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Mercury Risk Evaluation, Risk Management and Risk Reduction Measures in the Arctic (ARCRISK)

Inception Report

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Norwegian Institute for Water Research

REPORT

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Summary

The project “Risk evaluation, risk reduction and risk management action plans for mercury in the Arctic – a circumpolar management approach” (ARCRISK) has been developed to address mercury pollution in the Arctic. The main objective is to develop an action plan with targeted risk reduction measures for mercury releases from key sources to land and water in the Arctic. The action plan will cover key sources from each of the four selected case study river catchment basins in Canada (1), Norway (1), and Russia (2). The ARCRISK project team consists of experts from nine highly skilled research institutes, universities and other institutions, from Canada, Norway, Russia and USA. An inception workshop was held in Oslo in March 2020 to consolidate the team and collectively develop the project framework. The present report summarizes key deliberations and decisions made as part of the inception phase, to further operationalize the project, making detailed plans and decisions for implementation of the project in 2020-2022. In addition to the components described in the inception report, the framework also includes an updated budget and a workplan for implementation of WP2-6.

Four keywords

1. Mercury
2. Release
3. Arctic
4. Risk assessment

Inception Report

Mercury Risk Evaluation, Risk Management and Risk Reduction Measures in the Arctic (ARCRISK)

This report is quality assured in accordance with NIVA's quality system and approved by:

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Abbreviations

AC	Arctic Council
ACAP	The Arctic Contaminants Action Program
AMAP	Arctic Monitoring and Assessment Programme
APN	Akvaplan-niva
ARCRISK	Mercury Risk Evaluation, Risk Management and Risk Reduction Measures in the Arctic
BAT	Best Available Technique
BEP	Best Environmental Practice
ECCC	Environment and Climate Change Canada
EG	Expert Group
GMA	Global Mercury Assessment
Hg	Mercury
INEP	Institute of the Industrial Ecology Problems of the North
MC	Minamata Convention
MSU	Department of Land Hydrology at Moscow State University
NEA	Norwegian Environment Agency
NEFCO	Nordic Environment Finance Corporation
NIVA	Norwegian Institute for Water Research
PMG	Project Management Group
POI	Pacific Oceanological Institute of the Far Eastern Scientific Center of the Russian Academy of Sciences
POPs	Persistent Organic Pollutants
PSG	Project steering group
PSI	Arctic Council Project Support Instrument
SRI	Scientific Research Institute for Atmospheric Air Protection
TU	Trent university
UNEP	The United Nations Environment Programme
WG	Working Group
WWU	Western Washington University

Table of contents

Summary

The project proposal “Risk evaluation, risk reduction and risk management action plans for mercury in the Arctic – a circumpolar management approach” (ARCRISK) was initiated in 2017 to address mercury pollution in the Arctic. The main objective of ARCRISK is to develop an action plan with targeted risk reduction measures for mercury releases from key sources to land and water in the Arctic. The aim is closely aligned with the purpose of the Arctic Contaminants Action Program (ACAP); to prevent and reduce pollution and environmental risks in the Arctic. The action plan will cover key sources from each of the four selected case study river catchment basins in Canada (1), Norway (1), and Russia (2).

The comprehensive ARCRISK proposal package was developed over three years (2017-2019), in close collaboration with the ACAP expert group on mercury and persistent organic pollutants (Hg&POPs EG). After multiple deliberations and reviews, including the EG, the ACAP Working Group (WG), the Arctic Monitoring and Assessment Programme (AMAP), NEFCO, and various key stakeholders, ARCRISK was approved by the EG in December 2018 and the WG in February 2019. The Arctic Council Project Support Instrument (PSI) Committee (PCOM) decided on funding in October 2019 and the Contract between NIVA and NEFCO was signed in December 2019. Provided a successful completion of WP1 and PCOM approval, the WP2-6 will be implemented, tentatively starting in the last quarter of 2020.

The ARCRISK project team consists of experts from nine highly skilled research institutes, universities and institutions, in four countries (Canada, Norway, Russia and USA). Building on the robust project framework developed with input from experts from the ACAP Hg&POPs EG, the team have used the inception phase to further operationalize the project, making detailed plans and decisions for implementation of the project in 2020-2022.

The present inception report provides a description of the project framework developed throughout the inception phase, including a work plan, a budget and an overview of important deliberations and key decisions made at the project inception workshop in Oslo in March 2020.

In summary, the following key components have been elaborated and determined for further implementation of the project:

- The organizational set-up of the project, including tasks and responsibilities
- The geographic focus and scope of the project
- Important considerations concerning risk assessment
- The involvement of stakeholders
- Considerations around a project management group and an advisory group
- Country-wise budget allocations

The present report provides a thorough description of how the ARCRISK has been further operationalized, motivations for the choices made and important changes made in the original proposal.

1 Introduction

The development of the project "Risk evaluation, risk reduction and risk management action plans for mercury in the Arctic – a circumpolar management approach" (ARCRISK) was initiated in 2017 to address mercury pollution in the Arctic. In line with the mission of the Arctic Contaminants Action Program (ACAP), to prevent and reduce pollution and environmental risks in the Arctic, the main objective of ARCRISK is to develop an action plan with targeted risk reduction measures for mercury releases from key sources to Arctic rivers. The action plan will cover key sources from each of the selected case study river catchment basins in Canada, Norway, and Russia.

ARCRISK was developed in the backdrop of the ratification of the Minamata Convention (MC) on mercury that entered into force in 2017, with the objective to "*protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds*". Whereas emissions to air gained significant attention throughout the negotiations of the convention, less attention was bestowed to mercury releases to land and water. Two obvious explanations behind this tilted focus was the vast body of science available to document emissions from industrial sources (e.g. coal-fired power plants and boilers, non-ferrous metal- and cement production), in large contrast to the few studies available on industrial releases, and the co-benefit of a general increased focus on conventional air pollution control during the last decades. In general, the hesitancy to address releases to land and water has likely been due to the lack of a robust knowledge-basis on the characteristics, occurrence, and volume of mercury from release source categories. However, recently, the importance of the release sources has gained increased attention, and the release estimates made in the Global Mercury Assessment (GMA) was reinforced between the 2013 and the 2018 edition, providing data on new sources and revaluation of original ones (AMAP/UNEP 2013; 2018).[1] Still, the latter report concluded that more sources are likely to emerge in future updates of the report: "*In future assessments of aquatic mercury releases, it is reasonable to expect that additional releases may arise from sectors and activities not quantified in the 2015 inventory due to the lack of information that would enable a reliable global quantification, or from smaller anthropogenic sources not currently detailed in the global inventory work*" (GMA 2018, tech. report, p. 6-1). Probably reflecting this evolving science, the MC has to date still not produced a guidance document that may aid parties in identifying and addressing mercury release sources to land and water; in starch contrast to the Best Available Technique (BAT) / Best Environmental Practice (BEP) guidance document that was set up for air emissions already before the MC entered into force and adopted at the first Conference of the Parties (COP1).[2]

As the international community is gradually raising its attention to how release sources should be defined and addressed, there is presently also a lack of a comprehensive overview of mercury release

[1] The reports were coproduced by the Arctic Monitoring and Assessment Programme (AMAP) and UN Environment Programme (UNEP)
[2] More information available at www.minamataconvention.org

sources to the Arctic rivers and ocean. Empirical data that bridges the human and industrial sources with the fluxes and levels of mercury is scarce, and so is also a comprehensive understanding of the potential implications of these key sources for human health and the local ecosystems, both under the current and future scenarios. External stressors such as climate change, increased industrialization, and urbanization may further exacerbate the situation e.g. by influencing the natural mercury cycling and should therefore be taken into consideration when assessing mercury releases. Concurrently with the ongoing processes under the MC it is crucial to obtain a better understanding of the presence and magnitude of mercury release sources to the Arctic, and the risk associated with these releases, especially to locals and indigenous habitants.

The ARCRISK project was developed to bridge existing knowledge and strengthen the knowledge basis, feeding into the ongoing processes under the MC. In December 2019, the project contract was set up between the Nordic Environment Finance Corporation (NEFCO), as fund manager of the Arctic Council Project Support Instrument (PSI), and the Norwegian Institute for Water Research (NIVA). Financing was approved by the PSI Committee (PCOM) for the inception phase (Work Package 1) of the project. Provided the inception phase has been completed in a successful manner and the present inception report has been deemed acceptable by the PSI, the PCOM will process and assertively approve funding for WP 2-6.

