Ref. Ares(2025)3417100 - 28/04/2025

Deliverable 2.1.
1st One Health model

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ArcSolution

Arctic pollution in a One Health perspective
from complex challenges to sustainable solutions

Funded by
the European Union

This deliverable is a part of the ArcSolution project.

Deliverable number and info: 2.1. 1st One Health model.
Dissemination level: public

Funded by the European Union under the Horizon Europe
Program, Grant No. 101135051 — ArcSolution

www.arcsolution.eu

Title: Deliverable 2.1. 1st One Health model
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Internal reviewers: Christian Sonne and Trine Hvoslef-Eide
Publication date:
Page numbers: 25
Appendixes: 3

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Funded by the European Union

Executive summary

The Arctic is undergoing large disruptions. Multiple stressors such as climate change, and biodiversity loss in combination with infectious diseases and pollution from numerous sources, are affecting humans, wildlife and the environment in the Arctic. The ArcSolution project will provide comprehensive knowledge on these pressing challenges and will propose corresponding and accurate mitigating solutions for pollution, co-created with the people of the Arctic, all within a One Health framework.

ArcSolution project produces a new locally anchored and integrated One Health framework, which is based on different knowledge sources that consider local concerns, priorities, and needs in the context of pollution at the ArcSolution study locations in Northern Finland, Northern Norway, Greenland, Svalbard, and MacKenzie delta area, Canada. In addition, Faroese Islands have been added to the study locations in the beginning of March 2025. The study sites represent a diversity of Arctic communities with different geographies, population structures, livelihoods, lifestyles, pollution sources and effects of climate change. The project uses a community-based participatory approach, which started already in the project application writing period. The members of the communities have been involved in the process from early on by communicating their priorities and concerns.

The ArcSolution One Health framework is developed in WP2 (ArcSolution One Health framework) in collaboration with other WPs 3, 4, 5 and 6, over the course of the four-year study frame. In WP3 (Arctic pollution in a climate change context), pollutants in the environment are measured and modelled. Pollutant effects on ecosystems and humans are studied in WP4 (Impacts under different scenarios), and solution strategies from technological approaches to chemicals management are proposed in WP5 (Solutions: Resilience, adaptation, mitigation). In collaboration with the lead of WP6 (Exploitation, Dissemination and Communication), citizen science projects and communication and dissemination activities are planned and conducted together with local schools and municipalities. The results and knowledge produced in work packages will be feed back into the One Health Framework, and the knowledge will be synthetized and updated annually throughout the project stages.

This deliverable presents the first step for the ArcSolution One Health framework/model, regarding all dimensions of animal, environmental and human health. The framework is based on different types of knowledges and information gathered and combined during the first months of the ArcSolution project. The model includes reports and findings in natural sciences, health sciences, engineering, and social science, together with local, traditional ecological knowledge, and Indigenous knowledge, as well as citizen science knowledge.

1 Introduction

The Arctic is undergoing rapid changes. Climate change, and biodiversity loss, in combination with infectious diseases and pollution from local and remote sources, affects human health, wildlife, and the ecosystems of the Arctic region. One Health is a concept which combines the health of humans, wildlife and the environment into one, focusing on the interconnectedness of them, under the umbrella of the Triple Planetary Crisis.

One of the central aims of the ArcSolution project is to formulate a locally anchored One Health framework, which will be based on various knowledge sources and considers local concerns, priorities, and needs in the context of pollution at ArcSolution study locations in Northern Finland, Northern Norway, Canada, Greenland, and Svalbard. ArcSolution is designed with a community-based participatory approach, which means that inhabitants of the communities are involved in the project with their priorities and concerns since the beginning of the planning phase. The study areas represent the diversity of Arctic communities with different geographies, population structures, livelihoods, lifestyles, pollution sources, and effects of climate change. Figure 1 presents the map of the ArcSolution study locations, and the basic characteristics of the study localities are depicted in Table 1. A new partner from Faroese Island joined ArcSolution in March 2025. The development of locally anchored One Health frameworks needs collective efforts of experts from different scientific disciplines including natural sciences, engineering, health sciences, social sciences as well as holders of local and Indigenous knowledge and citizen scientists.

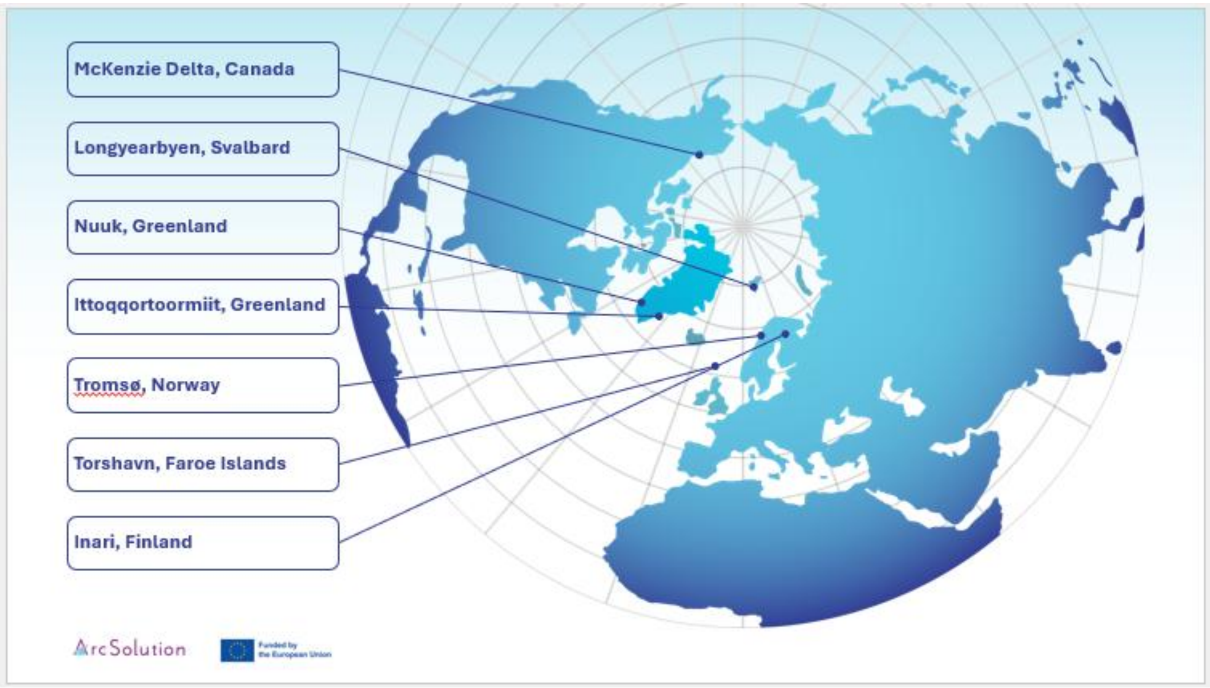

Figure 1 Map of the ArcSolution study locations.

Table 1 Characteristics of the different ArcSolution study locations.

Study location	Information	Characteristics
FINLAND		
Inari		
	Inhabitants:7125 in the municipality, among these about 2140 Sámi.	Sámi homeland, communities with reindeer herding. Inland settlements with mainly terrestrial and freshwater food sources. Continental climate with a January average of -9°C. The only landlocked location in this project.
GREENLAND		
Nuuk		
	Inhabitants: approx. 20000.	Capital of Greenland, cultural, financial and administrative centre. Maritime-influenced tundra climate, January average of −7.5°C.
East Greenland (Ittoqqortoormiit)		
	Inhabitants: approx. 450.	Inuit community with hunting traditions. Coastal settlements with traditional Arctic diet, including marine mammals. Maritime climate with a January average of -13°C.
NORWAY		
Tromsø		
	Population of approx. 80000, comprising more than 100 nationalities.	Cultural, economic and administrative centre in Northern Norway, a Sámi homeland with reindeer herding. Service, research, tourism and fisheries are important economic resources. Maritime climate with a January average of -3°C.
Skjervøy		
	Inhabitants: 2437.	The village of 1.34 km^2 is the administrative centre in Skjervøy Municipality in Troms County. The economy is based on the fishing industry. Average temperature in January is between –6 to -1°C.
Svalbard: Longyearbyen		
	Population of approx. 2500, of these about 17% non-Norwegians, and with high turnover. Large number of tourists (approx. 140 000 / year),	Largest settlement on Svalbard (Norway). Mining town until 2017. Maritime climate with a January average of -11°C.

CANADA		
MacKenzie Delta area and Great Slave Lake area		
	Inhabitants: The population of the MacKenzie Delta region is approx. 4000. More than half of the Northwest Territories' population lives on the lake shoreline, approx. 22 000 inhabitants.	Major communities include Aklavik and Inuvik. Land uses are limited to trapping, hunting, recreation, and tourism. High subarctic climate, mean January temperature is -26°C. Great Slave Lake is in southern Northwest Territories, Canada. Area has long supported a fishing sector and some trapping, but a major component of the regional economy has been mining—initially for gold and other ores and since the 1990s for diamonds. Mean January temperature is -20°C

The ArcSolution One Health framework will be developed in WP2 in collaboration with WPs 3, 4, 5 and 6 over the course of the four-year project duration of ArcSolution (see Figure 2). In the co-creation process for constructing the ArcSolution One Health framework, the project will analyze the pollutant situation in a climate change context, study pollution impacts on ecosystems and human health, develop solutions, and synthesize the results in the final ArcSolution One Health framework. Other WPs generate information for the framework-building in different ways. WP3 (Arctic pollution in a climate change context) focuses on the pollutants in the environment and measures and models them. Pollution effects on ecosystems and humans are studied in WP4 (Impacts under different scenarios). Solution strategies from technological approaches to chemicals management are proposed in WP5 (Solutions: Resilience, adaptation, mitigation). Citizen science projects are planned for all study locations, with associations to different WPs, and communication and dissemination activities are planned and conducted in WP6 (Exploitation, Dissemination and Communication).

As a final product, ArcSolution One Health framework will be presented, based on previous, ongoing, and new research conducted in the ArcSolution project and other sources of knowledges. Eventually, we will estimate and address future scenarios, which are based on what we know about pollution in the study locations. In building future estimations, we will use predictions under different climate and pollution scenarios. We will study the potential for transfer, expansion and generalization of the One Health framework results to a pan-Arctic and more global context over time.

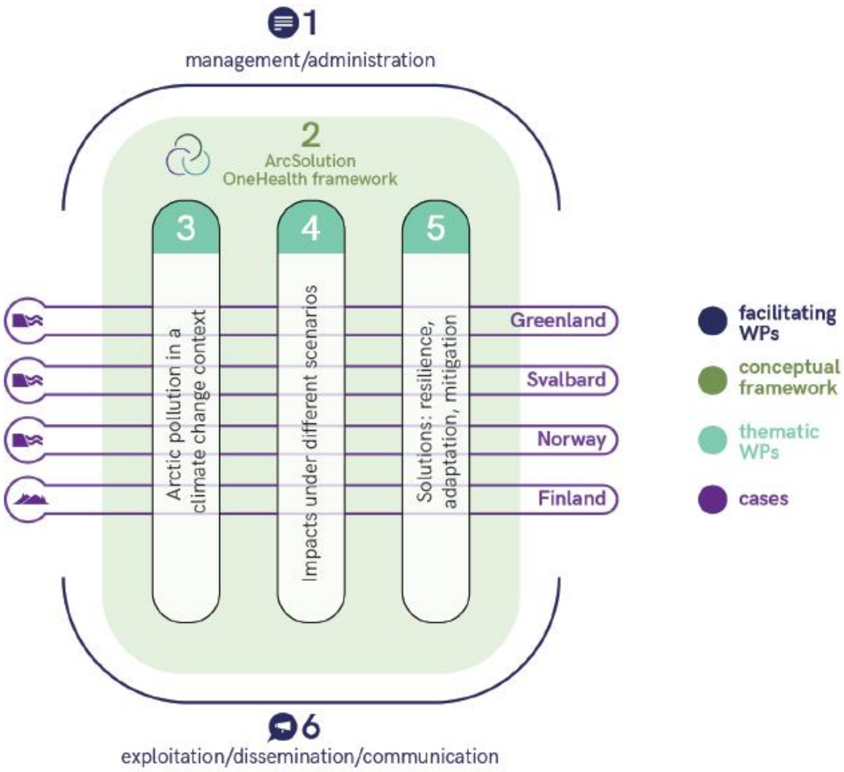

Figure 2 Pert Chart showing the correlations between the different WPs in ArcSolution

In this deliverable, we present the core elements of the ArcSolution One Health framework, with different types of knowledge and location-specific information collected during the first months of the ArcSolution project. The framework is based on different knowledge sources. The One Health model addresses each of the study localities (Table 1) and the pollution and One Health challenges they are facing.

2 Different types of knowledges included

The knowledge basis for the 1st One Health model includes several different knowledge types; **local, Indigenous, scientific**, and knowledge produced in **citizen science (CS)** projects. For the model, local and scientific knowledge with the knowledge individual citizens bring to a CS projects based on their personal background and experience in study sites, will be combined.

2.1 Local and Indigenous knowledges

ArcSolution fosters local inclusivity and sustainability knowledge co-production considering diverse cultural understandings as well as local, traditional, and Indigenous knowledges. In ArcSolution, **a round of workshops and feedback discussions** about study plans and results are held yearly in each study location, where locals can raise issues of concern related to pollution and One Health, and thus contribute to ArcSolution. ***Local and traditional knowledge*** refers to the unique knowledge developed over an extended period and held by a given society in a specific location (Naess, 2013). **Indigenous knowledge (IK)** usually refers to knowledge, practice, and belief of Indigenous peoples handed down through generations, about the relationship of living beings with one another and with their environment (Berkes et al., 2000). Synonyms of IK in academic literature include e.g. traditional ecological knowledge (e.g., Thompson et al., 2020). Information on previous local, traditional and Indigenous knowledge collected from the study locations are presented in Appendix 1. Summary of information produced in the consultation meetings and discussions are presented in Appendix 3.

2.2 Scientific knowledge

Scientific knowledge refers to research typically published in peer-reviewed articles in research journals, reports, or books. ArcSolution will integrate knowledge generated in research in several scientific disciplines, including environmental, natural, human health, animal health, technical, social, and socio-economical science research in the One Health approach. The scientific partners in the consortium cover this wide range of disciplines, including the fields of technical engineering, health sciences, natural sciences (including toxicity and environmental science, analytical chemistry, food production), social sciences, as well as cheminformatics and *in silico* data handling. Scientific information are presented in Appendix 2.

2.3 Citizen science

In addition, ArcSolution integrates knowledge produced by means of **citizen science (CS)** in its One Health model at various stages of the project. CS refers to scientific work that is done by citizens who are not professional scientists (Haklay et al., 2021). There are different ways of doing CS depending on the role and the level of involvement of the public, i.e. citizen scientists, and trained scientists. The role of citizen scientists ranges from them being involved partially, for instance participating in data production and data categorization, to the projects being carried out completely by the citizen scientists. Then, scientists only have a consultatory role (Bonney et al., 2009). Data produced through CS is derived from both local and scientific knowledge. Citizen scientists who participate usually have local knowledge on the topic, and the research target real-life issues and problems the local citizens are facing. Each citizen also brings their individual knowledge, preferences and experiences to a CS project. In ArcSolution, at least one CS project will be conducted in each study location, where local experts, educational institutions, and other local citizens will collaborate. We will also collect findings from already published CS studies from the ArcSolution study localities (Deliverable 2.2.) and include this information as well in our One Health model.

