition towards imported foods. While these transitions may lead to positive reductions in levels of contaminants, they can also have negative outcomes, such as reduced connection to the land, increased obesity, impaired dental status and declining vitamin D and iodine levels. Overall, contaminant levels are decreasing in many Arctic populations; however, these declines are not uniform or consistent across regions. Developing messaging around the risks and benefits of traditional, local and country foods is essential, but complex. Unfortunately, how risks of contaminant exposure are identified and assessed differs by jurisdiction, and studies of the interactions between nutrients and contaminants are needed to provide balanced advice on reducing risks from contaminants in food while maintaining the nutritional benefits of country, local and traditional foods and imported foods.

It is crucial that international efforts to regulate chemicals in the environment continue and that these regulations are implemented effectively. Use of harmonised approaches helps to support regulations by ensuring high-quality data and comparability of results. This is necessary during the collection and reporting of biomonitoring and health data.

There is growing awareness and use of multidisciplinary approaches such as the One Health paradigm, to address environmental health issues, including lifetime contaminant accumulation, lifetime exposure to zoonotic pathogens, and health consequences for wildlife and human consumers. For reasons that include dietary change, a warming Arctic may not greatly change contaminant exposure. Population migration towards urban centres and larger communities in the Arctic may be accompanied by changes in exposure to contaminants and zoonotic diseases. Future work may include links between contaminants, health and response to rapid changes, especially those that impact diet and food availability, such as zoonotic diseases, climate change and other stressors.

After review and assessment of the available evidence, four key recommendations were made in the 2021 Assessment Report. These are (1) reduce or eliminate contaminants at the source, (2) promote healthy food choices by promoting foods low in contaminants, (3) monitor and address food insecurity in Arctic communities, and, (4) expand efforts to collect data on exposure, dietary transitions, and health impacts. Regular assessments provide up-to-date, evidence-based recommendations for policy and decision makers. These recommendations are intended to assist in understanding and addressing the impact of contaminants on Arctic populations.

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