1.1 Mercury in the Arctic

Mercury is of concern for being neurotoxic and bioaccumulative. While toxic, mercury has remarkable chemical properties that humans have exploited since antiquity. Areas of application include consumer products (e.g. thermometers, sphygmomanometers, dental amalgam, switches and relays, fluorescent lamps, batteries), industrial processes (e.g. PVC production, chloralkali industry, paper and pulp production), and traditional gold extraction (Langford and Ferner, 1999). Moreover, mercury is a common impurity of most minerals, and thus mercury can be introduced to the environment where mining and burning of coal, oil, and gas is occurring (Romanov et al., 2012; Rytuba, 2003).

Mercury is a volatile element, and once in air it can be transported over long distances with wind currents (Selin, 2009). Thus, sources of mercury can be both local and long-range transport. Local sources of mercury in the Arctic is small compared to the total contribution from long-range atmospheric transport (AMAP/UNEP, 2019). Atmospheric mercury deposited on land will be stored in the soil and slowly leak to streams, rivers and lakes. Because of this slow leakage, despite being small compared to the total contribution from long-range transport, local sources may still be very important for the local impacts of mercury in the arctic.

The arctic region is particularly sensitive to mercury pollution due to the combination of several factors; the main air currents of the northern hemisphere directs towards the Arctic, bringing along mercury and other pollutants from anthropogenic activity further south (Ariya et al., 2004). The marine food chains can be long, which allows for elevated bioaccumulation of mercury through the food chain (Lavoie et al., 2013). Moreover, many people living in these areas have a high dependency on marine mammals and seafood in their diet. Cohort studies have revealed significant correlations between prenatal exposure to mercury and subtle, non-clinical effects in infants (Butler Walker et al., 2006; Dallaire et al., 2013). Considerable efforts are being made to address mercury pollution facing the Arctic ecosystems, e.g. the EU Mercury Strategy and the MC. However, to be able to reduce mercury levels in the arctic region there is a need to identify the main local sources, including local releases to land and water, in addition to tackling the global sources contributing to the Arctic by long-range transport.

1.2 The role of Arctic Rivers

Arctic rivers have been found to deliver significant amounts of mercury to the Arctic ocean, and particularly during the summer season with thawing and snow smelt (Leitch et al., 2007; Fisher et al., 2012; Graydon et al., 2009; Emmerton et al., 2013). The rivers transport mercury stemming both from active local release sources as well as from historical pollution deposited in soils and sediments (both of local and long-transported origin). Settlements and industries are typically located along the coastal zone and alongside large rivers, both constituting local release sources and risk endpoints. Examples of release sources include mining and other metallurgical industries, paper and pulp mills, and municipal wastewater. Mercury release from historical deposits (e.g. waste dumps, contaminated sites, industry closures, etc.) is particularly critical in the context of melting permafrost (Stern et al., 2012). The released mercury has a strong binding affinity to particulate and dissolved organic carbon with which it is transported (Kirk and St. Louis, 2009). Depending on local particle size distribution and flow regime, mercury-rich particles are typically deposited at the outlet of the river.

The level of knowledge of releases of mercury to the aquatic environment is very low compared to the emissions to the atmosphere; in the GMA 2018 it is stated that the "*inventory of global anthropogenic Hg releases to aquatic systems is a work in progress, and an important step towards filling a major gap in inventories of anthropogenic Hg releases to the environment*". In the GMA 2018, the most dominant release sources of mercury to water on the global level were ASGM, non-ferrous metal production, municipal wastewater, mercury added products, large-scale gold mining, coal-fired power plants, and coal washing (**Feil! Fant ikke referansekilden.**, UNEP/AMAP, 2018). The authors of the report emphasised that future updates are likely to include more and new sources, while also strengthening the data foundation of the sources that have already been documented. Several of these sources are also to some degree present in the Arctic. However, a dedicated and comprehensive overview of mercury release sources to the Arctic rivers and ocean is lacking. Hence, a better understanding of mercury release sources, current environmental levels and future levels in the context of a rapidly changing climate, as well as potential impact on human health and ecosystem within the Arctic circle is warranted to facilitate knowledge-based policy development and to identify priority reduction measures and strategies to mitigate such sources.

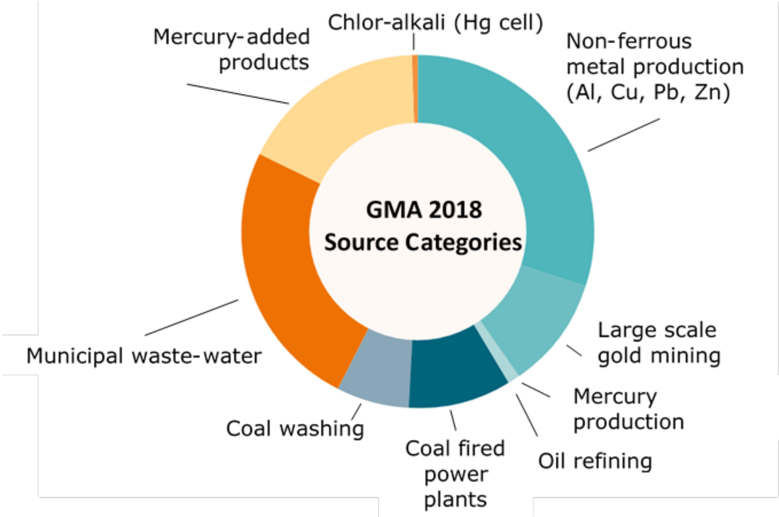

Figure 1. Prominent mercury release sources to aquatic environments globally (UNEP/AMAP, 2018). Note that ASGM, despite assumed to be largest source category, is not included in the figure and discussed separately in the GMA report.

1.3 Mercury - Risk Evaluation in the Arctic

Mercury has a high potential for bioaccumulation and biomagnification and thus poses a significant risk to the Arctic local population, primarily through the consumption of mercury contaminated fish and other marine animals (Langford and Ferner, 1999). Consequently, even though mercury concentration in water is low, the levels in fish and other animals can be high. In addition to knowledge on mercury release sources and exposure pathways, external factors may have a large impact on mercury risk for the following exemplified reason: For mercury to be taken up in the food chain it must be methylated and the process of methylation is typically mediated by bacteria under anoxic conditions. Anthropogenic activities may amplify this natural process by creating artificial anaerobic conditions, such as through the establishment of dams (Calder et al., 2016; Hecky et al., 1991).

A central part of the ARCRISK project will be to carry out a risk assessment of mercury exposure, adapted to the Arctic environment, that considers a probabilistic evaluation of multiple stressor effects from external drivers, such as climate change, industrial activity, and changing population patterns. Additionally, it will facilitate identification and prioritisation of targeted actions to reduce and eliminate mercury exposure to human health and the environment in the region. The need for more knowledge on this type of multiple stressors effect has repeatedly been highlighted by the Arctic Council (AC) and its working groups.

Currently there are substantial individual differences among the AC members on the management of risk. The present project may contribute to a greater consolidation of existing management efforts of the transboundary risk posed by mercury, thereby contributing to improving the effectiveness of national efforts to eliminate mercury releases. The project will include selected ACAP member state localities with point and non-point release sources of mercury input to the Arctic Ocean with riverine export, including Canada, Norway, and Russia. Following a comprehensive risk evaluation, the project will develop action plans to prioritise and reduce the risk of mercury releases to the Arctic environment, with a focus on feasible and efficient measures that will enable a sustainable development in the region.

1.4 Development of the ARCRISK project

The ARCRISK project is built on a robust project framework developed over a three-year period (2017-2019), with multiple consultations with a wide range of stakeholders (Table 1). To accommodate input and requests from the AC member states, the ACAP Working Group (WG), the expert group (EG) on mercury and persistent organic pollutants (POPs), and NEFCO, the project team has developed several revisions of the proposal package.

When the first sketches of an ARCRISK project proposal for ACAP was developed in 2017 it was also decided that Norway would be the lead country of the proposal. Concurrently with reaching out to potential collaborators in the AC member states, the NIVA team in October the same year met with both the ACAP EG Chair, Åke Mikaelsson, and NEFCO representatives to discuss formalities around submitting a proposal to ACAP.