3 One Health concept

The One Health concept recognizes that humans, animals, and the environment are interrelated and interdependent in complex ways and that human, animal, and ecosystem health are interconnected (Kutz & Tomaselli, 2019; de Castañeda et al., 2023; Berner et al., 2024). One Health is an increasingly accepted and established concept worldwide and it is often described as integral and the intuitive worldview of many Indigenous peoples, both in the Arctic and elsewhere (Berner et al., 2024). Arctic populations and ecosystems are faced with the complex challenges of global and environmental changes. These challenges include but are not limited to, effects of climate change, landscape and land-use changes, urbanization, loss and reduction of biodiversity, emerging and spread of infectious diseases, biological invasive species, demographic changes, unstable food and water safety and security, and exposure to anthropogenic pollutants (Berner et al., 2024). Gaining a holistic perspective of One Health requires recognition of cross-, inter- and transdisciplinary approaches of collaborative teams of experts from different scientific disciplines as well as other knowledge traditions for a better understanding and appropriate and context-specific responses (Gartler et al., 2025).

3.1 Pollution and One Health in the Arctic

The speed of climate change in the Arctic is almost four times as fast as in the rest of the world, a phenomenon known as Arctic amplification (Rantanen et al., 2022). Arctic socio-ecological systems are both exposed to climate-related changes and adapting to its consequences in different ways. Although climate change is interpreted as the most severe trigger, it is neither the only nor the first one. Before climate change, there were other problems mostly with their origin from lower latitudes, such as long-range pollution including heavy metals, plastics and marine litter, persistent organic pollutants, radioactive contamination, and Arctic haze, all of which were sources of great concern to Indigenous and other local peoples, NGOs, and the research community (Heininen et al., 2020). ArcSolution rests on decades of research on these intertwined challenges and the many consequences they produce.

Environmental pollutants, plastics, waste, and infectious diseases in terrestrial, freshwater, and marine environments are a major concern for environmental, animal and human health, and essential components of the ArcSolution One Health frameworks being developed. To an extent, pollutants originate from emission sources in the Arctic proper, such as through wildfires, oil and gas flaring, transportation routes and infrastructure, and numerous defined contaminated sites in the Arctic region (Langer et al., 2023). However, many contaminants are transported over long distances, traveling to the high latitudes via rivers, ocean currents, atmospheric pathways and migratory animals – where they combined represent a severe negative impact on the human, wildlife and environmental health (Arctic Council, 2023). For example, mercury and persistent organic pollutants (POPs), e.g., polychlorinated biphenyls (PCBs), as well per- and polyfluoroalkyl substances (PFAS) are some of these long-range transported pollutants in the Arctic (Dietz et al., 2022). PFAS are called "forever chemicals" due to their resistance against environmental degradation, metabolization, and excretion (Andersen-Ranberg et al., 2024; Sonne et al., 2017; Sonne et al., 2018). Once transported with the atmosphere to Arctic localities, these contaminants are deposited into the environment by precipitation and atmospheric deposition, whilst permafrost and glaciers may act as a long-term storage (Berner et al., 2024). Permafrost thaw and soil and peat erosion may therefore cause increased mobility of even more contaminants and pollution, leading to exposure for both humans, animals and the living environment to soluble contaminants (Gordon et al., 2016).

Since its establishment in 1991, the Arctic Monitoring Assessment Program (AMAP) has studied contaminants in the Arctic, including their occurrence and accumulation in Arctic ecosystems and food items, as well as human exposure, health effects, and risks associated with measured contaminants in the Arctic. This work has led to a series of high-quality reports with data, key findings, research priorities, and recommendations for policymakers (Reiersen et al., 2024). The first AMAP report was presented in 1998 and followed up thereafter by four assessment reports on human health (in 2003, 2009, 2015, and 2021a) as well as Assessment reports on heavy metals (2005), POPs and Chemicals of Emerging Arctic Concern (CEACs) (2004, , 2016, 2017, 2021b), Mercury in the Arctic (2011, 2021c), and Biological Effects of contaminants on Arctic wildlife and fish (2018; also Letcher et al. 2010). Based on this evidence, we find that POPs and their documented impact on human, wildlife health, and the health of the environment can be used as an example of how pollution is related to One Health.

POPs enter food webs and accumulate in lipid stores or, as is the case for PFAS, in protein-rich tissues of Arctic organisms (Abass et al., 2024; Lohmann et al., 2024). Being recalcitrant to biodegradation, POPs are effectively transferred in the food web. As food webs are more complex in the marine than in the terrestrial environment, this biomagnification process is particularly pronounced in marine ecosystems and leads to high concentrations in top predators, which is evidenced to increased health risks for Arctic residents (Arctic Monitoring and Assessment Programme (AMAP) 2021a), who consume fish and top animal predators as well as wild birds as part of their traditional diet (Basu et al., 2022, Reiersen et al., 2024). The traditional Arctic diet has a strong anchoring in many Arctic communities with cultural, spiritual, and economic relevance, including traditions of sharing and uniting in hunting risks and potential food shortage. Although Western food is available in the Arctic, it is not always affordable for community members (AMAP, 2021ab). Based on a history of insecure hunting outcomes, the experience of POP and Hg exposures through food, climate-related changes in species abundance, and the risk of zoonotic diseases, food safety, and security are of great significance in Arctic communities (Andersen-Ranberg et al., 2024).

All aspects of human health and well-being, quality of life, and living conditions are inseparably connected with wildlife health, which in turn depends on a clean and healthy environment. Exposure to toxic pollutants has synergistic effects on human and animal populations which are modulated by intrinsic and extrinsic factors that mediate rates of exposure, levels of physiological stress, and the potential for adverse health outcomes (AMAP 2021a; Dudley at al., 2015). Significant international research efforts were made to study the impact of POPs and other pollutants on the health of Arctic humans, animals, and the environment (see e.g. Appendix 2). However, more knowledge is needed on connections between pollutants, especially emerging ones, and vulnerable wildlife and human communities in the Arctic. Moreover, pollution is connected to climate change and globalization, and effects can be amplified in the presence of other stressors, which calls for more research and action. Migration of people, urbanization, commerce, warming temperatures and melting sea ice and glaciers and permafrost thaw influence the character and pattern of pollutant exposure, the deposition and cycling of microbiological agents between the atmosphere, hydrosphere, and the land. Furthermore, current waste sites (chemical and mixed domestic wastes) built on permafrost may begin to leak their contents into water systems or onto land masses as increasing parts of permafrost thaw. This may lead to land subsidence (Van Oort et al., 2022). The long-term effects of climate warming in the Arctic cannot be adequately predicted or mitigated without a comprehensive understanding of the interactive and synergistic effects between environmental contaminants and pathogens on the health of wildlife and human communities in Arctic ecosystems (Dudley et al., 2015). The One Health model under development is meant to understand and address these issues in a holistic way.

3.2 Sewage and drinking water in the context of pollution and One Health

International efforts to improve resource management acknowledge the need for improved food supply systems, drinking water access, and access to limited resources (such as nutrients and essential elements). This aligns with the concept of circular bioeconomy, i.e. economy powered by nature, as an approach to secure a more sustainable strategy in material production and plans for development and modernization of sewage and water infrastructure (Fritzsche et al., 2020). This is important in order to (1) reduce the human impact on the environment; (2) more effectively utilize essential resources for technological development and societal support; and (3) develop practices and institutions that remove barriers to circular processes. Circular bioeconomic strategies are attractive approaches for developing low-impact and Zero Pollution perspectives for Arctic communities and environments. ArcSolution will work with the resources of biowaste, wastes of grey/black water, solid waste, and water in WP5 to develop sustainable technological and societal solutions that minimize local emissions of pollutants and provide access to high-quality resources. This means that sewage and drinking water issues will not only be addressed as a pollution issue but also handled from a solution perspective, considering i) circular economy principles, ii) technology development and implementation, and iii) chemical management. Perspectives include food safety and security, stable water supply and clean drinking water, treatment of wastewater and sludge, waste disposal, and occupational/domestic activities, always considering location-specific conditions in a holistic approach. This implies that the final products, meant for consumption or further use, do not lead to an increased dispersion of pollutants in the local and wider Arctic environment. The work will, therefore, apply chemical analyses of indicator compounds as well as non-target screening and toxicity testing approaches. In addition, public awareness and acceptance of these new methods will contribute to a better implementation of new technologies at the local level.

Drinking water as an exposure source to pollutants has not been studied in the Arctic as much, as pollution studies have often focused on hydrophobic POPs that are poorly water-soluble (AMAP, 2021b). However, as PFAS and some CEACs have higher water solubilities and microplastics can be released from many plastic installations, drinking water may be a potential exposure source to pollutants concerns, and will also be in focus in the ArcSolution One Health framework development.

4 Towards the 1st One Health model - Summary of the existing data by study locations

Next, we present the summaries of existing data and knowledge on pollution and One Health based on collected local, traditional, and Indigenous knowledges from the study locations (Appendix 1), including publications using this knowlegde, knowledge from ArcSolution consultation meetings (Appendix 3), and previously published scientific research (Appendix 2).

We collected the knowledges through literature searchers from different databases (see more in Appendix 1 and 2 for methodology) and directly from ArcSolution partners. Volumes of existing information has been semi-quantitatively grouped in the Tables 2 and 3. The number, i.e. volume, of publications and resources from each study location was explored and assessed for each One Health dimension. This is the first step of the One Health framework building. The process is ongoing, and new inputs will be added to the framework building.

Table 2 Existing published local, traditional, and Indigenous knowledge for each study location.

Volume of existing information; - no information + little information ++ some information +++ lots of information ++++ studied extensively				
Location (Number of publications)	**Environmental health - Pollution**	**Wildlife health – Pollution & Infectious diseases**	**Human health - Pollution**	**Clean water and sewage water**
Longyearbyen and Svalbard (N=25)[a]	++	+	++	++
Consultation meeting	Wastewater management, sewage, pollution, tourism effects, contaminants, pollutants, heavy metals, climate change	Visible plastics in reindeer and birds, trichinella in polar bears, dogs, water safety for animals, climate change impacts, contaminants	Water and air quality, dump site, long range pollutants, safety, microplastics in blood	Wastewater management of high concern in all dimensions
Nuuk and Eastern Greenland (N=11)	+	++	+	-
Consultation meeting in Nuuk	Sewage, solid waste management, contaminants, plastic on shore from local sources	Sewage, solid waste management, fishing nets	Food sovereignty and security, clean food, sewage and clean water, solid waste management, infectious diseases, airport construction pollution, dust, plastics	Sewage is of concern in all dimensions
Tromsø and Skjervøy (N=10)	+	-	-	+
Consultation meeting	Quality of drinking water, sewage, pollution from contaminated sites and	Landfill pollution, health of fish	-	Sewage was mentioned in regards of environmental

	leakages from them, pollution from landfills, contamination of sediments, and microplastics in wastewater due to snow removal to the sea			and wildlife health
Inari (N=4)	+	+	-	-
Consultation meeting	Health of lakes and rivers, microplastics, plastics litter, heavy metals and radiation from Russia, air traffic pollution, emission from snowmobiles, mercury from gold mining, wastewater and litter issues due tourism	Health of fish, light pollution, mad cows' disease, ticks, health of reindeer herds, huskies and waste and noise pollution they produce	Noise pollution, light pollution, poor water quality in one river, climate change, and thinning ice	Wastewater and environmental health
MacKenzie Delta area and Great Slave Lake area, Canada (N=10)	++	+++	++	++
Consultation meetings held by ILLUQ project				

a) See more details for methodology and references in Appendix 2.

Most publications produced with local knowledge were found from Longyearbyen and they were conducted via various qualitative and mixed methods (see Appendix 1). Human health aspects were not covered in the studies, but studies on wildlife and environmental health were conducted. Pollution was not the sole focus of those studies. Likewise, in the studies identified from Tromsø, most studies focus on climate change and its effects, especially in the socio-economic spheres. Local knowledge of marine pollution was also studied. Traditional and Indigenous knowledge from Greenland has focused especially on wildlife health, on seals, toothed whales, reindeer, musk oxen, birds fish, and especially on polar bears, on f.eg. impacts on POPs on their health, with no identified studies on human health. Local, traditional and Indigenous knowledge studies from Inari were few and covered microplastics, the health of the wildlife and water, and Sámi reindeer culture. Canada has produced a lot of local, Indigenous and traditional ecological knowledge studies for example via their Northern Contaminants program, covering all aspects of One Health.

Table 3 Existing scientific knowledge from study sites.

Volume of existing information; - no information + little information ++ some information +++ lots of information ++++ studied extensively				
Location (Number of publications)	**Environmental health - Pollution**	**Wildlife health – Pollution & Infectious diseases**	**Human health - Pollution**	**Clean water and sewage water**
Longyearbyen and Svalbard (N=101)[a]	++++	++++	+	++
Nuuk and Eastern Greenland (N=30)[a]	++	++ (Nuuk) ++++ (East Greenland)	+++	
Tromsø (N=28)[a]	+	++	+++	
Inari (N=7)[a]	+	+	+	+
MacKenzie Delta area (N=74)[a] and Great Slave Lake area (N=34)[a]	+++	+++	+++	

[a]See more details for methodology and references in Appendix 2.

Table 3 is based on our assessment of existing **scientific knowledge** from study sites (presented in detailed in Appendix 2). The findings indicates that the areas of Longyearbyen and Svalbard, and MacKenzie Delta and Great Slave Lake in Arctic Canada received the most comprehensive scientific attention on a variety of different pollutants in the environment and on several key wildlife species. In Svalbard, fewer human health studies were conducted but in Canada many studies exist. In Tromsø lots of research have been conducted, and several of them are about human health studies conducted with human cohort studies. There has been a lot of research on wildlife species in Greenland, especially in Eastern Greenland. Nuuk and Eastern Greenland have also shown significant research already done in the pollution and health area. Inari was in focus of relatively smallest number of studies.

In addition to key scientific articles included in the Deliverable 2.1. and listed in the Appendix 2, twelve AMAP assessment reports published in the period 2003-2021 provided detailed data, time trends, executive summaries, directions for future research, and policy recommendations on contaminants and their effects on Arctic water, land, air, wildlife, fish, and human health. Knowledge gaps identified by AMAP (2021a) include research on routes of exposure (e.g. risk-benefit analyses to compare traditional foods with store-bought Western foods, co-production of knowledge in dietary research with academics and Indigenous communities, improved understanding on sources of exposure for PBDEs and PFASs), biomonitoring (expanding biomonitoring of pregnant women, considering seasonality of the timing of sampling, studying new chemicals of concern in the Arctic) and health impacts (expanding the use of cohort studies, conducting more studies to identify the mechanisms through which exposure can lead to health impacts, identifying prenatal and postnatal windows of vulnerability and increasing the focus of research on mixtures of POPs and their effects on reproductive health and the immune system).

Traditional and local food was consisting mainly of marine foods with many health benefits in the Arctic (Berner, 2008). However, the discovery of high levels of POPs and heavy metals (esp. mercury) in the late 1980s and 1990s in serum and breastmilk of mothers, as well as in Arctic marine mammals and fish, raised concerns about the safety of the traditional foods. This phenomenon is called “The Arctic Dilemma” – food with health benefits contains also high levels of pollutants. This concern contributed to the transition to other food sources which had poorer nutritional quality, especially Western type “market” food. The balancing in the dietary change is difficult, and it needs careful communication and advice strategies (AMAP 2021b). Risk communication activities in the Arctic countries have especially emphasized the importance of a nutritious diet, and contaminant-related restrictions relate mostly to exposure of mercury during pregnancy, breast feeding and among small children. A limited amount of advice is given on other contaminants (Krümmel et al., 2021).

Risk communication should be well-balanced and consider cultural aspects and benefits of the country food. However, effectiveness evaluation data is scarce and limited in the Arctic (Krümmel et al., 2021). Moreover, there is a general lack of information on risk communication for Indigenous Peoples in Arctic countries other than Canada. Besides risk communication activities, it is crucial that regulatory actions are effectively implemented to decrease contaminants in the environment to ensure low levels of contaminant exposures in human populations (Krümmel et al., 2021).

Next, we will describe the content of Tables 2 and 3 in more detail for each study location.

4.1. Longyearbyen and Svalbard

When summarizing the scientific research on Svalbard (Table 3 and Appendix 2), research articles confirm that there is relatively high contamination of ocean and sea water around Svalbard, with wildlife and fish at the highest potential risk of POP and other contaminant exposure and mediated health effects in Svalbard polar bears, seals, walruses, seabirds, and fish. In addition to the existing gap in studying pollution effects on human health among Svalbard residents (only a few studies), research articles indicate also, that the arctic fox from Svalbard may be an overlooked species in the Arctic Monitoring and Assessment Programs and it would add further information about pollution in the Arctic to include this species in the monitoring program.

Despite the transient nature of Svalbard's population, **local and traditional knowledge** has proven valuable in complementing formal scientific monitoring. Various qualitative and mixed methods, such as community science methodologies, web-based story mapping, in-depth interviews, focus groups, and cognitive mapping, have been employed to gather observations and narratives from residents and visitors. For example, Saville (2022), Hovelsrud et al., (2020) and (2023), and Olsen et al., (2022) studied the rapid transition of Longyearbyen, including transition from a mining town to a 'tourist town' and the local concerns about the impacts of tourism. However, not many studies utilizing local knowledge have explicitly focused on pollution, however. One of the exceptions is a study by Olsen et al., (2020) highlighting the need to address pollution from the increased ship traffic.

The first **consultation meeting** in Longyearbyen was held in collaboration between three EU-funded projects; ArcSolution, ILLUQ, and ICEBERG, and ILLUQ project was the organizer. A group of 12 scholars from the three projects participated in multiple meetings in Longyearbyen with municipality, local experts, businesses, the hospital, schools and the general public. Based on the discussions, many topics were raised in the meetings, which are presented in detail in Appendix 3, and summarized next. Concerning the **health of the environment,** central points of concern included wastewater management, sewage system issues, pollution from (closed) mines, and the negative effects of tourism. Pollutants, contaminants, and heavy metals were mentioned, so too was climate change as a risk with permafrost thaw specifically. Waste on the shores was an issue, too. When the **health of the wildlife** was discussed, visible plastics in reindeer and birds, water safety issues especially for dogs, and the increasing number of dogs and related waste and contamination risks in that regard were discussed. Contaminants threatening wildlife health were mentioned. Also, trichinella in polar bears was of concern. Concerns related to the **health of humans** included water quality and safety, air quality, wastewater management, new dump sites established in the area, pollutants and their accumulation, microplastics in blood, mental health issues and safety of locals and tourists as related to permafrost thawing and degrading. Also, health issues between long-term and short-term residents were discussed.

Pollutants that were mentioned during the consultation meetings as of concern, included: PFAS, heavy metals, lead, mining waste, plastics, pharmaceuticals, diesel, PVBs, fluor, and chemicals/pollution emerging from permafrost.

4.2. Nuuk and Eastern Greenland

The scientific literature has been focused on monitoring programs for key contaminants in the environment, wildlife species such as polar bears, seals, wolves, fish, sea- and shorebirds, and local people for over 30 years. Many past uncertainties on the sources, transport, and transformation in the Arctic environment were addressed. AMAP reports show that some of the pollutant concentrations measured in the past decades are generally highest in Greenlandic mothers and children (e.g., some PFAS and mercury) and in the environment, compared to the rest of the Arctic. Since large concentrations of pollutants were found in many species of Greenland, marine food intake and exposure to seafood have been found to be associated with higher blood levels of POPs, PFASs and heavy metals in Greenlanders. Omissions of data for this area are in identifying causes of diseases associated with organic pollutants as well as a necessity for continued and expanded time series and human biomonitoring.

The findings of studies using **local, traditional, and Indigenous knowledge,** indicate that the research in Greenland has focused on polar bears. Studies have examined polar bear populations in East and Southeast Greenland, highlighting their adaptation to changing environments, and burdens caused by POPs (Dietz et al., 2001). Sandell et al. (2001) investigated the effects of POPs on polar bears by interviewing hunters, analysing tissue samples from polar bears and comparing frequencies of morphological anomalies in samples of polar bear skulls and anomalies in sledge dogs studied by hunters. Laidre et al. (2018) analyzed two decades of traditional knowledge, revealing shifts in polar bear catches linked to climate change. Baztan et al. (2017) investigated the links between climate science and Inuit knowledge. They based their research on 10 years of anthropological participatory research in Uummannaq, Northwest Greenland, along with two fieldwork periods, and a quantitative bibliometric analysis of the international literature on sea ice.

A consultation meeting in Nuuk was held with a smaller group of ArcSolution researchers (coordinator, two WP leads and UGreenland partner). Central points of concerns related to the **health of the environment** were sewage, solid waste management, contaminants, and plastics on shore from local sources. The **health of wildlife** related to the same topics, such as levels of contaminants, infectious diseases, sewage, solid waste management, and in addition to fishing nets were of concern. **Human health** and pollution were discussed, especially regarding food, food sovereignty and security. Also, sewage and clean water were of concern, as well as solid waste management, infectious diseases, pollution coming from airport construction, and plastic pollution.

Mentioned pollutants and contaminants of concern were Hg, Pb, plastics and dust, sewage and clean water, solid waste management and fishing gear. The central message from the Greenland meeting was that it is important to focus on the environment when studying pollution issues in the area. The goal is a pollution-free environment (together with locals and experts), and practical solutions are needed. We must move from knowledge to solutions. Arctic Hub is a link between Greenlandic people and Greenlandic research, and sharing information from the ArcSolution project (e.g., stories annually).

4.3. Tromsø and Skjervøy

MISA 1 and 2 studies (the Northern Norway mother-and-child contaminant cohort study) have since 20007 been a comprehensive and continuous assessment of the exposure to environmental pollutants experienced by women and their newborns. A comprehensive array of biological samples (blood, urine, hair, nails, cord blood, and breast milk) and questionnaires on past and present food intake, socio-demography, lifestyle habits, and obstetrical history have been collected. MISA has revealed a reduction in exposure to PFAS and organochlorines (Xu et al., 2022). Similarly, the Tromsø study also revealed a declining organochlorine trend of 86% from 1986 to 2007 (Nøst et al., 2019; Berg et al., 2021). Among health effects, several health implications for PFAS were indicated, i.e. a negative effect on thyroid hemostasis, asthma, metabolism, and endocrine disruption. The MISA study has reported significant associations between contaminants and dietary intake (Veyhe et al., 2012; Berg et al., 2014). Traditional foods such as marine fish and mammals, fish liver and seagull eggs, freshwater fish, and land-based wild animals were predictors of toxic substances. These findings underscore the potential risks associated with PFAS exposure and the need for further research and public health interventions to mitigate these risks as well as highlight the importance of dietary choices in reducing exposure to toxic substances and the potential for dietary interventions to improve public health. Studies also focused on **the environmental health**, for instance air pollution (Law et al., 2017), and on **wildlife health** of birds, fish and marine mammals.

Some **community-based studies of local knowledge** from Northern Norway were focused on the changing Arctic due to climate change and its different socio-ecological impacts and on how communities may respond to the changes. The topic of pollution was not in the clear focus of most of the studies, but negative One Health impacts related to these significant changes that communities need to adapt to were studied with local people.

Consultation meetings in Northern Norway were held in Tromsø and Skjervøy. Points of concerns related to the **health of the environment** included the following: quality of drinking water, sewage, pollution from contaminated sites and leakages from them, pollution from landfills, contamination of sediments, and microplastics in wastewater due to snow removal to the sea. The h**ealth of the wildlife** was less discussed and then landfill pollution and the health of fish came across as concern. The **health of humans** was not discussed in the consultation meetings. Abandoned fishing nets and gear were of pollution concern.

4.4. Inari

Some studies were published on pollution and health effects from the local environment, food, wildlife, and human health in the Finnish Sámi home area. POPs and potentially toxic elements were found to be low in pregnant women and local food items, whereas PCBs were the organochlorine compounds in highest levels in pregnant women and in food samples, even though in the last 14 years serum PCB levels decreased 63% in pregnant women (Abass et al., 2022). The levels of radioactive substances, toxic elements, and POPs were below the permitted EU maximum content in food products. Concentrations of all investigated toxic elements were highest in mushrooms, except for Hg, which was highest in fish. Mushrooms, fish, and reindeer were found to be important markers in the combined risk assessments for the contents of metals and radioactive substances. Despite it is a relatively pristine Arctic wilderness environment, microplastics were present in the local waters.

There is some research with **traditional and Indigenous knowledge** conducted in Inari and Finnish Arctic region. Mustonen et al., 2018 studied the effects of climate change on the rivers and in Soininen et al., (2024) study, Sámi Indigenous knowledge proved to be a beneficial and important initiator because locals recognize the possible sources and transport pathways of plastic litter, and practical sampling sites in the complex freshwater systems of the area. A "Feasibility study on co-production of knowledge between researchers and Indigenous communities for climate change adaptation" project organized several workshops with Sámi reindeer herders, producing local and TEK data on the climate change impact and adaptation (Näkkäläjärvi & Juntunen, 2023). Fewer projects deal directly with human health aspects.

Consultation meeting in Inari was held with two ArcSolution scholars who had 6 meetings with the representatives of the municipality, airport, Friends of Nature Association, Metsähallitus, SámiSoster, Sami Education Institute and tourism industry. There was no consultation meeting due to the wishes of the Sami Parliament. Central points of concern from meetings regarding **the health of the environment** were: health of water, microplastics and plastics litter, other garbage, pollution from snowmobiles, radiation and heavy metals from Russia, air traffic, and related pollution and emissions from recreational use of snowmobiles. Problems with mining, as well as wastewater in relation to tourism, and the litter tourists leave behind were mentioned. In relation to **wildlife health,** the health of fish, mad cows' disease, ticks, and weaker reindeer herds were mentioned. Huskies were also discussed. Farms cause noise pollution, and huskies produce waste which may be a risk to the health of the environment. **Human health** concerns in relation to pollution were noise pollution, light pollution, poor water quality in one river, and climate change effects of thin lake ice.

The main concerns were microplastics and plastic from the reindeer feed bales in lakes and forests, hand warmers left to ice and found in Lake Inari, and canisters left in the wilderness.

4.5. MacKenzie Delta area (by co-funding from Canada)

The current body of research demonstrates significant progress in understanding pollution dynamics and their impacts on the environment, wildlife, and human health in the Mackenzie River Basin and Great Slave Lake area. Strengths include robust baseline data on pollutant levels, growing integration of TEK, and strong community involvement in human health research. While bioaccumulation of mercury and POPs is well-documented, the ecological consequences of climate-driven changes in the food web remain uncertain. Future studies should focus on the long-term effects of these shifts on fish, bird, and human populations. There is still limited local input in environmental and wildlife health studies, insufficient research on emerging contaminants, and a lack of long-term, low-dose exposure studies. A clear trend across all areas is the increasing recognition of the need for participatory research and the integration of local knowledge. Looking ahead, future research should prioritize emerging contaminants, investigate the impacts of climate change on pollution dynamics, and develop actionable health interventions. By addressing these gaps, researchers can provide more comprehensive and actionable insights to support the health and sustainability of Canadian Arctic ecosystems and communities.

In the Canadian Arctic, and also in the MacKenzie Delta area, research on pollution, which include both **Indigenous knowledge** and Western science, has been conducted. Studies have been focusing e.g. on wildlife health and ecotoxicology, on contaminants on ringed seals, and on water and ice. In The Northern Contaminants Program established in the 1990s, a lot of research has been conducted. They follow an interdisciplinary approach, which includes natural and social sciences, community-based monitoring and traditional knowledge.

No consultation meetings were held in the MacKenzie Delta area.

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APPENDIX 1. LOCAL, TRADITIONAL AND INDIGENOUS KNOWLEDGE

Methodology

Information on local, traditional and Indigenous knowledge and pollution in the Arctic was found from various databases, Google and Google Scholar. The search included a) article searches from three databases: Scopus, Web of Science and EBSCOhost, b) article search from Google Scholar, c) a search for research projects in Google, and d) citation changing. In addition, ArcSolution partners added information to the Tables based on their knowledge of work conducted in the study locations.

The search from databases was done using the words ”traditional ecological knowledge” AND pollutants OR pollution AND Arctic. An additional search was made in EBSCOhost using the words (“traditional ecological knowledge” OR “indigenous knowledge” OR “traditional knowledge” OR “indigenous ways of knowing”) AND (pollution or pollutant) AND Arctic. The search string was also done by replacing Arctic with Norway/Svalbard/Finland/Greenland.

Local and Traditional Ecological Knowledge (TEK) from Longyearbyen

Table 1a Links to research databases and institutions in Svalbard

Svalbard, Longyearbyen	**Research databases**	**Links**
	SIOS SESS reports: 2017 – 2024	https://sios-svalbard.org/SESSreport
	Monitoring of Svalbard and Jan Mayen (MOSJ)	https://mosj.no/ (Norwegian) https://mosj.no/en/ (English)
	Svalbard Miljøvernfond (SMF)	https://www.miljovernfondet.no/prosjekter/ (Norwegian) https://www.miljovernfondet.no/en/projects/ (English)
	Research in Svalbard (RIS)	https://www.researchinsvalbard.no/
	Svalbard Social Science initiative	https://www.svalbardsocialscience.com/
	The Association of Arctic Expedition Cruise Operators: Cruise Database & Live Scheduler	https://aeco.no/tools-and-resources/cruise-database/

Summary written by UOULU and edited by NORD (Julia Olsen)

Despite the transient nature of Svalbard’s population, local ecological knowledge has proven valuable in complementing formal scientific monitoring. Table 1 shows the wealth of research and several databases on research in Svalbard. According to literature on local knowledge in Svalbard, various qualitative and mixed-methods such as community science methodologies, web-based story mapping, in-depth interviews, focus groups, observations, citizen science, and cognitive mapping have been employed to gather observations and narratives from residents and visitors. These methods capture experiential knowledge tied to strong place attachment, even among short-term inhabitants, enriching scientific perspectives on environmental change and fostering a holistic understanding of ecosystems (Lennert et al. 2023, SVALUR). Hovelsrud et al., (2020) and Meyer (2022) examine climate change impacts and adaptation in Svalbard, describe observed changes and perceived societal impacts of climate change and discuss adaptation measures and related understandings of adaptation. Meyer conducted ethnographic fieldwork and interviewed planners, engineers, architects, scientists, construction workers and local politicians. Prof. Grete Hovelsrud has been engaged in Svalbard Research for over 30 years and together with her colleagues has multiple publications related to climate change adaptation, environmental governance, tourism development and sustainable dilemmas and the role of stakeholders in managing fjord ecosystems (Hovelsrud et al. 2020, Hovelsrud et al. 2023).