Table 1. Timeline and milestones for development of the ARCRISK proposal

Year	Month/date	Task
2017	April	Drafting of ARCRISK proposal initiated
	September	Project concept note developed
	September	Outreach to potential partners
	October	ARCRISK team meeting with Norwegian Environment Agency (NEA)
	October	ARCRISK team meeting with Hg & POPs EG Chair
	October	ARCRISK team meeting with NEFCO representatives in Helsinki
	October	Concept note submitted to Hg & POPs EG
	November	First proposal draft circulated among project team members
	November	Hg & POPs EG first discussion on proposal
	November	ARCRISK proposal submitted to Hg & POPs EG
	November	ARCRISK proposal development welcomed by ACAP WG in Anchorage
2018	February	Proposal shared with AMAP for comments
	April	First revision of proposal based on input from EG
	August	Second revision of proposal based on input from EG
	November	Third revision of proposal based on input from EG
	December	Full project proposal approved by Hg & POPs EG
2019	February	Full project proposal approved by ACAP WG
	August	Contract development by NEFCO
	December	Contract for ARCRISK work package 1 (inception phase) signed
2020	January	Start-up of project
	March	Inception meeting
	May 1st	Deadline draft inception report
	May 29th	Deadline final inception report

Throughout this process, involving revisions and feedback from the EG, WG and AMAP, it was recommended to reduce the original scope of the project. Initially planned as a circumpolar project with field work in all eight of the AC member states, it was decided to reduce the size of the project by focusing on three states: Canada, Norway and Russia. Furthermore, it was recommended to split the project into smaller work packages and reduce the budget accordingly. As a consequence, it was decided that the project would not carry out own measurements of mercury in the environment, but rather base the project on existing data and information, supplementing with input from interviews with local stakeholders (municipalities, industry, NGOs, etc.). The plan to carry out sampling at case study locations, to obtain high-resolution data on release sources present in the selected catchments, was thus abandoned. Moreover, it was at this point decided not to develop a full quantitative BN model for each of the sites. Rather the project will strive to develop a conceptual model as a starting point. Understandably, with this change, the project design also had to be changed to include sites where data was existing and accessible to the project team.

1.5 ARCRISK - Project objectives

The project objective for the *complete* ARCRISK project is to develop an action plan with targeted risk reduction measures for mercury releases[3] to land and water from key sources in the Arctic. The selection of sources will be based on an assessment of mercury releases from point and non-point sources of mercury, and their relative contribution and potential effects (Figure 2). The action plan will include targeted policy measures, management options, best practices, and recommendations for technology investments that can effectively reduce the risk of mercury exposure for humans and the environment in the Arctic. The action plan will cover 2-3 key sources from each of the four selected case study catchment basins in Canada (1), Norway (1), and Russia (2).

[3] The term 'releases' is derived from the terminology used under the Minamata Convention on mercury, where the word 'releases' is used to describe releases to land and water, whereas 'emissions' is used to describe releases to air.

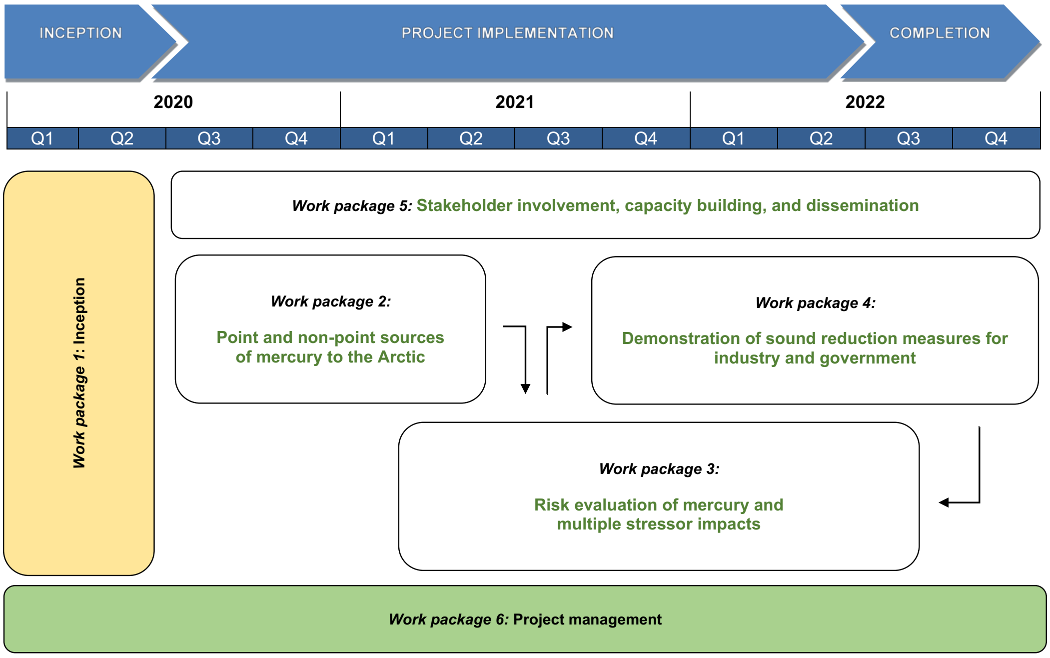

Figure 2. An overview of the main work packages for the ARCRISK project, including: inception (1 Ongoing), point and non-point sources of mercury (2), risk evaluation and impacts from external stressors, including climate change, industrial development, and urbanization (3), demonstration of reduction measures for industry and government (4), stakeholder involvement, capacity building, and dissemination (5), and project management (6).

In the proposed project, the NIVA, in collaboration with partners from four AC member states and selected stakeholders, will evaluate risks of mercury releases to the Arctic environment. The project will include four localities in three ACAP member states with potential point and non-point sources of mercury input to the Arctic Ocean, including Canada, Norway, and Russia. These localities have been chosen in accordance with explicit selection criteria, including their potential for representing various other sites in the Arctic (see Chapter 3 for a description of decisions made in inception phase). Following a risk evaluation of sources and environmental impact, based on existing data, the project will develop targeted action plans to mitigate the risk of mercury releases from key sources to the Arctic environment, with a focus on feasible and cost-efficient measures that will enable a sustainable development in the region.

An important outcome of the project will be a prioritised list of effective actions and investments for reduction of mercury risks to the Arctic populations and environment. The risk-based approach, including a review of sources and identification of key measures in the four localities, will provide concrete reduction measures with high relevance for a larger part of the Arctic. The project will not only identify and assess the current risks, but also consider the risks associated with different plausible future environmental (e.g. climatic), societal and economic development scenarios. This will ensure valuable project outcomes with relevance for Arctic communities in both a short (months and years) and longer perspective (years and decades).

The ARCRISK project is divided into six work packages, of which PSI financing has been approved for work package 1 (WP1) – the inception phase. The present inception report documents the work that has been carried out during WP1, including a description of decisions made and important changes in the project framework.

2 Inception Phase

2.1 Approach (inception phase)

Representing a large international collaboration project between multiple organizations and various Arctic States the ARCRISK project was designed with an inception phase. An essential part of the inception phase was to bring partners together, to closely develop the project framework, building on the approved proposal and partner capacities, taking into consideration the different perspectives and professional input, as well as the geographic and socioeconomic differences.

Once the ARCRISK project was approved by ACAP (EG and WG), the PSI/NEFCO released funding for the inception phase with a purpose to prepare a final, detailed, and operational project framework including work plans, budget details and organizational set-up with key stakeholders. A contract was set up between PSI-NIVA in December 2019 with a project timeline from 1 January – 29 May 2020. However, various project preparations had been carried out also through the entire project development phase between 2017-2019. Throughout this period, catered by consultations with stakeholders and partners, the ARCRISK team had thoroughly been preparing grounds for project design and implementation (Table 1).

The core activities within the inception phase – as specified in the terms of references (Annex A) was to:

- Organize an inception workshop and unite the project team
- Develop a complete project framework
- Set up a project management and advisory group

The advancement of the three elements will be elaborated further in the sub-Chapters below, with the decisions made and rationale presented in Chapter 3.

2.2 Inception workshop

Building on the ARCRISK proposal the project lead organization NIVA in January 2020 started preparations for an inception workshop during the Spring 2020. All project partners were invited and asked to prepare material and presentations, as a foundation for discussions and for sharpening the project design. The meeting was held in Oslo during 3rd and 4th of March 2020, just prior to the large outbreak of the Covid-19 in Europe. Representatives were physically present from Russia, Canada and

Norway, with additional participants from Canada, US and Finland taking part by web conference (Annex C). Between six- and nine-hour time difference between the meeting in Oslo and our most distant participants, induced some challenges for participating a full day workshop, but the electronic means worked well, and all participants were able to contribute constructively with input to the proposal development.