For the past 10 years, Hovelsrud's colleague Olsen has been conducting qualitative research on the consequences of increasing shipping and cruises on Svalbard's environment and society. Through qualitative analysis (interviews and observations) she identified environmental impacts from ship traffic, sustainable dilemmas in tourism industry and the role of socio-economic transition on community viability in Longyearbyen and Barentsburg (Olsen et al. 2019, Olsen et al. 2020, Olsen et al 2022). She concludes that despite the transient nature of the population, local residents are highly aware of the impacts of climatic and environmental changes and are engaged in responses. Saville (2022) explains the rapid transition of Longyearbyen from a mining town to a 'tourist town' and the local concerns about the impacts of tourism. She utilised a mixed-method approach to examine value systems, especially on nature-culture relationships. She conducted semi-structured interviews with Svalbard residents and stakeholders and a small-scale survey with tourists and tourist industry representatives. Also informing the research were her ethnographic experiences as a temporary tour guide and as a tourist. Meyer and Sokolíčková (2024) approach climate change as a discourse and explore the reception and reproduction of the dominant climate change discourse locally in Longyearbyen and compare it to other stories about climate change and adaptation. They conducted ethnographic fieldwork, including interviews and informal conversations, and found counter-stories that nuance and contest the dominant climate change discourse. Also, other members of Svalbard Social Science Initiative have been producing relevant publications.

Research gaps identified were the need for more social science research on the transforming society and its transition into a "green" future in Longyearbyen (Meyer 2022) and presenting a more complex picture of climate change and human activities impacts by listening to local voices (Meyer and Sokolíčková 2024, Olsen et al., 2020).

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2. Fowler, C., Tefre, M. & Richardson, J. (2016). Seeds on ice: Svalbard and the Global Seed Vault. First Edition. ed. Westport, CT: Prospecta Press, an imprint of Easton Studio Press, 160 p.
3. Gjørv, G. H., Goloviznina, M. & Tanentzap, A. J. (2014). Environmental and human security in the Arctic. D. Bazely (Ed.). Earthscan from Routledge, 285 p.
4. Hop, H. & Wiencke, C. (2019). The Ecosystem of Kongsfjorden, Svalbard: Springer International Publishing.
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11. Lund, T. (1996). Det har hendt på Svalbard. Lundblad Media, 112 p.
12. Meyer, A. (2022). Physical and feasible: Climate change adaptation in Longyearbyen, Svalbard. Polar Record, 58, e29. https://doi.org/10.1017/S0032247422000079
13. Meyer, A., Sokolíčková, Z. (2024). 'Melting Worlds' and 'Climate Myths': Diverging Stories of Climate Change in Longyearbyen, an Arctic 'Frontline Community'. Ethnos, 1-18. https://doi.org/10.1080/00141844.2024.2329690
14. Norderhaug, M. (1982). Svalbard: mennesket i den siste villmark. Tromsø: Universitetsforlaget, 157 p.
15. Olsen J., Hovelsrud G., & Kaltenborn B. (2020). Increased shipping and community engagement: A case from Longyearbyen, Svalbard. In Arctic Marine Sustainability. Arctic Maritime Businesses and the Resilience of the Marine Environment. Springer Nature. 305–331.
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17. Olsen. J., Vlakhov, A. & Wigger, K. (2022). Community viability during economic transition: Case studies of Barentsburg and Longyearbyen, Svalbard. Polar Record, 58, E7. doi:10.1017/S0032247422000043
18. Saville, S.M. (2022). Valuing time: Tourism transitions in Svalbard. Polar Record, 58, e11. https://doi.org/10.1017/S0032247422000055
19. Sokolíčková, Z. & Eriksen, T. H. (2023). The paradox of Svalbard: climate change and globalisation in the Arctic. Pluto Press, 202 p.
20. Wielgolaski, F.E. (1997). Polar and alpine tundra. 1st ed. Elsevier, 920 p.
21. Åkerman, J. (2023). Svenska sällskapet för antropologi och geografi. Det nya Svalbard. Sweden: Svenska Sällskapet för Antropologi och Geografi, 187 p.

References collected by UOULU:

22. AMAP (2021). AMAP Assessment 2021: Human Health in the Arctic. Arctic Monitoring and Assessment Programme (AMAP), Tromsø, Norway. x+240pp
23. Lennert, A.E., van der Wal, R., Zhang, J. et al. (2023) Rich local knowledge despite high transience in an Arctic community experiencing rapid environmental change. *Humanities and Social Sciences Communications,* 10, 782. https://doi.org/10.1057/s41599-023-02310-9
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Local, Indigenous and Traditional Ecological Knowledge (TEK) from Nuuk and Eastern Greenland

Table 1b Links to research databases and institutions in Greenland

Nuuk	**Research databases and institutions**	**Links / other sources**
	Arctic Hub	https://arctichub.gl/
	Greenland Research Council	https://nis.gl/en/
	Polar Bear Range States - Polar bear management and TEK	https://polarbearagreement.org/polar-bear-management/involvement-of-indigenous-peoples-and-incorporation-of-tek

Summary written by UOULU

Government of Greenland (2022) emphasizes in its research strategy that research should be done with close cooperation with local stakeholders combining Indigenous, local and specialist knowledge. Addressing research ethics, the Inuit Circumpolar Council (2022) recommends eight protocols for equitable and ethical engagement such as always engaging with Inuit, recognizing Indigenous knowledge, practicing good governance and communication, building trust and meaningful partnerships, sharing information and data, and equitably funding Inuit representation and knowledge.

Research on pollutants and health in Greenland including traditional knowledge has focused on traditional knowledge of polar bears. Studies have examined polar bear populations in East and Southeast Greenland, highlighting their adaptation to changing environments and burdens caused by POPs (Sandell et al. 2001; Dietz et al. 2001). Polar bears acquire relatively large burdens of POPs because their diet consists primarily of seals, and this affects their health and reproductive performance. Sandell et al. (2001) investigated the effects of POPs on polar bears by interviewing hunters, analyzing tissue samples from polar bears, and comparing frequencies of morphological anomalities in samples of polar bear skulls. Dietz et al. (2001) also asked the hunters about anomalities in sledge dogs. Laidre et al. (2018) analyzed two decades of traditional knowledge, revealing shifts in polar bear catches linked to climate change. Lennert (2016) states that "Traditional knowledge combined with natural science and studies of the fate of contaminants in Arctic marine ecosystems can indicate behavioural factors and elements that might act as additional stressors on animals and communities relying on them. Knowledge of the hunters is important for conservation and co-management." Baztan et al. (2017) investigated the links between climate science and Inuit knowledge. They based their research on 10 years of anthropological participatory research in Uummannaq, Northwest Greenland, along with two fieldwork periods, and a quantitative bibliometric analysis of the international literature on sea ice.

Food safety and information on contaminants in country food is essential for Arctic Indigenous peoples. In their assessments on human health, AMAP has included not only scientific knowledge but communicated directly also with regional experts, health officials and Indigenous representatives. They have concluded that there are several gaps in knowledge such as the lack of studies on the effectiveness of risk communication (Krümmel et al. 2024). Other research gaps identified were the need to focus on environmental features that matter to communities to foster their adaptations to change and the need to co-construct research with local communities (Baztan et al. 2017).

References/Publications added by ArcSolution scholars:

1. Dietz, R., Sonne, C., Born, E. W., Sandell, H. T., & Sandell, B. (2001). Forekomst af afvigende isbjørne i Østgrønland: En interviewundersøgelse 1999. *Danmarks Miljøundersøgelser, Aarhus Universitet. Faglig rapport fra DMU Nr. 359.*
2. Government of Greenland (2022). *Research – the road to progress. Greenland's National Research Strategy 2022 – 2030*. Ministry for Education, Culture, Sports and Church. https://nis.gl/wp-content/uploads/2023/01/english-book.pdf
3. Inuit Circumpolar Council (2022). *Circumpolar Inuit Protocols for Equitable and Ethical Engagement*. https://www.inuitcircumpolar.com/project/circumpolar-inuit-protocols-for-equitable-and-ethical-engagement/
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References collected by UOULU:

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9. Danto, A., Pertel, L., Danto, J., & Likhacheva, K. (2022). Linguistic Biodiversity, Natural Biodiversity and Traditional Ecological Knowledge: A Common Extinction. Questioning the Adaptive Capacities of Indigenous Peoples from Arctic and Sub-Arctic Regions. *Études finno-ougriennes*, (54), 37-62.
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11. Vongraven, D., Aars, J., Amstrup, S., Atkinson, S. N., Belikov, S., Born, E. W., ... & Wiig, Ø. (2012). A circumpolar monitoring framework for polar bears. *Ursus*, *23*(sp2), 1-66.

Local, Indigenous and Traditional Ecological Knowledge (TEK) from Tromsø and Skjervøy

Table 1c Links to research databases and institutions in Norway

Tromsø, Skjervøy	References / publications	Links
	Academic Research	https://en.uit.no/ub/searchhelp/databases
	Academic research at Nord University	https://www.nord.no/en/library/databases-and-resources

Summary written by UOULU, edited by NORD (Julia Olsen)

Many TEK-related studies from Northern Norway focused on the changing Arctic due to climate change, its different socio-ecological impacts and how communities may respond to the changes. The topic of pollution was not in the clear focus of most of the studies, but negative One Health impacts related to these major changes that communities need to adapt to were studied. There are studies on local and Indigenous knowledge on the changing economic and socio-ecological context of fisheries (Neis et al., 2013; Broderstad & Eythorsson, 2014). The study of Tiller et al. (2016) focused on local marine stakeholder perceptions on changes happening in their contexts and showed how they did not underestimate their risks to climate change. Sandersen et al (2020) highlights the importance of knowledge in adaptation strategies for Norwegian aquaculture sector. An article on Sámi ecological knowledge of reindeer herding examined to what extent herder´s knowledge and maps of seasonal pastures and migratory routes were used in local decision-making (Hausner et al., 2020). Their maps were highly complex and extensive. Sámi herders expressed concerns over the use of the pastures in the county administration, and they perceived threats from green energy development, tourism, recreation, public road construction, and powerlines. There was an indication that reindeer herders had a say in decision-making, e.g. 43% of the small-scale hydropower development cases were denied a license when the concerns were expressed.

Olsen et al. (2020) and Deshpande et al. (2019) present a method for extracting *local knowledge* of fishing gear handling and management practices for a more sustainable management of fishing gear since they add to the pollution load of the marine environment. In this context, local stakeholders' knowledge remained the only source of information. Danto et al. (2022) argue in their paper, how Indigenous languages that transmit TEK about the local environments are crucial for the adaptation to changing Arctic conditions. Indigenous languages are linking traditional knowledge with scientific findings for better understanding and management of natural resources.

Hovelsrud et al. (2021) studied climate change adaptation strategies in the context of avalanche danger, acknowledging the role of local knowledge and flexibility in preparedness strategies.

Tromsø books and papers added by ArcSolution scholars

1. Broderstad, E. G., & Eythórsson, E. (2014). Resilient communities? Collapse and recovery of a social-ecological system in Arctic Norway. *Ecology and society*, 19(3)
2. Eira, I. M. G., Magga, O. H., Bongo, M. P., Sara, M. N., Mathiesen, S. D., & Oskal, A. (2008). The challenges of Arctic reindeer herding: The interface between reindeer herders' traditional knowledge and modern understanding of the ecology, economy, sociology and management of

Sámi reindeer herding. In *Governing shared resources: connecting local experience to global challenges*, 12th Biennial conference of the International Association for the Study of Commons, Cheltenham (pp. 14-18).
3. Hausner, V. H., Engen, S., Brattland, C., & Fauchald, P. (2020). Sámi knowledge and ecosystem-based adaptation strategies for managing pastures under threat from multiple land uses. *Journal of Applied Ecology*, 57(9), 1656-1665.
4. Hovelsrud, G. K., Veland, S., Kaltenborn, B., Olsen, J., & Dannevig, H. (2021). Sustainable Tourism in Svalbard: Balancing economic growth, sustainability, and environmental governance. *Polar Record*, 57, e47.
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8. Tiller, R., De Kok, J. L., Vermeiren, K., Richards, R., Ardelan, M. V., & Bailey, J. (2016). Stakeholder perceptions of links between environmental changes to their socio-ecological system and their adaptive capacity in the region of Troms, Norway. *Frontiers in Marine Science*, 3, 267.

References added by UOULU:

9. Danto, A., Pertel, L., Danto, J., & Likhacheva, K. (2022). Linguistic Biodiversity, Natural Biodiversity and Traditional Ecological Knowledge: A Common Extinction. Questioning the Adaptive Capacities of Indigenous Peoples from Arctic and Sub-Arctic Regions. *Études finno-ougriennes*, (54), 37-62.
10. Deshpande, P. C., Brattebø, H., & Fet, A. M. (2019). A method to extract fishers' knowledge (FK) to generate evidence for sustainable management of fishing gears. *MethodsX*, 6, 1044–1053. https://doi.org/10.1016/j.mex.2019.05.008

Local, Indigenous and Traditional Ecological Knowledge (TEK) from Inari

Table 1d Links to research databases and institutions in Finland

Inari	Databases	Links
	Snowchange Cooperative	https://www.snowchange.org
	Natural Resources Institute Finland - LUKE	https://www.luke.fi/en/research
	Finnish Environment Institute - SYKE	https://www.syke.fi/en/research
	Giellagas Institute	https://www.oulu.fi/en/university/faculties-and-units/faculty-humanities/giellagas-institute
	Dialogues and Encounters in the Arctic	https://www.dialoguesencounters.com/

Summary written by UOULU

There is not much previous research done in Inari from a local, traditional or Indigenous perspective on pollutants, but some studies exist. Soininen et al. (2024) detected microplastics for the first time in lakes and rivers used by Skolt Sámi communities, with concentrations ranging from 45 to 423 microplastic particles per cubic meter. This research was initiated based on observations made by Sámi women about changes in water quality, demonstrating the value of traditional knowledge in guiding scientific inquiry. SnowChange is an organization which was started in late 2000 to document and work with local and Indigenous communities of the Northern regions in and around Finland. Participants are Finns devoted to the advancement of local traditions and culture and the health of the environment. They also collaborate with a network of local and Indigenous cultures around the world including the Saami, Inuit, Inuvialuit, Inupiaq, Gwitchin, Icelandic, Tahltan, Maori, and many others. Some of their works have touched upon pollution topics. One of their projects was about traditional knowledge on northern waters (Mustonen et al., 2018). During the project, over 9000 data items including Indigenous knowledge and oral histories to weather records were produced. Centrally, climate change is negatively affecting the health of fish and ecosystems in the Finnish Arctic. Also, a "Feasibility study on co-production of knowledge between researchers and Indigenous communities for climate change adaptation" project organized several workshops with Sámi reindeer herders, producing local and TEK data on the matter (Näkkäläjärvi & Juntunen, 2023).

Natural Resources Institute LUKE and Finnish Environment Institute SYKE have conducted some projects that include different types of knowledges, as found in the links in the Table 1d. Giellagas Institute located in Oulu Finland has a nation-wide responsibility to organize, introduce and provide Sámi language and cultural studies and research at the academic level. Their webpages contain information about studies including Indigenous knowledges.

Refrences/publications added by UOULU:

1. Mustonen, K., Mustonen, T. & Kirillov, J. (2018). Traditional knowledge of northern waters. Snowchange Cooperative. http://www.snowchange.org/pages/wp-content/uploads/2018/12/TraditionalKnowledge.pdf

2. Näkkäläjärvi, K. (2009). Perspective of Saami reindeer herders on the impact of climate change and related research. In *Climate Change and Arctic Sustainable Development: scientific, social, cultural and educational challenges*. UNESCO: Paris, 131-143.
3. Näkkäläjärvi, K., & Juntunen, S. (2023). Co-production of Knowledge on Climate Change Adaptation in Reindeer Sámi Culture: Research Methodology and Ethics. In *Reindeer Husbandry: Resilience in the Changing Arctic, Volume 2* (pp. 1-21). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-031-42289-8
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Local, Indigenous and Traditional Ecological Knowledge (TEK) from Canada

Table 1e Links to research databases in Canada

Canada	**Databases**	**Links**
	Northern Contaminants Program	https://www.science.gc.ca/site/science/en/northern-contaminants-program
	Inventory of TEK Projects and Engagement in Canada The study identifies existing frameworks in Canada for the engagement of Indigenous communities associated with Traditional Ecological Knowledge (TEK) at the international, national, provincial/territorial, and community levels, as well as TEK-related projects undertaken by universities and research institutions, public and government institutions, and private sector partners in Canada that have included the engagement of Indigenous and local communities.	http://www.cec.org/publications/inventory-of-tek-projects-and-engagement-in-canada/

Summary written by UOULU

In the Canadian Arctic on MacKenzie Delta area, research including both Indigenous knowledge and Western science has been conducted. In Canada, the Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in wildlife species that are important to the traditional diets of northern Indigenous peoples (Furgal et al., 2014). Thus, since the 1990s, scientists and Indigenous peoples have worked together across Inuit Nunangat to study contaminants and their many impacts. Henri et al. (2022) describes a project about science outreach and knowledge mobilization, developed as a part of contaminant monitoring programs on ringed seals. School workshops had a good potential to braid Western science and Inuit knowledge to support engagement of Inuit youth in environmental research. In another study, wintertime oceanography was explored using information from native elder from Eskimo Lakes and MacKenzie Delta River area (Garmack & McDonald, 2008). Different aspects of ice and water were examined. Among many aspects, they noticed that certain circulation features of ecological significance were relevant to concerns of development and transport of pollutants. A review by Johnson et al. (2023) studied how Indigenous and Western ways of knowing were woven together in research papers in the context of wildlife health and ecotoxicology. According to the results, 17 studies were identified, and most of them were initiated by mutual agreement between community partners and researchers, but research was not Indigenous led. Reviewed studies focused on environmental contaminants and health-related topics related to wildlife. Avian cholera, metals, and trace elements were primarily studied.

References added by UOULU

1. Bocking, S. (2017). Toxic Surprises: Contaminants and Knowledge in the Northern Environment. *Ice Blink: Navigating Northern Environmental History*, 421–464. (No free access, 27.2.2025)
2. Carmack, E., & MacDonald, R. (2008). Water and Ice-Related Phenomena in the Coastal Region of the Beaufort Sea: Some Parallels between Native Experience and Western Science. *Arctic Journal*, 61(3), 265–280.
3. Furgal, C., Boyd, A. & Chan, L.H.M. (2014). *Assessment of contaminant and dietary nutrient interactions in the Inuit health survey: Nunavut, Nunatsiavut and Inuvialuit - part 1: Risk perception and message evaluation study.* Ottawa, Canada: Synopsis of Research conducted under the 2013-2014 Northern Contaminants Program; 2014 [cited 2023 Dec 10]. p. 472. Available from: https://pubs.aina. Ucalgary.ca/ncp/80365.pdf
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5. Johnson, L. R., Wilcox, A. A., Alexander, S. M., Bowles, E., Castleden, H., Henri, D. A., ... & Orihel, D. M. (2023). Weaving Indigenous and Western ways of knowing in ecotoxicology and wildlife health: a review of Canadian studies. *Environmental Reviews*, 31(3), 452–470.
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7. McGregor, D. (2008). Linking traditional ecological knowledge and western science: aboriginal perspectives from the 2000 state of the lakes ecosystem conference. *The Canadian Journal of Native Studies*, 28(1), 139-158.
8. Poirier, S., & Brooke, L. (2000). Inuit Perceptions of Contaminants and Environmental Knowledge in Salluit, Nunavik. *Arctic Anthropology*, 37(2), 78–91. (No free access, 27.2.2025)
9. Usher, P. J., Baikie, M., Demmer, M., Nakashima, D., Stevenson, M. G., Stiles, M., & Arctic Environmental Strategy. Northern Contaminants Program [Sponsor]. (1995). *Communicating about contaminants in country food: the experience in aboriginal communities*. (No free access, 27.2.2025)

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Local and traditional ecological knowledge from the Arctic regions. References collected by UOULU.

1. Behe, C., Daniel, R. & Arndt, D.S. (2018). Indigenous knowledge and the coproduction of knowledge process: creating a holistic understanding of Arctic change. State of The Clim In 2017 *Bulletin of American Meteorological Society*. 2018;99 (8):SSi–SS310.
2. Boyd, A.D. & Furgal, C.M. (2019). Communicating environmental health risks with indigenous populations: a systematic literature review of current research and recommendations for future studies. *Health Communication*, 34 (13):1564–1574. doi: 10.1080/10410236.2018.1507658
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3. Fernández-Llamazares, Á., Garteizgogeascoa, M., Basu, N., Brondizio, E. S., Cabeza, M., Martínez-Alier, J., ... & Reyes-García, V. (2020). A state-of-the-art review of indigenous peoples and environmental pollution. *Integrated environmental assessment and management*, 16(3), 324-341. https://doi.org/10.1002/ieam.4239
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APPENDIX 2. SCIENTIFIC KNOWLEDGE

METHODOLOGY for APPENDIX 2

Information on research publications, included in this Appendix, came in primarily two non-systematic ways:

1. Initially, relevant key academic literature on pollution and One Health were informed about by ArcSolution WP leads and researchers by leveraging their expertise in the research field. Information was sent by email communication.
2. Additional limited Scopus search by UOULU team (Anastasia Emelyanova) via key terms included three main parts: non-specified pollutants, health, and geographical location. The results were specified to search within title-abstract-keywords filed, adding search filters, such as Year range (2010-2025), Document type (article, book chapter, review), Country/territory (e.g. Canada, Norway, Greenland etc.), and Language (English). The found articles were checked for suitability via abstract reads and, if needed, full text screening. Relevant articles were added to the tables in this Appendix and used to draw summaries. The references included were handled by Zotero software. Duplicates were removed when comparing Scopus search data with the references provided by ArcSolution partners.

The final product is an iterative process involving ArcSolution researchers from all WPs with regard to the data collection and analysis, several rounds of checks, discussions among the authors, and the work of internal reviewers. In the database search made by UOULU, we limited the time of the published articles to 2010-2025 and used search terms depicted below. It might be that the chosen databases and search string did not find all the relevant existing research. The 1st One Health model described in the Deliverable 2.1. is the first version of the model, and the process is ongoing for three more years for producing the ArcSolution One Health framework. References and data can be added at later stages.

Table. Keywords and search results for Scopus*

Query string for pollution and health related keywords	Geographical location related keywords	Full string	Number of hits in Scopus
pollution OR contaminant OR toxic OR pollutant *AND health* *AND human OR animal OR wildlife OR environment**	Svalbard OR longyearbyen	TITLE-ABS-KEY (((pollution) OR (contaminant) OR (toxic) OR (pollutant)) AND (health) AND ((human) OR (animal) OR (wildlife) OR (environment*)) AND ((Svalbard) OR (longyearbyen))) AND PUBYEAR > 2010 AND PUBYEAR < 2025 AND (LIMIT-TO (AFFILCOUNTRY,"Norway")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"re")	19

		) AND (LIMIT-TO (LANGUAGE,"English"))	
	Nuuk OR (East AND Greenland)	TITLE-ABS-KEY (((pollution) OR (contaminant) OR (toxic) OR (pollutant)) AND (health) AND ((human) OR (animal) OR (wildlife) OR (environment*)) AND ((Nuuk) OR (East Greenland))) AND PUBYEAR > 2010 AND PUBYEAR < 2025 AND (LIMIT-TO (AFFILCOUNTRY,"Greenland")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (LANGUAGE,"English"))	12
	Troms* OR skjervøy OR (Arctic AND Norway)	TITLE-ABS-KEY (((pollution) OR (contaminant) OR (toxic) OR (pollutant)) AND (health) AND ((human) OR (animal) OR (wildlife) OR (environment*)) AND ((Troms*) OR (Arctic AND Norway))) AND PUBYEAR > 2010 AND PUBYEAR < 2025 AND (LIMIT-TO (AFFILCOUNTRY,"Norway")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (LANGUAGE,"English"))	40
	Inari OR (arctic AND finland))	TITLE-ABS-KEY (((pollution) OR (contaminant) OR (toxic) OR (pollutant)) AND (health) AND ((human) OR (animal) OR (wildlife) OR (environment*)) AND ((inari) OR (arctic AND finland))) AND PUBYEAR > 2010 AND PUBYEAR < 2025 AND	9

		PUBYEAR > 2010 AND PUBYEAR < 2025 AND (LIMIT-TO (AFFILCOUNTRY , "Finland")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English"))	
	aklavik OR inuvik OR (arctic AND canada) OR (northwest AND territories)	TITLE-ABS-KEY (((pollution) OR (contaminant) OR (toxic) OR (pollutant)) AND (health) AND ((human) OR (animal) OR (wildlife) OR (environment*)) AND ((aklavik) OR (inuvik) OR (Arctic AND canada) OR (northwest AND territories))) AND PUBYEAR > 2010 AND PUBYEAR < 2025 AND (LIMIT-TO (AFFILCOUNTRY,"Canada")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"ch") OR LIMIT-TO (DOCTYPE,"re")) AND (LIMIT-TO (LANGUAGE,"English"))	137

*Note: Query was done within TITLE-ABS-KEY (title, abstract and keywords) field. Additional search filters were used: Year range (2010-2025), Document type (article, book chapter, review), Country/territory (e.g. Canada, Norway etc.), and Language (English).

Table 2a Scientific information and data (with references) from Svalbard and Longyearbyen

Svalbard and Longyearbyen	Environmental health - Pollution	Wild-life health – Pollution & Infectious diseases	Human health - Pollution	Notes
Existing scientific information and data (references marked with numbers)	1-2,4-5,7-9,12-13,16-17,20,22,24-25,29-33,35-39,41-45,47-56,58-63,65-67,70-71,74-75,78-82,85,87-88,90,92-93,96-98,100 https://www.researchinsvalbard.no/	3-6,10-12,14-15,18-19,21,23,26-28,34,40,46,57,64,68-69,72-73,76-77,83-84,86,89,91,94-95,99	Meta database 15,39,44,76	
Data collection needed (gaps)	https://www.miljovernfondet.no/prosjekter/ (Norwegian) https://www.miljovernfondet.no/en/projects/ (English)	19,72,86 SMF project information	Women health survey will start 2025-	
Input of locals in study sites selected	SIOS SESS reports:2017 – 2024			
	Monitoring of Svalbard and Jan Mayen (MOSJ)			

Summary written by UOULU

Even though located quite remotely, Svalbard still shows relatively high contamination levels of ocean and sea water (Bonanno Ferraro et al. 2024). From the available research evidence already twenty-fifteen years ago, it could be argued that wildlife and fish at the highest potential risk of POP and other contaminant exposure and mediated health effects are Svalbard polar bears, several species of gulls and other seabirds from the Svalbard area, and fish such as Arctic char (Letcher et al. 2010). Among birds, gulls were studied for concentrations of organochlorine contaminants (Sonne et al. 2012) and the occurrence of plastics in glaucous gulls breeding on Svalbard was also documented for the first time (Benjaminsen et al. 2022). Other studies for the first to report a significant and negative relationship between POPs and telomere length in a free-living bird and highlights sex-related susceptibility to banned pesticides (Blévin et al. 2016, 2017). **Marine and terrestrial mammals:** studies on health effects of pollutants were done on one of the most contaminated species from Svalbard such as walruses (Routti et al. 2019, Scotter et al. 2019), seals (Kanerva et al. 2012, Routti et al. 2014), Greenland sharks from Svalbard (Molde et al. 2013), polar bears (Bytingsvik et al. 2012, Vongraven et al. 2012, Gustavson et al. 2015, Tartu et al. 2017, Ciesielski et al. 2018), arctic fox (Pedersen et al. 2015). **Fish:** Current status, between-year comparisons and maternal transfer of organohalogenated compounds in Arctic char from Bjørnøya, Svalbard (Bytingsvik et al. 2015). **Human health:** Some pollution related human health studies have been published (Ørbæk et al. 2007; Brorström-Lundén et al. 2014; Kallenborn et al. 2016; Jensen et al. 2018). **The environmental health:** Kallenborn and co-authors have published extensively on POPs, PCBs, PFASs, pharmaceutical and other anthropogenic chemicals, and the influence of climate change to its distribution in Arctic air, soil, ice, permafrost and marine environment based on analysis in Svalbard (see f.ex. references 41-63 in the reference list).

As for the other data gaps, most researchers highlight the necessity of combining contaminants with other environmental factors in Svalbard animals such as age, element exposure, diet, and infectious micropathogens exposure need to be investigated as co-factors (Sonne et al. 2012, Scotter et al. 2019), reproductive health is of utmost importance and little studied (Bytingsvik et al. 2015). It was noted that the arctic fox from Svalbard may be an overlooked species in the Arctic Monitoring and Assessment Programs and it would add further information about pollution in the Arctic to include this species in the monitoring program (Pedersen et al. 2015).

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Table 2b Scientific information and data (with references) from Nuuk and Eastern Greenland

Nuuk and Eastern Greenland	Environment - Pollution	Wild-life – Pollution – Infectious diseases	Human health - Pollution	Notes
Existing scientific information and data (references, marked with numbers)	AMAP Assessments AMAP Review articles Solitary scientific articles 4,5,7,10,17,27	AMAP Assessments AMAP Review articles Solitary scientific articles Science of the Total Environment 3,7,8,17,27-28 Special Issue: AMAP Assessment 2021: Mercury Assessment in the Arctic 7 Mercury in Arctic biota (2,9,14,28) Contaminants in arctic wildlife (11-13,15,19,20-23,25) Daugaard-Petersen	A lot of AMAP data (e.g., Eva B-J et al)) Solitary scientific articles including comparative animal-human data (3,17,18,23) Human effects from contaminants (1,6,18,24,26-27,29-30)	New comparative data: animal-humans https://www.amap.no/documents/doc/amap-assessment-2021-mercury-in-the-arctic/3581 https://www.amap.no/documents/doc/amap-assessment-2018-biological-effects-of-contaminants-on-arctic-wildlife-and-fish/1663 https://www.amap.no/documents/doc/amap-assessment-2021-human-health-in-the-arctic/3593 In addition, effect review article in preparation (AMAP-related) plus primary references in all above
Data collection needed (gaps)		Reindeer Atlantic cod Humans (Scoresby Sound immune testing)	7, 26	
Input of locals in study cites selected				

Summary written by UOULU

The AMAP Assessment reports on heavy metals (2005), the latest ones on mercury (2021) and POPs (2016) in the Arctic, collected evidence and trends on some of the key contaminants in the environment of Greenland for over 30 years. The land, air and seas around Greenland have been studied and the contaminants have been found to be present, at times in the largest concentrations in the Arctic. Many past uncertainties on the sources, transport and transformation in the Arctic environment were addressed. Since the 1990s, there has been a trend of decreasing e.g. mercury and lead exposure; however, in Greenland, mercury and lead guidelines were still exceeded (AMAP 2021a). Anthropogenic effects have been seen even in the remote atmosphere of the North Atlantic, such as rapid increase in atmospheric iodine levels since the mid-20th century (Cuevas et al. 2018).