Since ARCRISK includes a team of experts from nine different institutions located in four different countries, a significant share of the first day was set off to introducing the team's different expertise and the institutional capacity within the team. The purpose behind the introductory session was to bring everybody "on the same page" and contribute to establishing a strong and unified project team. In addition, some of the experts had been asked to carry out a more thorough preparatory assessment of proposed study locations, which implied using their local expertise to assess relevance, suitability and feasibility of case study river catchment systems. A complete description of the selection of study sites and the motivation of applying them in the ARCRISK project is provided in Chapter 3. Moreover, two of the Bayesian Network experts presented a proposed risk assessment approach, based on the Bayesian Network Relative Risk Model developed by Professor Wayne Landis.

The project lead from NIVA provided a detailed account of how the project proposal had been developed in close cooperation with the ACAP Hg & POPs EG and later the WG, with several rounds of revisions and modifications to accommodate the conditions and requirements of ACAP. Although project partners have regularly been informed about the three-year project development, they had not an in-depth knowledge of all input and requests provided by ACAP and its member states, key determinants for shaping the proposal to what it has become. To complement this information and to provide further details around the formal procedures of approving the inception report and executing WP2-6, Mrs. Annukka Valkeapää, Manager for Environment and Technology from NEFCO, informed the team about next steps once the report has been approved. Unfortunately, there were technical difficulties with connecting her by web conferencing, so following phone conversations the information was provided by email correspondence.

Throughout the workshop the team discussed numerous outstanding issues, technical and practical challenges, and methodological approaches. Some of the key issues that were discussed included the selection of case study locations, the risk assessment approach, case study comparability, types of sources, data validity and strength and key deliverables from the project. Further description of the outcome of these discussions is provided in Chapter 3.

2.3 Project framework

Since the ARCRISK project proposal have been developed over three years as described in section 1.2, with multiple rounds of inputs from project partners, AC member states, ACAP Hg & POPs EG, ACAP WG and other stakeholders, the proposal package have achieved a rather advanced state, building on robust expert advice from AC member state nominated Hg & POPs experts. Hence, the inception phase was set-up to develop the proposal into a more practical and operational framework with further concretization of workplan specifying tasks and responsibilities, budget allocations, stakeholder output, and as appropriate, draft contracts.

The project framework submitted as part of this inception report has been developed based on the deliberations introduced in section 2.2. and will be described in further details in Chapter 3. The package consists of the following documents:

- Inception report with annexes (A-D)
- A workplan describing tasks and responsibilities (Attachment 1)
- A budget for ARCRISK work package 2-6 (Attachment 2)
- Contract between NIVA and PSI (Attachment 3)

A contract between NIVA and PSI/NEFCO, covering the inception phase, was set up in December 2019. As part of the inception phase contract were set up also with the partners participating in the inception workshop and contributing to the inception phase. These contracts however will only cover work package 1. It was considered premature to start drafting contracts for work package 2-8, at this point, since the inception report has not yet been processed and approved.

2.4 Organization

The organizational setup of the ARCRISK project is illustrated in Figure 3. Originally planned as an entirely circumpolar project, including all eight member states, the original scope and budget frame was considered too large and it was thus suggested to include fewer case study countries in the project. With the objective to still cover a wide geographic span of the Arctic, encompassing a range of potential release sources, diversity of human interferences and geographic settlements, as well as highly proficient institutional presence: Canada, Norway and Russia were selected as case study countries.

ARCRISK is an ACAP project that was initiated and is led by NIVA. The host country for the proposal is Norway. NIVA have reached out to eight different institutions in four of the Arctic member states, also including US, that all were enthusiastic to take part of the project.

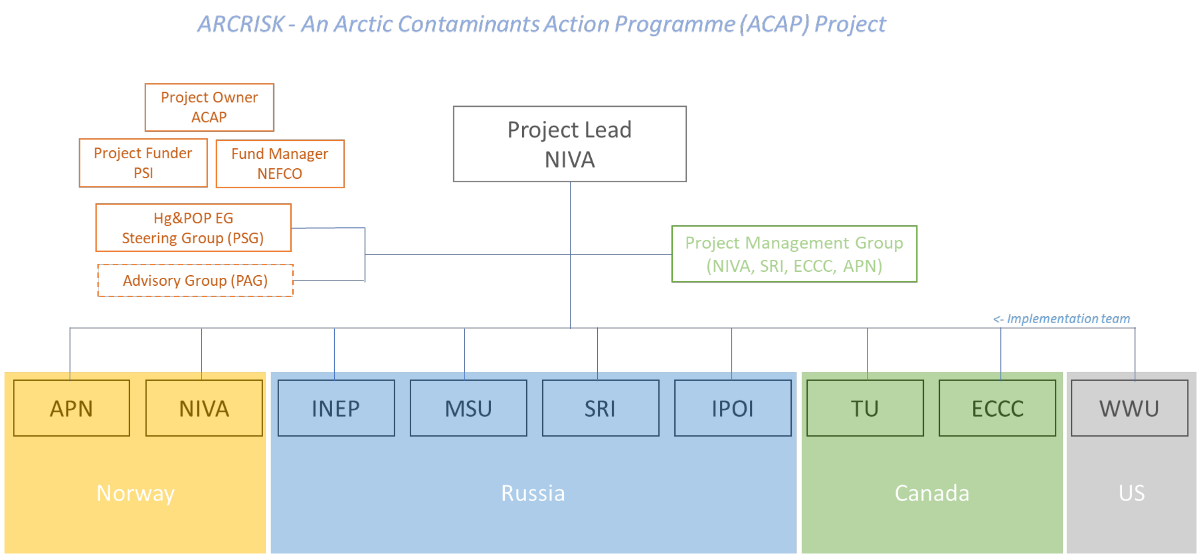

Figure 3. An overview of the ARCRISK organizational chart.

One of the decisions made in the inception workshop was to designate both a country lead and thematic work package lead (Figure 4). The first will be responsible to facilitate smooth coordination of task within each of the three countries, whereas the latter will ensure thematic coherence, comparability and exchange of best practices between countries and regions.

Furthermore, a Project Management Group (PMG), consisting of four institutions and with representatives from each of the three countries, was established to safely coordinate the project. The PMG will be responsible for ensuring progress of the project, developing annual budgets and activity plans, progress reporting to stakeholders, coordination and handling of any deviations from the plan. When appropriate the ARCRISK PMG will also contribute to necessary communication and outreach.

It is a common practice within the ACAP EG to assign an ad-hoc group of experts, here termed a project steering group (PSG) that follow the project closely and interact with the project lead when necessary. Beyond the PSG and the PMG, it has been an ambition to set up an advisory group for the project. In the early phases of the development of the project (2017), the leads reached out to relevant candidates, that were positive to contributing to the project.[4] However, since the project approval procedure stretched out and took around three years, some of the candidates have either taken on other responsibilities and priorities or left their position. Hence, candidates for such an advisory group will have to be approached once WP2-6 has been accepted. It is in this case important to note that a concern was raised at the inception workshop that the organization of the project and its different steering groups would become too bureaucratic and reporting requirements too burdensome. This comes on top of a wide range of stakeholder outreach activities that are integrated in the project. Another concern was that this may place a considerable load on an already comprehensive and ambitious project with already extensive outreach and field work at four localities in three different Arctic States.

Nonetheless, it should be emphasised that in spite of such a concern the ARCRISK team sees the relevance of having a group of experts/advisors, with different capacities and local expertise, that can be consulted and involved as appropriate and in an efficient manner. To this end, a list of relevant stakeholders and potential advisors has been prepared, experts that the ARCRISK team has considered relevant and has regularly contact with (Annex D). That said, the final composition, role and organization of such a potential group will be settled first when the inception phase have been improved and a full-scale implementation of the project has been granted. Consequently, once setting up contracts for work package 2-6, we invite ACAP to a discussion on a feasible approach on this matter and how to set up an effective and acceptable mechanism for expert advice throughout implementation of the full-scale project.

[4] Mr. Lars-Otto Reiersen, former secretary of AMAP and Mrs. Mikala Klint, Ministry for Environment & Food, Denmark, where two of the experts the ARCRISK team reached out to in 2017.

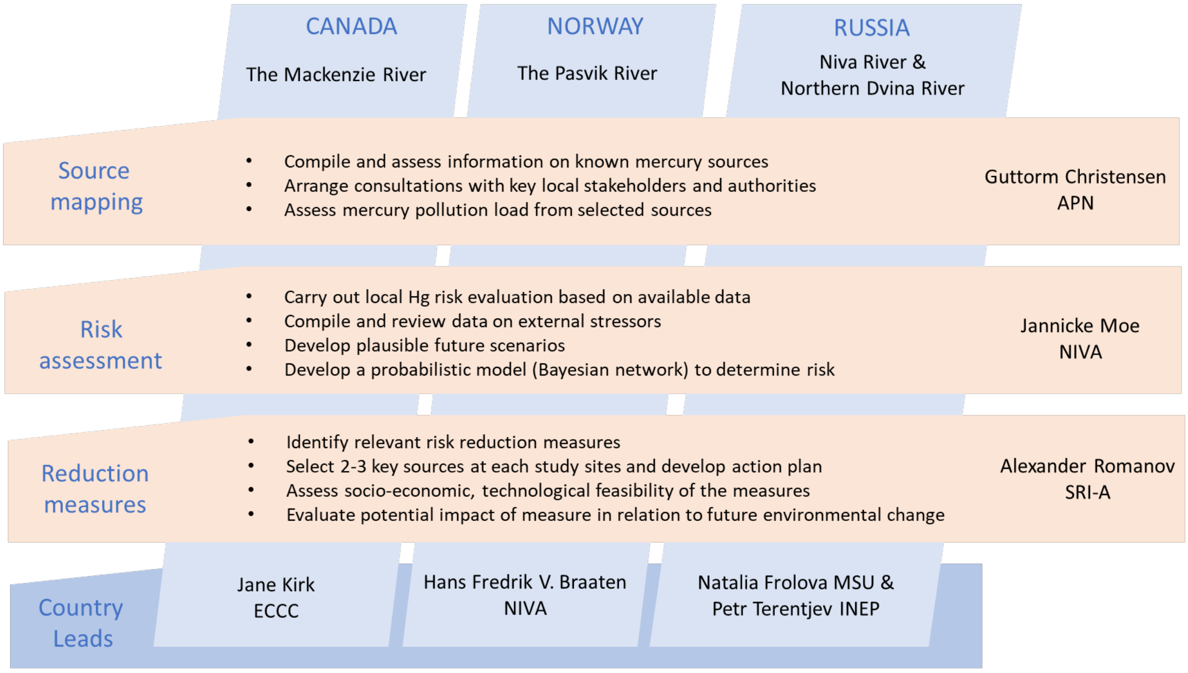

Figure 4. An overview of the ARCRISK implementation approach, including country leads and thematic leads.

2.5 Project team

The project team has been assembled to represent the broad scientific expertise needed to answer the overall project objectives. The team complement each other interdisciplinary by constituting i) natural scientists and technical experts experienced in mercury pollution, fate and transport in the Arctic, ii) specialists in risk assessment and management, in particular using Bayesian network for environmental risk assessment, and iii) social scientists and policy experts with long experience in working towards the industry and governments with mercury releases and regulations.

2.5.1 Expertise on mercury pollution, fate and transport

From all three countries, Russia, Canada, and Norway, natural scientists are represented that both have experience in studying the pollution, fate, transport and trends of mercury in the Arctic, as well as local knowledge on the selected study sites. This combined experience/knowledge is critical to obtain a thorough understanding of each case study site regarding the identity and importance of release sources, assessing the influence from external stressors on the natural mercury cycling, and the identity of the local risk endpoints.

From Russia the three natural science institutions: *Institute of the Industrial Ecology Problems of the North* (*INEP*), *the Department of Land Hydrology at Moscow State University* (*MSU*), and the *Pacific Oceanological Institute* (*POI*) *of the Far Eastern Scientific Center of the Russian Academy of Sciences* are participating in the project.

- INEP is a leading institute in the field of Arctic terrestrial and freshwater biological systems and has its study sites mainly on the Murmansk peninsula, including River Niva. One of the focus areas of the institute is to study the technological possibilities of processing poor deposits of copper-nickel ores and industrial wastes from mining, and to develop possible technological solutions to reduce the environmental load from mining industry. INEP has a long history of participating in international projects and the staff includes specialists in industrial pollution and how this effects natural waters, sediments, and biological systems of different trophic levels.

- The Department of Land Hydrology at MSU has expertise in the hydrological, hydrochemical, and hydrobiological regime of rivers, lakes, and reservoir. For this project, their expertise in the hydrology of the large Russian rivers is particularly valuable for understanding the transport of the released mercury, as well as local knowledge on the Northern Dvina River.
- The POI major research fields include basic investigations in physical oceanography: hydrology, climatology, hydrodynamics, hydrophysics in Pacific and Arctic regions. POI leads and coordinate marine field studies in the Arctic Ocean including cruises of RV “Akademik Mstislav Keldysh” in 2020 and 2021. This will provide important knowledge understanding to the transport of mercury in the river delta regions of the Arctic ocean.

From Canada, *Trent University* (TU) and *Environment and Climate Change Canada* (*ECCC*) both have long experience with conducting research on mercury transport and cycling in the arctic as well as local knowledge on the selected study site.

- TU has environmental research as one of its key strategic areas of research. The group from TU that participates in the project focuses on the speciation and fate of metals in the environment, particularly mercury. Field study involvement includes both national and international sites, covering diverse ecosystems including polar regions. The fractionation of mercury isotopes is explored to unravel the biogeochemical cycling of mercury. The research addresses management of diffuse and point sources of contaminants including the effect of climate change on permafrost thawing and the associated export of mercury and organic carbon.
- ECCC works to protect and conserve the Canadian natural heritage, and ensuring a clean, safe and sustainable environment for present and future generations. The participating research group from ECCC focuses on understanding the biogeochemical cycling of elements and contaminants in the environment. With regards to mercury, extensive work has been done on its deposition, transformation, and bioaccumulation in aquatic ecosystems undergoing change. The change is typically external stressors such as climate change and eutrophication.

From Norway, the *Norwegian Institute for Water Research* (*NIVA*) and *Akvaplan-niva* (*APN*) will contribute with experience on mercury cycling and with local knowledge of the selected case study site.

- NIVA is the leading research institute in Norway on water pollution topics. NIVA has long and broad experience in mercury research, from the development of sensitive analytical methods, to the establishment of sound sampling routines, and to the study of transport and cycling of mercury in the natural environment. NIVA has for several years provided expert advice to the

Norwegian Government on mercury issues, including technical support connected to the MC. NIVAs experts have been nominated as experts to the releases group under the MC, and as mercury experts to the GMA 2018 and the upcoming AMAP mercury assessment. For more than a decade NIVA has supported China in preparation, ratification and implementation of the MC.

- APN is a leading research and consulting company in freshwater-, marine environment and aquaculture. The company is owned by NIVA and head office is located at the Framsenteret in Tromsø, Norway, well situated to conduct high quality Arctic research. Over the past 30 years, their employees have carried out several research projects related to pollution in the freshwater and marine environment and through this have very good knowledge of the status of pollution in Norway. APN has been working the Pasvik watercourse system over the last 20-years.

2.5.2 Expertise on risk assessment and management

Our core expert team on risk evaluation and management includes scientists and experts from NIVA and Western Washington University (WWU), USA. These experts will contribute with expertise within ecological risk assessment and relative risk modelling using Bayesian Networks.

Key members of the project team with this kind of expertise is Professor Wayne Landis at WWU in the US. A Professor in Environmental Science and a Director of the Institute of Environmental Toxicology at WWU. Landis has over 25 years of experience in ecological risk assessment research, using Bayesian networks to guide adaptive risk management decision making. His group has developed the Bayesian Network Relative Risk Model for large-scale risk assessment of multiple stressors and multiple endpoints, which has been applied for various types of situations and case studies world-wide (Johns et al., 2017; Harris et al., 2017). Experiences also includes consultancy work for industry; non-governmental organizations as well as federal (U.S. and Canada), state, provincial, and local governments. In addition, Dr. Jannicke Moe at NIVA has also about 15 years research experience, of which a recent focus has been the use of Bayesian networks to assess the ecological impacts of environmental stressors including global climate change and associated risks.

This expertise is key for the project as the method of Bayesian modelling will be used to assess the effects, including socio-economic aspects, of the suggested risk reduction measures, also including effect from external stressors such as climate change.