It was established that time or temporal trends of contaminants diverge among environment, wildlife, and humans e.g. heavy metals, PFAS (Lohmann et al., 2024) and POPs (Abass et al., 2018). Mercury, one of the most regionally comprehensively monitored pollutants, is found in Greenlandic marine and terrestrial biota, such as mammals, fish, seabirds and shorebirds (Dietz et al., 2013, Treu et al., 2022, Dietz et al., 2022). The species of polar bear, wolf, and seal were of particular focus of scientists studying species in Greenland (Letcher et al. 2010, Dietz et al. 2015, Levin et al. 2016, Daugaard-Petersen et al. 2018, Dietz et al. 2018, Dietz et al. 2019, Ho et al. 2023, Lohmann et al. 2024). Monitoring the diets of upper trophic level consumers in Eastern Greenland (McKinney 2013) and marine food intake in humans and exposure at the seafood processing work have been found associated with higher blood level of POPs, PFASs and heavy metals in Greenlanders (e.g. Dudley at el., 2015, Wielsøe et al. 2022, Long et al. 2023, Sonne et al. 2023, Andersen-Ranberg at al. 2024, Wielsøe et al. 2025).

Human health: Some of the PFAS and mercury concentrations for pregnant women and children measured in the past decade(s) are generally highest in Greenland, compared to the rest of the Arctic (AMAP 2021a).

Gaps in knowledge: AMAP assessment reports highlight the need for continued and expanded time series and human biomonitoring of e.g. blood, plasma or serum sampling to identify and show trends in contaminants in Greenland (e.g. AMAP 2021a, 2021b). Research studies suggest omissions of data in identifying causes of diseases. One example is thyroid autoimmunity in Greenlandic Inuit: study suggests genetic component in Inuit, but the impact of cold, selenium, and persistent organic pollutants needs to be elucidated (Noahsen et al., 2022)

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Table 2c Scientific information and data (with references) from Tromsø

Tromsø	Environment - pollution	Wild-life – pollution - infectious diseases + others	Human health – pollution	
Existing scientific information and data (references, marked with numbers)	23	18-22, 24-28	1-6, 17; MISA1 & 2 7-10; Fit Futures 2 11, 12; The Tromsø study	
Data collection needed (gaps)			Updated human concentrations from Tromsø	MISA: 105 blood/urine/BMilk/ hair/nail samples available for chemical analyses from Tromsø women/child, collected 2022-24
Input of locals in study cites selected				

Summary written byUiT (Solrunn Hansen)

Human health. The Northern Norway mother-and-child contaminant cohort study (MISA 1), established in 2007, has been a comprehensive and continuous assessment of the exposure to environmental pollutants experienced by pregnant and postpartum women and their newborns. The study, with repeated measurements spanning three periods, from the second trimester of pregnancy to six weeks postpartum, included 515 women from selected places in Northern Norway from 2007 until 2009, with 391 completing all study periods (Veyhe, 2012). An additional 50 new cross-sectional inclusions were added in 2014/15. As a continuation, MISA 2 was conducted in 2017, with a broader focus on contaminants, diet with a special focus on iodine, and lifestyle of women of reproductive age, namely non-pregnant (n = 137), pregnant (n = 112), and postpartum women with their babies (105 postpartum women and babies living in Tromsø). A comprehensive array of biological samples (blood, urine, hair, nails, cord blood, and breast milk) and questionnaires on past and present food intake, socio-demography, lifestyle habits, and obstetrical history have been collected. A large group from Tromsø and the nearby region participated in MISA 1, but previous publications have not stratified on location.

Relevant to ArcSolution and the Tromsø region, the newly collected MISA 2 allows for an up-to-date analysis of contaminants in breastfeeding women and their newborns. Further, data from MISA 1 and MISA 2 bring the potential for trend studies.

MISA has revealed declining serum concentrations of both PFAS and organochlorines from 2007 (n = 391) to 2020 (n = 40, not Tromsø) (NTNU, 2021; Xu et al. 2022), which reflects the reduction in exposure to these harmful pollutants. PFAS has declined by around half to 70% in the 10 years for PFOS (7.7. ng/mL vs. 2.3 ng/mL) and PFOA (1.5 vs. 0.8 ng/mL) (NTNU, 2021). Interestingly, the Fit Futures 2 study from 2011 with adolescents living in Tromsø has reported serum PFAS concentrations of females with, e.g., median PFOS of 5.8 ng/mL and PFOA of 2.06 ng/mL (Averina et al. 2018). The Tromsø study, including the adult population, observed an increasing trend for serum PFAS from 1986 to 2001 and a decreasing trend from 2001 to 2007, except for a continuous increase for longer-chained substances (Berg et al. 2021).

Similarly, the Tromsø study also revealed a declining organochlorine trend of 86% from 1986 to 2007 (Nøst, 2019). For the MISA study, we have reported generally low geometric mean (GM) serum concentrations of organochlorines with a decreasing trend from 2007 until 2019 (NTNU, 2021; Xu et al., 2022). The signature PCB 153 declined from 160 pg/g to 25 pg/g GM (NTNU, 2021). The serum concentrations for pooled samples of Σdioxin, including dioxin-like PCBs, declined from 24.6 in 2007 to 6.5 pg-TEQ/L (GM) in 2019 (Xu, 2022). Likewise, the most frequently detected pesticides, such as p,p'-DDE (85 vs. 72 pg/mL), trans—and cisnonachlor, declined by 32 56 % (NTNU, 2021). For pooled samples, pesticides were undetected primarily in 2019, except for p,p'-DDE, and hexachlorobenzene (HCB), with GM concentrations of 0.26 and 0.09 µg/L (DDE) and 0.09 and 0.05 µg/L (HCB) for 2007 and 2009, respectively.

When addressing toxic elements, MISA 1 revealed generally low whole-blood concentrations, except elevated Pb (7.4 µg/L), which was indicated to be contributed by hunted reindeer/moose and grouse (Veyhe et al., 2015). For Hg, unchanged GM concentrations from 2007 (1.21 ug/L) to 2015 (1.2 ug/L) were observed (Adlard et al., 2021).

The MISA study has reported significant associations between contaminants and dietary intake. Traditional foods such as marine fish and mammals, fish liver and seagull eggs, freshwater fish, and land-based wild animals were predictors of toxic substances (Veyhe et al., 2012; Berg et al., 2014). For PFAS, diets with various sources depending on substances were predictors, and marine food and meat were the dominating sources (Berg et al., 2014). These findings highlight the importance of dietary choices in reducing exposure to toxic substances and the potential for dietary interventions to improve public health.

In our studies from Northern Norway and Tromsø, several health implications for PFAS in adolescents and women of reproductive age are indicated. These include a negative effect on thyroid hemostasis (Berg et al., 2015), asthma (Averina et al., 2019), metabolism (Averina et al., 2021), and endocrine disruption (Averina et al., 2024). These findings underscore the potential risks associated with PFAS exposure and the need for further research and public health interventions to mitigate these risks.

The MISA study where samples from Tromsø participants are included.

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Summary written by UOULU

Environmental health. Local emissions of Arctic air pollutants and their impacts on climate, ecosystems and health are poorly understood. Air data were collected, for the first time, downwind of shipping and petroleum extraction facilities in the European Arctic, with a focus on the Norwegian coastal region. Present-day shipping/petroleum extraction emissions already appear to be impacting pollutant (ozone, aerosols) levels along the Norwegian coast and are estimated to cool and warm the Arctic climate, respectively (Law et al. 2017).

Wildlife health. Avian predators (birds) were studied for various pollutants and whether those caused adverse health effects. Mercury (Hg) exposure in Norwegian subpopulations of northern white-tailed eagle (Haliaeetus albicilla) was consistently below the suggested threshold for adverse health effects (Sun et al. 2019). Another study suggested that some legacy biomagnifying organohalogenated compounds challenge the antioxidant capacity in nestlings of white-tailed eagles (Sletten et al. 2016). Northern goshawk (Accipiter gentilis) measured for trace element pollution to study regional exposure, hypothesizing the potential health risks of metals and other trace elements, from nestlings from Tromsø (northern Norway). Overall metal and trace element levels do not indicate a high risk for toxic effects in the nestlings. Levels of Cd in Tromsø and Hg in Trondheim were however above sub-lethal toxic threshold levels. For holistic risk assessment purposes, it is important that the concentrations found in the nestlings of this study indicate that terrestrial raptors are exposed to various trace elements (Dolan et al. 2017).

Hg was declining in **freshwater fish** in Fennoscandia, including boreal and subarctic Norway (Braaten et al. 2019). Molluscs i.e. **Mytilus spp.** were used in environmental monitoring for seasonal and spatial variations in biomarker baseline levels within a 60-km radius from Rakkfjorden near Tromse, Norway and were found to be representative for mussels on a regional scale (Storhaug et al. 2019).

The compounds of emerging contaminants, such as phthalates, have been also found in **marine mammals** off the Norwegian coast, in most concentrations in white-beaked dolphin (Rian et al. 2020; Andvik et al. 2024). Concentrations were lower for porpoises collected along the coastal area of Bodø (Nordland), Lebesby (Finnmark) and Varangerfjord (as compared to other coastal areas); these areas are among the least populated coastal areas but also the most distant (>700 km) from offshore active oil and gas fields (Rian et al. 2020). These studies are important for future monitoring and management of legacy and emerging toxic compounds among various species, because concentrations and compounds were found quite drastically different among them from non-presence to already very toxic levels. Varying diet composition might cause these striking differences in legacy and emerging contaminant concentrations. For instance, the observed variations in contaminant levels were strongly correlated with diet composition across locations in the North Atlantic, emphasizing that diet and not environmental variation in contaminant concentrations among locations is crucial in assessing contaminant-associated health risks in killer whales (Remili et al. 2023). Future compound monitoring sampling design should include repeated sampling and collection of pollution history, water chemistry, fish and marine mammals age and other key parameters to enable evaluation of emission reduction policies. Monitoring marine mammal strandings is another important aspect of ecosystem management as stranded animals can provide indications on ecosystem health, pollution and adverse effects due to anthropogenic activities. Mass strandings of seven toothed and baleen whale species in Northern Norway in March 2020 call for further investigation (Aniceto et al. 2021) on whether pollutants were the cause of it.

The semi-domesticated **reindeer** (Rangifer tarandus) was studied for concentrations and geographical variations in selected toxic elements over northern Norway. The concentrations of all the studied elements in reindeer meat were generally low and considerably below the maximum levels (ML) available for toxic elements set by the European Commission. Thus, conclusion was that reindeer meat is not likely to be a significant contributor to the human body burden of toxic elements (Hassan et al. 2012).

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Table 2d Scientific information and data (references) from Inari

Inari	Environment - Pollution	Wild-life – Pollution - infectious diseases + others	Human health - pollution	Notes
Existing scientific information and data (references, marked with numbers)	1,2,3,4	1,2,3,5,6 Spatial and dietary sources of elevated mercury exposure in white-tailed eagle nestlings in an Arctic freshwater environment, https://doi.org/10.1016/j.envpol.2021.117952 - examined drivers of mercury contamination in White-tailed eagles in northern Finland Improved Environmental Status: 50 Years of Declining Fish Mercury Levels in Boreal and Subarctic Fennoscandia https://doi.org/10.1021/acs.est.8b06399	1,2,3, 7 Self-reported exposure to dust and diesel exhaust, respiratory symptoms, and use of respiratory protective equipment among Arctic miners https://doi.org/10.1080/22423982.2024.2343125	NFBCs and Nugen available From Inari pilot study also dietary data (1) available
Data collection needed (gaps)				

Input of locals in study cites selected				

Summary written by UOULU

Pollution and health effects in the Finnish Sámi home area have been gaining attention and since 2017, some studies have published results from the local environment and food, wildlife, and human health. POPs and potentially toxic elements were found to be low in pregnant women and local food items, whereas PCBs were the organochlorine compounds in highest levels in pregnant women and in food samples, even though in the last 14 years, serum PCB levels decreased 63% in pregnant women (Abass et al. 2022). Consuming locally harvested food products was analysed for important contaminant groups — radioactive substances, heavy metals, and POPs – also earlier in 2013-2015. The results showed that, in general, the levels of radioactive substances, toxic elements, and POPs were below the permitted EU maximum content in food products. Concentrations of all investigated toxic elements were highest in mushrooms, except for Hg, which was highest in fish. Mushrooms, fish, and reindeer were found to be important markers in the combined risk assessments for the contents of metals and radioactive substances. Further research, as well as the development of methodologies for combined assessments, are recommended (Hansen et al. 2017, Nalbandyan-Schwarz et al. 2024).

Microplastics should be monitored in the Finnish Sámi area, according to the most recent research. Despite its relatively pristine Arctic wilderness environment, microplastics were present in the local waters (Soininen et al. 2024). Sámi Indigenous knowledge proved to be a beneficial and important initiator because locals recognize the possible sources and transport pathways of plastic litter, and practical sampling sites in the complex freshwater systems of the area (Soininen et al. 2024).

Parasites were of interest to researchers in the local area. The prevalence of the Trichinella parasite, the one that thrives in the Arctic and subarctic and poses a risk for public health, was a focus infection studied in local wild carnivores. The results suggest that within some years and in the absence of T. spiralis reintroduction in the domestic habitat, it might even disappear from Finnish wildlife (Oksanen et al. 2018, Oksanen et al. 2022).

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Table 2e Scientific information and data (references) from Canada from Scopus and Memorial University

Canada **MacKenzie Delta area**	Environment health - Pollution	Wild-life health – Pollution & Infectious diseases	Human health - Pollution	Notes
Existing scientific information and data (references, give numbers)	2,3,6,7,9,12,15,22-26,32,34,41,54,56,63,64,71-74	4,5,7,9,10-12,14,16,20,23,25-27,29-31,33,35,36,37-40,42,45,49,51,52,55,57,58,60,62,63,65-67	1,7-9,13,18,19,21,23,24,28,30,36,38,39,43,44,46-53,61,67,68,69,70,72	
Data collection needed (gaps)	Uncertainty in sources and transport pathways of pollutants (e.g., PAHs, mercury). Limited understanding of climate change impacts on pollutant distribution. Lack of research on emerging contaminants (e.g., microplastics, PFASs). Insufficient long-term monitoring data to assess pollution trends	Limited studies on chronic toxicity of low-level pollutant exposure in wildlife. Poor understanding of interactions between pollutants and infectious diseases. Need for more research on the biomagnification of organic pollutants in Arctic food webs. The combined effects of climate change and pollution on wildlife health remain understudied.	Risk-benefit assessment of traditional food consumption vs. contaminant exposure is incomplete. Limited data on chronic health effects of low-level, long-term exposure to pollutants. Emerging contaminants (e.g., PFASs) and their health risks in Arctic populations are poorly understood. Lack of community-driven interventions based on contaminant exposure research.	
Input of locals in	Limited direct involvement: Many studies (e.g., Yunker et	Moderate involvement: Studies like Brook et al. (2009) and Schwalb et al.	Stronger local involvement: Studies on human biomonitoring	

study sites selected	al., 2002; Millot et al., 2003) focus on geochemical processes but rarely mention local input in selecting study sites. Emerging community-based approaches: Some recent studies (e.g., Åkerblom et al., 2022) incorporate community-based monitoring, where local knowledge helps identify critical areas for water quality assessment.	(2015) highlight the importance of local knowledge in identifying wildlife health issues and selecting study sites. Traditional Ecological Knowledge (TEK): Research on beluga whales (e.g., Scharffenberg et al., 2021) and fish populations (e.g., Jorgenson & Gyselman, 2009) often relies on local observations to guide site selection.	(e.g., Ratelle et al., 2018, 2020) and dietary exposure (e.g., Walker et al., 2021) frequent	

Summary written by Memorial University (Bing Cheng)

Research in the Mackenzie River Basin and Arctic regions has made significant strides in understanding the impacts of pollution on environmental health, wildlife health, and human health. However, critical gaps remain, and future directions must address these to ensure comprehensive and actionable outcomes. This summary synthesizes findings from the provided studies, highlighting trends, strengths, weaknesses, and future opportunities.