2.5.3 Expertise on policy, management and stakeholder interaction

The ARCRISK team also includes social scientists and policy experts who have wide experience with cross-sectorial, interdisciplinary work, who will pay a key role in interacting with government bodies, indigenous groups, industry officials and others. The different stakeholders will contribute with information and knowledge about local release sources, existing mitigation measures and/or practices, policies and reduction measures. Hence a considerable part of the project will be to reach out to and interact with these groups to obtain a solid knowledge basis, on which the ARCRISK deliverables may be built.

The social scientists and experts at NIVA and APN have considerable experience working with risk management at various governance levels, as well as different risk approaches, e.g. how local communities and local government perceive and handle different types of stress. SRI Atmosphere complements this expertise with their unique in-depth knowledge of industrial release and emission sources of mercury in Russia and neighbouring states. SRI Atmosphere is an apex research institute when it comes to inventorization of mercury sources in Russia. All the three organisations NIVA (NO), SRI (RF) and ECCC (CA) have been important in their support to respective governments with scientific support during the negotiations and implementation of the MC.

Combined these capacities will also be important in the communication and dissemination of results and suggested reduction measures to key stakeholder groups.

3 Operationalization and decisions made

Throughout the inception phase the project team has made key decisions on various components of the project, including the selection of appropriate case study sites, choices related to the risk assessments, source identification and approach, the project organization (as described in Chapter 2) and stakeholder outreach. Part of this information will feed into the project baseline that will developed in the initial part of the project (WP2). Three of these issues have key importance for the implementation of the project and warrant further elaboration: selection of case study sites, the risk assessment approach using Bayesian Networks and stakeholder outreach.

Figure 5 Geographical overview over the selected case study sites: Mackenzie River (CA), Pasvik River (NO), Niva River (RF), and Northern Dvina River (RF).

3.1 Case study sites

A total of four rivers have been included from the three countries (Figure 5). All rivers are large and constitutes important transporters of mercury to the arctic ocean (Table 2). Certain parts of the shores of the rivers are inhabited, ranging from smaller indigenous communities to larger metropolitan cities. The local people rely on the river for food and sometimes for water supply, transport and as a source of energy to various industrial activities. Different types of mercury release sources are covered by the rivers, including mining and metallurgical activities, pulp and paper mills, municipal wastes, and other types of smaller scale industries, in addition to anthropogenic influences in the natural mercury cycle (e.g. dams). Moreover, these rivers are influenced to a varying degree from the external stressors like climate change, migration, and industrialisation.

With this current selection of rivers, we aim to cover a variety of mercury release sources and risk-end points of the greater arctic so that the results from this project can be extrapolated to the greater arctic region.

Table 2. Overview of the case study rivers including information of country of origin, river name, type of mercury release source and availability of existing mercury data.

River	Size (length/basin area)	Examples of potential sources	Data available?
River Niva (RF)	36 km /12,800 km^2	Mining and metallurgical ind., municipal waste	Some
Northern Dvina (RF)	774 km/ 357,000 km^2	Paper and pulp mills, municipal waste	Yes
Mackenzie (CA)	1,738 km/ 1,805,200 km^2	Mining and metallurgical ind., thawing permafrost	Yes
Pasvik (NO)	148.8 km/ 18,288 km^2	Mining and metallurgical ind., municipal waste	Yes

3.1.1 Russia

Russia constitutes the most industrialised land area of the Arctic. In particular, the north-western part of Russia is densely industrialised, resulting from the occurrence of valuable natural resources such as minerals and wood. Although Russia has signed the MC, the country has not yet ratified the treaty. Nevertheless, several measures have been taken to reduce mercury pollution such as stopping all mining of mercury (from year 1995) and reducing the use of mercury in various consumer products and industrial processes. However, there are still several ongoing processes of potential mercury pollution (e.g. large-scale mining and combustion of fossil fuels), and there are likely deposits of mercury in soils and sediment from historical use and discharges (Gordeeva et al., 2017; Romanov et al., 2012). Based on the presence of various mercury release sources in the Russian Arctic, the occurrence of major river inputs to the Arctic Ocean, and the potential strong climatic changes expected to occur in the region, it was decided to include two study sites from Russia: the Niva River in Murmansk Oblast and the Northern Dvina River in Arkhangelsk Oblast, both located in the north-western part of Russia. The rivers have a different physical, hydrological and geographic profiles and will contribute with different knowledge when it comes to sources and risks.

3.1.1.1 Niva River, Murmansk Oblast, Russia

The Niva River is in the Murmansk Oblast (Figure 6) where it constitutes one of the largest catchments of the region (12,800 km^2). The river drains from Lake Imandra to the Kandalaksha Gulf of the White Sea. The river shores are relatively densely populated with more than 200,000 people in six different cities. Mercury risk for the local population is mainly posed through the consumption of fish and partly drinking water from the Niva River basin. Fish is an important part of the diet for the local population, and fishing activities are widespread within the river basin both including recreational and commercial fishing. Most of the cities along the Niva River shores are supplied with drinking water from large reservoirs from the river basin.

The river system is heavily affected by industrial activities including mining, ore processing, power production, ferrous metallurgy, non-ferrous metallurgy, mechanical engineering, metal working, and chemical industry. Lake Imandra is surrounded by these different types of metallurgical industries. A few studies have been conducted determining mercury levels in water, sediment and/or fish at different location of Lake Imadra and the connecting rivers. Results show that the mercury levels in sediment surface are among the highest levels in the region (2.89 µg/g dry weight (Dauvalter and Kashulin, 2018; Dauvalter et al., 2009).

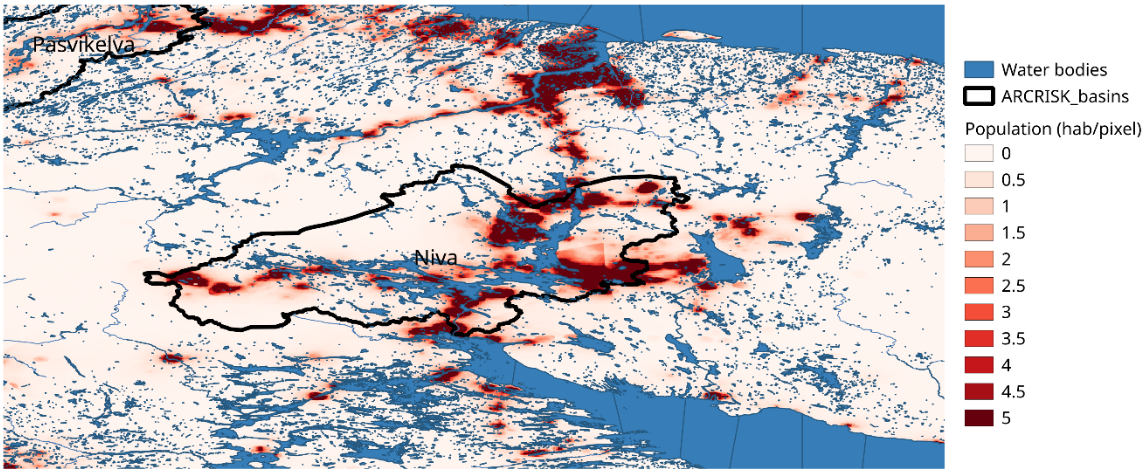

Figure 6. Map showing the location of the Niva River catchment (spatial demography coloured in red (Tatem, 2017)), an area of 12,800 km^2 on the Kola peninsula in the Murmansk Oblast, Russia.

3.1.1.2 Northern Dvina River, Arkhangelsk Oblast, Russia

The Northern Dvina River (Figure 7) is a wide and long river situated in the Vologa and Arkhangelsk Oblasts (East of the River Niva) that drains into the Dvina Bay of the White Sea. The Northern Divna River basin is the most densely populated in the Russian arctic zone with a total of 25 urban and 197 rural settlements. The largest industrial and economic centre is in the large city of Arkhangelsk (> 350,000 inhabitants), situated just at the river mouth. Fishing is an important industry, and the city of Arkhangelsk is the harbour of trawl fleets and is the location of a fish processing factory. While fishing has always played an important part of the economic activity, poaching and deterioration of water quality have led to a decrease in the fishery in these waters.

Potential major release sources of mercury to the Northern Dvina River are three large pulp and paper mills located along the river (*The Kotlas-, The Arkhangelsk-,* and *The Solombalsky Pulp and Paper Mill)*. The traditional method for bleaching paper involved the use of large amounts of mercury (as an electrode in the generation of the bleaching agent, sodium hydroxide). While the pulp and paper mills are now using a new and less harmful method for paper bleaching (membrane or diaphragm technology to produce sodium hydroxide), mercury deposits are likely to be found in the soils and sediments surrounding the mills. *The Kotlas Pulp and Paper Mill* located in the inland city Koryazhma along the shores of the Northern Divina is the largest pulp and paper mill in Russia. The two other mills are located further downstream of the river and close to the outlet: *The Arkhangelsk Pulp and Paper mill* in the city of Novodvinsk and the *Solombalsky Pulp and Paper Mill* in the city of Arkhangelsk. Other potential sources of mercury release to the Northern Dvina include woodworking enterprises (e.g. the Solombalsky machine plant in the city of Arkhangelsk), heat and power generating plants, and municipal waste.

A number of studies have documented elevated mercury levels at several sites along the Northern Dvina River, including the areas in the vicinity of the pulp and paper mills (Holm-Hansen, 2002), at the delta area of the river (Krasnoyarskiy et al., 2016), at internal ducts crossing Arkhangelsk, and in the city of Novodvinsk (Fedorov et al., 2018).

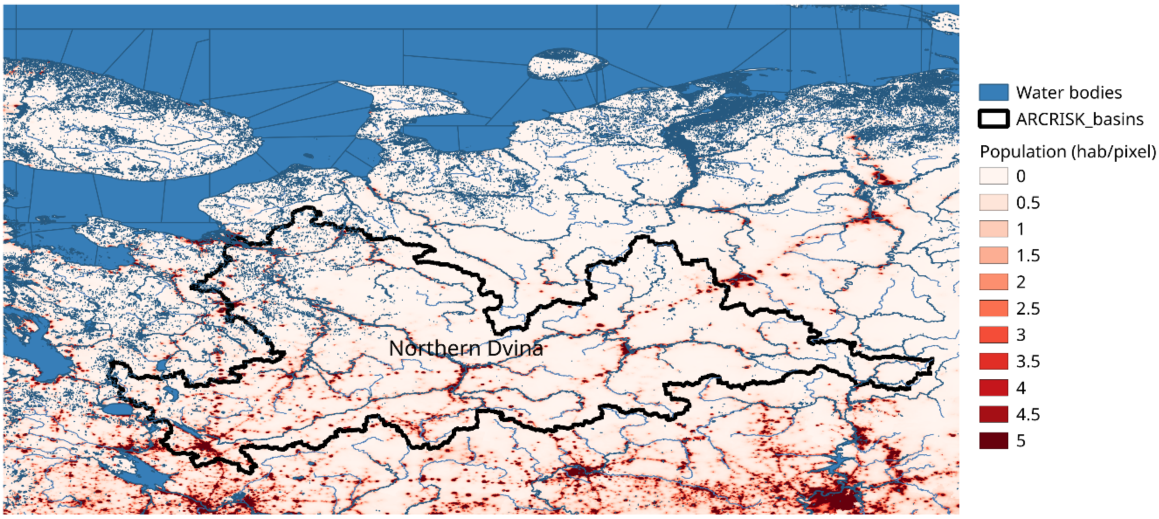

Figure 7. Map showing the location of the Northern Dvina River catchment (spatial demography coloured in red (Tatem, 2017)), an area of 357,000 km^2 in the Vologa and Arkhangelsk Oblasts, Russia. The map also illustrates the relatively high population density of this river catchment.

3.1.2 Canada

The Arctic mainland region of Canada is not as urbanized and industrialised as the Russian region. However, the Canadian Arctic is inhabited by a relatively large population of Indigenous people that are particularly vulnerable to mercury contamination since they rely on fishing and hunting for food and for its socio-economic benefits. The Mackenzie River was selected as the study site.

3.1.2.1 The Mackenzie River, Northwest Territories, Canada

The Mackenzie River is the largest river in Canada and is located in the North-west Territories (Figure 8). It constitutes an important source of mercury to the Arctic Ocean (Emmerton et al., 2013; Graydon et al., 2009). The river discharges into the Beaufort Sea near the city of Inuvik. Inuvik is the largest town north of the Arctic circle (3,200 inhabitants) and is the home to a high number of Indigenous people (Inuvialuit, Gwich'in and Metis) that rely on the basin's aquatic ecosystems for hunting, fishing, and trapping. Fishing is widespread both in lakes of the watershed (Great slave region) and in coastal wetlands (e.g. Huskie lakes). In addition to fish, marine mammals (seals, whales, and polar bears), which occupy the highest trophic levels of the arctic food web, are important as traditional food staples for the Indigenous communities.

Several different studies have documented both elevated and increasing levels of mercury in fishes of the region (Chételat et al. 2015 and references therein). There are currently fish consumption advisories in numerous of the lakes within the Mackenzie Basin, and specifically within the delta region (Government of Northwest territories). In Great Slave Lake, mercury concentrations of lake trout and burbot from both the West Basin and East Arm increased significantly by 2–5%/y since the 1990s

(Evans et al., 2013). Moreover, long-term monitoring of mercury in burbot of the Mackenzie River near Fort Good Hope showed that from 1985 to 2009, concentrations of mercury in muscle and liver approximately doubled (Stern et al., 2010) . Periodic sampling of lake trout in the Mackenzie River Basin showed that mercury increased in four of seven lakes, with greater increases in the smaller lakes (NCP, 2012). It is unclear what environmental factors are driving these recent trends in Hg bioaccumulation, and additional study is needed to examine the role of climate change in the region as well as potential changes in deposition patterns of atmospheric mercury.

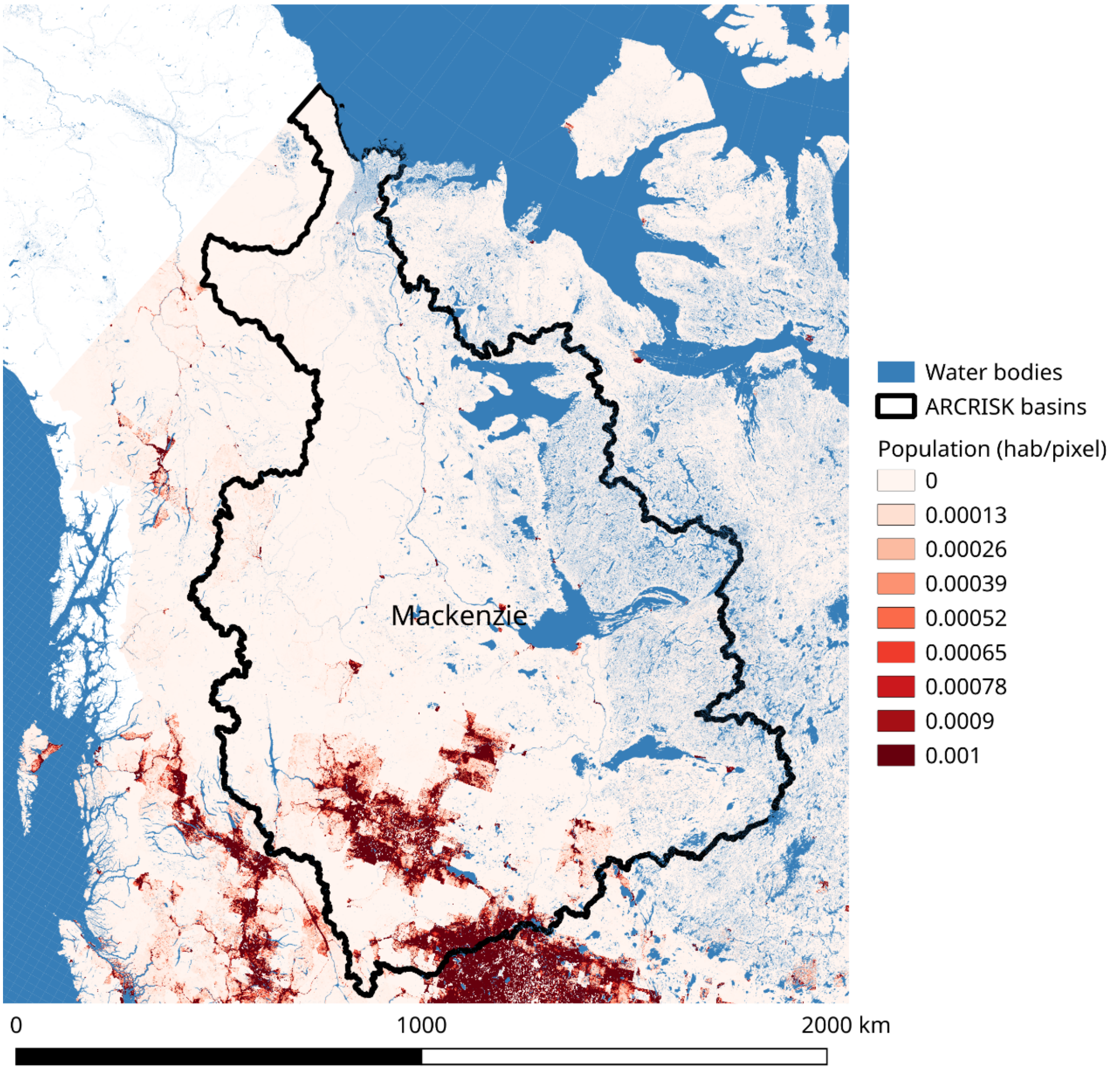

Figure 8. Map showing the location of the Mackenzie River catchment (spatial demography coloured in red (Tatem, 2017)), an area of 1,805,200 km^2 in the Northwest Territories, Canada. The different colours illustrated the different geographical distribution of this region.