Environmental Health - Pollution

Current research on environmental health in the Mackenzie River Basin and Arctic regions has extensively documented the sources, transport, and distribution of pollutants such as polycyclic aromatic hydrocarbons (PAHs), mercury, and heavy metals. Studies like Yunker et al. (2002) and Åkerblom et al. (2022) have mapped the geochemical processes governing pollutant pathways, particularly in riverine and coastal systems. Long-term monitoring efforts, such as those by Evans et al. (2005), have established baseline data for contaminant levels, providing a foundation for assessing trends over time. A notable trend is the increasing use of community-based monitoring approaches, as seen in Åkerblom et al. (2022), where local knowledge is integrated to identify critical areas for water quality assessment. However, local involvement in study site selection remains limited in many environmental health studies, and there is a lack of research on emerging contaminants like microplastics, polycyclic aromatic compounds (PAC), and per- and polyfluoroalkyl substances (PFASs). Additionally, the impacts of climate change on pollutant dynamics, such as the release of stored contaminants from thawing permafrost, are underexplored. Future research should prioritize participatory approaches to align study sites with local concerns, investigate emerging contaminants, and assess climate change-driven shifts in pollutant distribution.

Wildlife Health - Pollution & Infectious Diseases

Research on wildlife health has highlighted the bioaccumulation and biomagnification of pollutants like mercury, PFOS, PFNA (Lohmann et al. 2024), and PAHs in Arctic wildlife, particularly in fish, beluga whales, polar bears, Canadian ringed seals, and birds. Studies such as Scheuhammer et al. (2015) and

Hebert et al. (2011) have demonstrated the significant impact of these contaminants on wildlife populations, including reproductive and immune system effects. A growing trend is the integration of Traditional Ecological Knowledge (TEK) in identifying wildlife health issues and selecting study sites, as seen in Scharffenberg et al. (2021) and Brook et al. (2009). However, there is limited understanding of the chronic effects of low-level pollutant exposure and the interactions between pollution and infectious diseases. For example, while some studies have explored the role of pollutants in weakening immune responses, the broader implications for disease dynamics in wildlife populations remain poorly understood. Furthermore, the role of climate change in exacerbating these impacts, such as through habitat loss or altered disease vectors, is underexplored. Future research should focus on long-term, low-dose exposure effects, strengthen investigations into pollution-disease interactions, and systematically integrate TEK into study designs to ensure relevance to local contexts.

Human Health - Pollution

Human health research in the region has provided critical insights into contaminant exposure among Indigenous populations, particularly through the consumption of traditional foods. Studies like those by Ratelle et al. (2018ab, 2020b), Laird et al. (2018), and Binnington et al. (2016) have used human biomonitoring to assess exposure to mercury, PAHs, POPs and PCBs, and other contaminants, while also exploring the nutritional benefits of traditional diets. A strong trend in this area is the emphasis on community-driven research, where local populations are actively involved in study design and site selection, as demonstrated by Bennett (2012) and Ratelle et al. (2018). This participatory approach has improved the relevance and applicability of research findings to local health concerns. However, there is limited research on the chronic health effects of low-level contaminant exposure, particularly for emerging pollutants like PFASs. Additionally, while studies have identified risks associated with traditional food consumption, there is a lack of actionable health interventions based on these findings. Future research should expand investigations into chronic health impacts, prioritize emerging contaminants, and develop community-driven health interventions to address contaminant exposure risks.

Overall Assessment and Future Directions

The current body of research demonstrates significant progress in understanding pollution dynamics and their impacts on the environment, wildlife, and human health in the Mackenzie River Basin and Arctic regions. Strengths include robust baseline data on pollutant levels, growing integration of TEK, and strong community involvement in human health research. However, weaknesses persist, such as limited local input in environmental and wildlife health studies, insufficient research on emerging contaminants, and a lack of long-term, low-dose exposure studies. A clear trend across all areas is the increasing recognition of the need for participatory research and the integration of local knowledge. Looking ahead, future research should prioritize emerging contaminants, investigate the impacts of climate change on pollution dynamics, and develop actionable health interventions. By addressing these gaps, researchers can provide more comprehensive and actionable insights to support the health and sustainability of Arctic ecosystems and communities.

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Table 2f Scientific information and data (references) from Great Slave Lake

Great Slave Lake	Environment - Pollution	Wild-life – Pollution - infectious diseases + others	Human health - pollution	Notes
Existing scientific information and data (references)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34	3, 5, 6, 7, 10, 11, 12, 14, 15, 18, 22, 24, 25, 27, 28, 29, 30, 31	6, 24, 34	
Data collection needed (gaps)	Limited research on emerging contaminants (e.g., PFASs, microplastics); climate change impacts on pollutant dynamics underexplored; inconsistent long-term monitoring.	Chronic, low-level pollutant effects poorly understood; pollutant-disease interactions unclear; climate change impacts on wildlife health understudied.	Chronic health effects of low-level exposure underexplored; emerging contaminants (e.g., PFASs) understudied; need for better risk-benefit assessments.	Future directions: Environment: Study emerging contaminants, and climate impacts, and enhance monitoring; increase local input. Wildlife: Investigate chronic toxicity, pollutant-disease links, and climate effects; integrate TEK systematically. Human: Focus on chronic effects, emerging contaminants, and risk-benefit trade-offs; expand

				community-driven research.
Input of locals in study cites selected.	Local involvement is rare; some recent studies use local knowledge for site selection (e.g., floodplain sampling).	TEK is used informally; moderate involvement in identifying wildlife health issues.	Strong local involvement in biomonitoring; community-driven research aligns with local priorities.	

Summary written by Memorial University (Bing Chen)

Research in the Great Slave Lake and its surrounding areas has provided critical insights into the impacts of pollution on the environment, wildlife, and human health. Below is a synthesis of the current state of research, highlighting key findings, strengths, weaknesses, and future directions.

Environment – Pollution

Great Slave Lake receives a wide range of contaminants from long-term upstream river and atmospheric transport. Heavy metals such as arsenic, mercury, and lead, as well as organic contaminants like polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs), are commonly detected in the sediment and water column. Localized areas occasionally exceed water or sediment quality guidelines, particularly near historical gold mines and oil sands development sites. Studies have established baseline data and monitoring programs to track the impacts of resource development and climate change on pollution in the lake area. For example, sediment core analyses reveal significant shifts in algal communities since the early 2000s, linked to declining ice cover and warming temperatures. These changes suggest that the Great Slave Lake is entering a new ecological regime, with potential cascading effects on the lake's carbon dynamics and food web. However, research on emerging contaminants like microplastics and per- and polyfluoroalkyl substances (PFASs) remains limited, and the long-term impacts of climate change on pollutant dynamics are not fully understood.

Wildlife – Pollution

Fish species such as lake whitefish, burbot, and predatory birds like gulls and terns are often used as bioindicators to detect cumulative levels of contaminants in the Great Slave Lake ecosystem. Studies have shown that mercury and some persistent organic pollutants (POPs) tend to biomagnify in top predator fish and birds. While most species remain within safe contamination ranges, higher concentrations are occasionally observed in predatory fish or specific areas, such as near the abandoned Giant Mine. The recent shift in algal communities, driven by climate change, may further impact fish populations by altering the base of the food web. However, the long-term ecological consequences of these changes, including potential impacts on fish health and biodiversity, are still unclear.

Human Health – Pollution

Wild resources, particularly fish and waterfowl eggs, are a vital source of protein for local First Nations and Métis communities. Most monitoring indicates that contaminant concentrations in fish are generally below federal or regional consumption guidelines, though occasional exceedances occur in specific species or locations. Studies evaluating the risk of PAHs and heavy metals have concluded that the overall carcinogenic risk or health threat is within acceptable limits. However, targeted monitoring and risk assessments are needed to address localized contamination hotspots and emerging contaminants like PFASs. Additionally, the ecological shifts in the Great Slave Lake, such as changes in algal communities, may indirectly affect food security and cultural practices for Indigenous communities reliant on the lake's resources.

Overall Trends and Future Directions

Environment: Research has established robust baseline data on traditional pollutants, but emerging contaminants and climate change impacts require further investigation. Enhanced long-term monitoring and community-driven research are needed to address these gaps.

Wildlife: While bioaccumulation of mercury and POPs is well-documented, the ecological consequences of climate-driven changes in the food web remain uncertain. Future studies should focus on the long-term effects of these shifts on fish and bird populations.

Human Health: Current risk assessments suggest that contaminant levels in fish are generally safe for consumption, but localized exceedances and emerging contaminants warrant targeted monitoring. Community involvement in research and risk communication is essential to address the needs of Indigenous populations.

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APPENDIX 3. INFORMATION RECEIVED FROM FOUR CONSULTATION MEETINGS

Table 1 Information received from four consultation meetings

LONGYEAR-BYEN	Central points of concerns from meetings regarding **the health of the environment**	Central points of concerns from meetings regarding **the health of wildlife**	Central points of concerns from meetings regarding **the health of humans**	**Mentioned pollutants**	**Wishes for researchers**, what is important to study	**Schools and citizen science**	Notes
Projects and Participant groups							
ILLUQ	Thawing permafrost Landslides Safety of surface water, sediment analyses (tentative)	Tentative	Revision of land use plan: more information needed Safety of tourists & locals, e.g., hiking, sailing,			Citizen science about permafrost (together with schools)	Maptionnaire (incl. eg. pollution, infrastructure, safety matters, cultural heritage) Water (sediment analysis) Schools + CS (year 3)

ICEBERG							Governance and policy briefs
ArcSolution **Consultation meetings**	**Wastewater management** (leaking sewers, releasing of freshwater / cloak in ocean, waste on the shore). **Pollution from** (closed) mines, weather stations, power plant, fisheries **Affects from flights, increased tourism, cruise ships** (diesel, grey water, black water, combustion system, garbage) **Pollutants, contaminants, heavy metals,** snowmobile and boats running with diesel as a source of pollution	**Reindeer and visible plastics**, (eg., nets, ropes) **Plastic in birds,** ubiquitous nanoplastic contamination of the air, effect on bird behavior, human health too. **Waste water management** **Water safety** and quality for dogs **Pharmaceuticals** (fish) Is there **avian flu** in Svalbard? (dead birds)	**Water quality and safety** (legionella, biofilm, fluor, manganese, vulnerability of the water source by sabotage and nearby road traffic) **Air quality** (diesel smoke and fumes: bad quality? Car exhaust. Poor pipes?) **Wastewater management** (leaking sewers creating ponds where children, dogs and tourists walk) New **dump site** locations (solid waste collection and transport to other locations, dumping of coal burning residue)	PFAS Hormones Heavy metals, lead from hunting Mining waste Plastics, microplastics, plastic additives, nanoplastics, rubber particles Styrofoam Pharmaceuticals Products of burning Diesel pollution Pollutants from melting glaciers PCBs Permafrost chemicals	**Communication, open and easy access to data and results** (newsletters, news, website, tool for mapping, access to maps, briefs for the public, summary of findings and publications, popular science summaries, dashboard monitoring available for water quality, contaminants, hearing from other study locations too). All in one place, with easily understandable language. **Collaboration and contacts with local authorities:** better communication about water quality (elderly and sick locals and tourists)	Collaboration with Folkehøgskole and Longyearbyen skole (incl also CS) Possible CS project with society concentrating on outdoor activities Citizen science collaboration & authorities, link	Women health population study will start Mentions about risks for cultural heritage (see **ILLUQ**). f.ex. differentiating cultural heritage vs. General waste Remobilization is worrisome Concerns over land use plans, changes in land use Wide-spread support for nuclear power is worrisome Wishes: clean source of

	Effect of settlements on nature **Climate change,** changes in nature, permafrost thaw, melting glaciers, landslides, avalanche, safety of visitors and natural disasters, high CO_2 release **Rainwater:** water runs off and takes everything from the streets into the rivers	**Trichinella** in polar bears **Contaminants and animal health** (Are there areas where animals /organisms are more contaminated? PFAS, contaminated soil draining to the sea by the airport and coal port (fishing)) **Climate change:** new species, more animals, animal health and biodiversity, wet weather More **dogs** in Svalbard -> biological waste, diseases	Cocktail of **pollutants** (combined effects and compounds that have unknown effects, **accumulation** of pollutants, **long range pollutants,** contaminated mushrooms under the coal transportation lines? **Microplastics in blood, women's health** **Mental health** (dark season, culture in small towns, rumors, gossiping, alcoholism, rape culture) **Long-term sickness** **Safety** of locals and tourists, permafrost and failure to infrastructure, physical injuries, avalanche: soil and	Whatever there is in drinking water (fluor)	and zoonosis (avian flu & reporting the dead birds), official channel for answering questions and provide information about pollution and health **Environmental awareness and actions:** More coast cleaning, identification of pollution hotspots, remediation of land and water potentials, upgrade/switch out filter for cloak and pipes, reduce the risk of diesel (shore to ship) **Mapping of emissions, pollution** (Different pollution maps of LYB, marine litter hot spots, warming scenarios, environmental effects of windmills)		energy (wind and solar) & reduce the risks of diesel (transported by ships, spills to the sea, fumes)

			dirt will come to town **Health of long-term residents vs. short-term residents**		**Long-term monitoring and following** of development of different aspects of nature and community **Material for use in education,** can project data be used in schools, like in math classes? **Suggested studies:** Study of hormones; Samples form dead dogs, and other killed animals (hunters); study of health of dogs; Knowledge for land-use planning; study of different lifestyles **Collaboration with** Aktiv i friluft, with Polarinstitute. Unis involvement, High North News, posting in “Ros & Info Longyearbyen” in FB, Svalbardposten.		

					Other suggestions: *What is the baseline?* *Modelling of the flux* *Transect measurement* *Measure length)* *Time series and possibilities to combine data*		
Schools / teachers			**Human health:** Lifestyles		**Teachers:** Dumping of sewage water as CS topic. **CS needs to be part of the curriculum**, useful for teachers, let students be useful. **To create a bridge between younger and older students.** To connect actions to 10th grade and vocational school students.	Students of Technology and science class **interested in participating in science projects**, esp. water related. Interested in communication with other schools participating in project, online/offline. Photography, video-making as part of projects, exhibitions, gallery	**Researcher suggestion** to schools: visible and invisible pollutants, plastics, microplastics, other contaminants, contaminants from waste or sea plastics, water samples, speci fic species

					OneHealth framework would work well. Psychology related task/project for the students.	Pollution topic in curriculum. Interested in making a pedagogical package. To visualize to students e.g. the heavy metals, microplastics to human health. Laboratory visits.	Taking soil samples for pollutants. Chemical experiment. Schedule: May and June challenging times.
NUUK	Central points of concerns from meetings regarding **the health of the environment**	Central points of concerns from meetings regarding **the health of wildlife**	Central points of concerns from meetings regarding **the health of humans**	**Mentioned pollutants**	**Wishes for researchers, what is important to study**	**Schools and citizen science**	Notes
ILLUQ - Ilulissat, Sisimiut, Nuuk (Qanaaq), own consultation meetings						CS project in elementary school (2. Year) in Ilulissat	Sewage solutions, and raw water measurement, sediment samples

ICEBERG - Southern Greenland, own consultation meetings						CS project with school (on going)	
ARCSOLU-TION **Consultation meeting**	Sewage Solid waste management Contaminants Plastics on shore, local source	Sewage Solid waste management Fishing nets	Food sovereignty, security Clean food Sewage and clean water Solid waste management Infectious diseases Explosions in airport construction sites, dust Plastics	**Hg**, Pb (one PhD working in contaminated mines) Plastics, fishing gear	**Pollution of the environment** (where is it coming from?). Infective diseases, pollution, and solutions, how to have better health of environment and settlements, food and behavior in general, solutions for food safety. Possibility to reach high-level impacts from the results at the local level). **Main perspective is to focus on environment,** change the focus from human health to the health of environment.	Fishing gear, film about it? Previous observations by hunters and fishermen (pictures and notes). Herders? Exchange between project participants possible. **Material for education:** Biological issues with focus on environment – wild-life – impacts to the humans	Fishing gear: possible collaboration with Skjervøy Role of traditional food central **Concern:** Plastics; how to use the guidelines, position paper; lack of persons who are working from Indigenous side; how to get rid of contaminants? Different concerns in

					Ethical issues: data governance (who can use, protection of Indigenous data), dissemination of results in local level **Importance of dissemination and communication** between researchers and Indigenous peoples, language important, stories, pictures. Communication with decision makers. **How to follow different ethical guidelines/regulations** in EU, non-EU, national, Indigenous Peoples – the demand of open data from EU side **How to catch industry?** **Smaller projects**: Brown fat; ecotoxicology,		**urban and in rural areas** **Arctic Hub** as an important link in study site (ethics, Indigenous issues, connections with stakeholders, produces materials, organizes events) Concern: Status of social media

					mining toxicity; food and behavior.		
Education, University	Pollution free environment				**Collaboration with education of nurses**: biological/environmental topics, local knowledge, joint sessions with education institutes from other study sites **Collaboration with the university of Greenland**: internet courses, PhD courses (PhD course in the connection of Nunamed 2025 and perhaps an ArcSolution session), what kind of education is needed now? Inueli courses, Institute of learning, Arctic education collaboration **Communication** from international to local levels: not a	Joint sessions with educational institutes.	

					book, practical solutions needed **Local methods** need to be developed together with the locals **Collaboration:** Brown fat project and polar bear connection with Christian Sonne Present on-going courses that could be involved jointly, e.g., Nursing science, biology (or something else from nature) Meetings/workshops every year and participating in local events		
Tromsø /Skjervøy	Central points of concerns from meetings regarding **the health of the environment**	Central points of concerns from meetings regarding **the health of wildlife**	Central points of concerns from meetings regarding **the health of humans**	Mentioned pollutants	Wishes for researchers, what is important to study	Schools and citizen science	Notes

Consultation meetings	Quality of drinking water Sewage Leakages of pollutants from contaminated sites Microplastics in wastewater, removed snow is disposed to the sea, problems with microplastics, tire wear from cars Pollution from landfills, contamination of sediments	Landfill pollution, health of fish		Microplastics, landfill pollution	Fish samples from Orndalen Collaboration with D Solve possibly on fishing nets		NILU project on tyre wear in cars
Schools					Sustainability is good topic for collaboration Establishing a joint platform for ArcSolution school projects	**Tromsø:** Interested. They could be designed, run and interpreted by the pupils with scientists having a consultory role Skjervøy: Positive towards	Plans in schools should be made in April/May for the following school year.

						collaboration. possible projects on marine and freshwater fisheries, aquaculture and hunting/reindeer herding. Important if pupils would learn new methods	
INARI	Central points of concerns from meetings regarding **the health of the environment**	Central points of concerns from meetings regarding **the health of wildlife**	Central points of concerns from meetings regarding **the health of humans**	Mentioned pollutants	Wishes for researchers, what is important to study	Schools and citizen science	Notes
Consultation meeting s	**Health of water:** lakes, rivers (oceans) **Microplastics** **Plastics,** plastic litter from feed bales of reindeers in forest and in lake, hand warmers left to ice and found in Lake Inari, canisters and beer cans found in	**Health of fish** in lake Inari Some species have disappeared, new have appeared **Noice pollution** from aircraft, from huskies	Noice pollution from **aircraft, huskies** **Lightpollution** from f.e.x tourism construction sites Poor water quality of one river due farming caused stomach issues Climate change thins the ice which is dangerous, driving	Microplastics plastics heavy metals Radiation Chemicals carbon dioxide Finnofoam Polystyrene anti-slip chemicals	LUKE and Inari municipality had a socio-economic project of lake Inari. They are looking for author for doing a synthesis/lit review on this Mercury is not problem but it is found in connection with gold mining on	Citizen science project to take samples from fish and water?	Municipality is doing stormwater survey There is water quality restoration project in one river, Akujoki only river with poor quality

	the Vätsäri wilderness Finnfoam, polystyrene Garbage left by tourists Pollution from snowmobiles Problems with recycling Heavy metals and radiation due Ukrainian war from Russia **Air traffic** and pollution of it, air quality, anti-slip chemicals, propylene glycol for aircraft de-icing, carbon dioxide emissions, dust from airport **Emission from recreational use of snowmobiles**	**Lightpollution** Worry if **mad cows' disease** in deer in Norway will come to Inari **Ticks** **The reindeer herds** are becoming weaker as calves are sold for meat Good health of huskies is important. Problem: they poop on ice and it is not cleaned	conditions also more difficult	propylene glycol for aircraft de-icing mercury	Kutturantie especially, the drainage ditches could be examined		water due farming To enhance recycling in the area and in tourism industry is important, to plan campaigns for reduce littering

	Mercury in gold mining Problems with **mining** **Tourism** and all their **wastewater** goes to one wastewater treatment plant, **litter the tourists left,** need better recycling Hay and grass increasing, likely due the reindeer feeding						
Schools					Restore Indigenous knoweldge on plants and reindeer treatment and preparation for food	CS is of interest, in relation to SAKK and Sami villages (Nellim, Lisma). Good if continues after the project in schools New slaughterhouse will be built to SAKK, how to treat its waste as a CS project, and samples of reindeer stomachs	Guides are educated in SAKK. Teacher state that a change in attitude of students would be necessary for sustainable development

						SAKK has fish processing unit, samples from there possible	

Summary of the information received from the consultation meetings:

ArcSolution researchers organized four consultation meetings in four study locations; in Longyearbyen Svalbard (8/2024), Nuuk Greenland (10/2024), in Tromsø and Skjervøy (11/2024) northern Norway, and in Inari (1/2025) Northern Finland.

1. Longyearbyen, Svalbard

The meeting held in **Svalbard** had a team of 12 researchers and the project manager from the ArcSolution project spending four days in **Longyearbyen, Svalbard**, initiating the co-creation process with **municipality, local experts, businesses, the hospital, schools, and the general public**. The meeting was organized in collaboration with ArcSolution sister projects ILLUQ and ICEBERG, and some activities were carried out together. Several meetings were held. The main topics of discussion from the consultation meetings are presented in Table 1.

First, a **permafrost-related meeting** was held, and the aim was to understand 1) what is already going on within permafrost research in Svalbard and 2) learn about what is planned in the three new EU projects ILLUQ, ArcSolution and ICEBERG. During the discussion round, the participants stressed the importance of coordinating research initiatives relating to permafrost and the need to organize similar events during the project period.

The aim of the meeting in the **hospital** was to inform the local hospital in Longyearbyen about the planned activities in the ArcSolution project, specifically regarding pregnant women and the collection of human tissue samples from the general population. The need for the hospital's support in sampling from pregnant women, as well as the logistical arrangements necessary for sampling all fertile women in Longyearbyen, were discussed. The conversation also focused on how the project can effectively reach the diverse population in Longyearbyen,

Lokalstyret open meeting on water supplies was held. The communication officer at Lokalstyre could assist in feeding information about the projects into Lokalstyret's *innbyggerapp* (citizen app), which includes interactive maps and easy-to-read documents. There was also a **meeting with Longyearbyen waste management**.

There were **three meetings with the tourism industry representatives** with researchers of NORD and UOULU. The main concerns were plastic in birds, and as waste on the shores, sewage, vulnerability of drinking water, dog waste, invisible pollution from the diesel powerplant, trichinella in polar bears, pollutants from the mines and from the equipment left behind by past research projects, and the effects of climate change to the safety of visitors in case of natural disasters such as landslides and collapsing ice caves. Their wishes for the projects included doing something together with the locals and local schools and communicating with locals through Svalbardposten and Facebook. They would like to know what happens in other research locations. They also hoped to reduce the risks of diesel and increase for clean sources of energy. They campaign for tourists to stay longer because the emissions from travel are a big problem. In the future "last chance" tourism will increase but they are likely to ban cruises with more than 500 to 750 passengers. People come to see wildlife, the polar bears, whales, walruses and birds. They also think that biofuels will be important in the future.

There were two consultation meetings, one with stakeholders and one open to the public. They were arranged together with ArcSolution, ILLUQ, and ICEBERG. Participants were asked three questions: 1) What are your concerns related to pollution, health, and permafrost? 2) What are the specific pollutants of concern? How can the projects best address these concerns? 3) What are your wishes and needs? To summarize the discussions, the greatest concerns were PFAS, PCBs, plastics, wastewater management, the quality of drinking water, pharmaceuticals, pollution from closed mines, weather stations, the power plant and fisheries, air quality, pollutants from melting glaciers, permafrost chemicals, and the health of dogs. The wishes for the researchers included communication on the results and access to data, collaboration with local authorities, and mapping of emissions and pollution, to name a few.

There were **meetings with local schools** where teachers were very interested in joint citizen science (CS) projects with ArcSolution. CS needs to be part of the curriculum. In Svalbard Folkehøgskole they were interested in communicating with other schools participating in the project, and that students would use their preferred communication channels to pass on the information to each other about the CS project and to plan the CS project. They can also take photography as a part of the CS activity. Teachers also want to show science as a creative project. They could make a video or have a photo exhibition. Topics for CS projects could be visible and invisible pollutants or consequences of dumping sewage water in the fjord. In LYB school teachers wished that CS needs to be part of the curriculum, so that it is useful for the schools and teachers, and that students would do research activities. Topics suggested for the CS project were micro plastics or taking soil samples and studying pollutants. Keeping in touch with the university and making laboratory visits would be interesting for the students. Researchers could also visit the school and meet the students there. The CS project (in the curriculum) could benefit all grades including the youngest students. A teacher suggested a psychology-related task for the students in participating schools.

2. Nuuk

For Greenlanders the important topics are traditional food, ethical issues (together with data governance of human biological data and protection of Indigenous data), dissemination and education (internet courses, PhD studies and a course in the connection of Nunamed 2025) at the local level. Infective diseases and food security (sovereignty) were mentioned to achieve better health in the environment, wild-life, and communities. Joint activities in research, e.g., the brown fat project was introduced. The contaminants concerns are Hg, plastics and dust, sewage and clean water, solid waste management, and fishing nets. There are hopes and suggestions for collaboration e.g., in biological issues and topics in nursing science and environmental pollution. Annually arranged meetings and workshops are important for feedback and new openings, and the goes for *joint sessions* with education institutes from different study sites. Data is needed to stay in Greenland, and all research should give high-level impacts at the local level. All research should be done by using a community-based participatory research approach, and the One Health approach is starting from the health of the environment. The goal is a pollution-free environment (together with locals and experts), and practical solutions are needed – from knowledge to solutions. Arctic Hub is a link between Greenlandic people and Greenlandic research, and it shares information from the ArcSolution project (e.g., stories annually).

3. Tromsø and Skjervøy

In Tromsø and Skjervøy five scholars from ArcSolution participated to the meetings. In Tromsø, meetings were held in Kongsbakken VGS (high school), Tromsø municipality, D-Solve and with AMAP secretariat. School was visited in Skjervøy.

The main concerns for the municipality were the quality of drinking water, sewage (fish nearby the harbor/city), leakages of pollutants from contaminated sites, microplastics in wastewater, removed snow disposed to the sea, pollution from landfills, and contamination of sediments. Stakeholders were positive to be involved in the project and noted that they can contribute with the collection of samples.

It was suggested that fish samples would be taken from Ørndalen in Tromsø, which is a popular fishing place for tourists but contaminated by wastewater. Collaboration with D Solve was planned possibly on fishing nets.

In Skjervøy there was interest in collaboration with other sites concerning trout and reindeer. Abandoned fishing nets and gear are a concern there.

The schools suggested that sustainability is a good topic for collaboration. In Tromsø they were interested in CS projects that could be designed, run and interpreted by the pupils with scientists having a consultatory role. The main ambitions of the project were to obtain scientific results (from CS as well), and rise awareness of the issue of Arctic pollution. Pupils could also speak with decision makers on their projects. In Skjervøy they were positive towards collaboration with possible projects on marine and freshwater fisheries, aquaculture and hunting/reindeer herding. Issues of concerns were plastic pollution, effects of climate change to fish habitats, and PFAS in fish. They considered it important for pupils to learn new methods. Schools should make plans in April/May for the following school year.

4. Inari

There were two people from ArcSolution in Inari from January 6 to 9. They had 6 meetings with the representatives of the municipality, airport, Friends of Nature Association, Metsähallitus, SámiSoster, Sámi Education Institute and the tourism industry. Five meetings were arranged face-to-face and one was arranged online. There was no consultation meeting due to the wishes of the Sami Parliament.

The main concerns were microplastics and plastic from the reindeer feed bales in lakes and forests, hand warmers left to ice and found in Lake Inari, and canisters left in the wilderness. Also, water quality was an issue, especially with one old wastewater treatment plant and the increasing number of tourists. There was poor water quality in one river due to farming, which caused stomach issues. Other worries were emissions from the recreational use of snowmobiles, mercury in gold mining, and the air traffic and its chemicals and effect on air quality. There were also concerns over heavy metals and radiation possibly coming from Russia due to the Ukrainian war.

Regarding wildlife, the central concerns were the health of fish in Lake Inari and the possibility of mad cows' disease in deer spreading from Norway. Other worries concentrated on noise pollution from aircrafts and from huskies, light pollution, the spreading of ticks, the reindeer herds becoming weaker as calves are sold for meat and the health of huskies and a possible health concern for wildlife since the dogs poop on ice and it is not cleaned.

The municipality of Inari is conducting a stormwater survey in case of a sudden increase in rainfall to avoid the situation in Spain (where flash floods caused destruction in cities). The municipality also had a socio-economic project with LUKE (Natural Resources Institute Finland) regarding Lake Inari. This included, among other things, the impact of tourism and snowmobiles on water quality. For schools, citizen science projects would be very good because the problem there (among students) is understanding scientific information.

For SAKK it is crucial to restore Indigenous knowledge on plants and the treatment and preparation of reindeer for food. There will be a reindeer slaughterhouse to be completed for the educational institution in the fall of 2026, as well as a leather processing plant for training facilities. This would provide, for example, reindeer stomachs, rumen contents or poop for research purposes. SAKK also has a fish processing unit, so samples can also be taken from fish. A teacher had stated that a change in attitude would be necessary for students regarding sustainable development.