Major potential mercury release sources include mining activities at the inland Great Slave region and oil sands exploration along the shorelines of major tributaries. In addition, climate-induced smelting of permafrost may represent an important mercury release source. The carbon-rich permafrost contains large amounts of natural mercury as well as mercury that was previously deposited during decades of more intense global mercury pollution. However, now with the warmer climate, these stores of mercury are potentially being released into the watershed at unknown rates. Other ongoing anthropogenic activities of the region that likely haves an impact on the mercury cycling includes forestry activities and the establishment of reservoirs. The latter has been found to enhance mercury methylation and thereby largely enhancing the biological uptake of mercury into the food -web. The large stretches of permafrost contain mercury and is very sensitive to release during climate change induced smelting.

3.1.3 Norway

The Arctic constitutes a relatively large geographical part of mainland Norway. But the region is relatively sparsely populated and there is little industry. The most polluted river is the Pasvik River, which is located close to various mercury emitting industries.

3.1.3.1 The Pasvik River, Finnmark, Norway

The Pasvik River is located to the far northeast of Norway and is a border river between Norway, Russia, and Finland (Figure 9). On the Norwegian side, the Pasvik catchment is part of both the Troms and Finnmark counties. The river flows from Lake Inarijärvi in Finland, into the Bøkfjorden in Norway and further draining into the Barents Sea. The largest cities and communities in the area are Ivalo in Finland (4,000 inhabitants), Nikel (12,000 inhabitants) and Zapolyarny (15,000 inhabitants) cities in Russia, and the city of Kirkenes in Norway (3,500 inhabitants). These people are exposed to mercury through the consumption of fish and also some drinking water from the river. The Pasvik watercourse has a long history of fishing, both freshwater and coastal. Kirkenes is located just at the outlet of the river and constitutes an important harbour for marine fishing. In the Pasvik Valley, a fish factory was previously located, receiving yearly 30 ton of fish from the river. While the fish factory was closed in 1997, people still harvest fish from the river, both for private and commercial interests. Sport fishing in the Pasvik river is becoming increasingly popular and an important tourist attraction. In Lake Inarijärvi commercial fishing is still ongoing with annual catches of up to 450 tons. In the Pasvik catchment, some houses and some cabins are served with drinking water from the Pasvik basin.

Research and monitoring have been carried out over the last 30 years in Pasvik watercourse. This includes also mercury analysis of water, sediments and fish at several location in the river. Elevated levels of heavy metals have been documented in water, sediments, and fish of the Pasvik watercourse. The major source of pollution, including mercury, is the Pechenganikel Mining and Metallurgical Combine in the city of Nikel in Russia that produces copper, nickel and sulphuric acid. The smelter and the city of Nikel likely release contaminants directly into Kuetsjarvi Lake which is part of the Pasvik watercourse. Additionally, pollution is transported by air from the chimneys of the smelter. Other potential sources of mercury constitute the smaller scaled mining and metallurgical industries in Zapolyarny in Russia and in Kirkenes in Norway, in addition to municipal waste from the cities. Anthropogenic influence on the natural mercury cycle includes the seven hydropower plants constructed in the river, that may enhance the production of methyl mercury. This likely result from increased prevalence of anoxic conditions and availability of organic material to the methylating bacteria (see e.g. Eckley et al. 2015; Calder et al. 2016 and references therein).

Pasvik watercourse receives quite a lot of attention in Norway due to environmental pollution in the area. Almost every year the County office and the municipality arrange a workshop where representatives from Russia, the Norwegian Ministry of Climate and Environment, County Governor of Troms and Finnmark, Sør-Varanger Municipality, local reindeer herders, local game and fishing association, NGOs and researchers that are carrying out research and monitoring in the area participate.

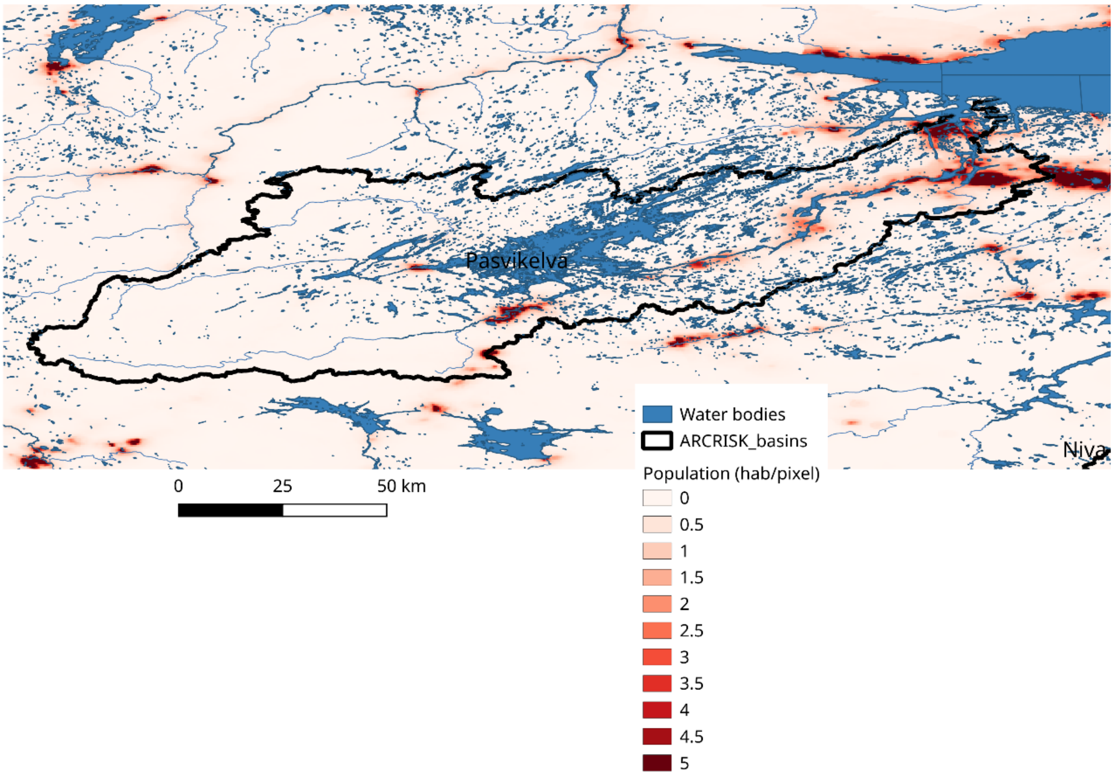

Figure 9. Map showing the location of the Pasvik River (spatial demography coloured in red (Tatem, 2017)), a catchment area of 18,288 km^2 on the border between Norway, Russia, and Finland.

3.1.4 Best practices and extrapolation

An important discussion that took part in the inception phase was the potential for exchanging best practices and extrapolation of results between countries. There are still knowledge gaps in all countries when it comes to the characteristics, occurrence and significance of local mercury release sources in the Arctic. Although all three countries currently have regulations and measures in place to prevent mercury releases to land and water, there are differences. Whereas Canada and Norway have both ratified the MC, Russia has signed the instrument, but so far not ratified.

Another difference between the three countries are the presence of industry sources and the degree of settlements and urbanization. These are key determinants for mercury releases and is expected to influence the release of mercury to the selected river systems.

The project team acknowledged that the selected catchments are different and that will challenge the comparability between the countries. Nonetheless, there will be important experiences from all countries, best practices and technologies, policy measures, etc. that will provide an important input to the development of action plans – a key deliverable of the project.

3.2 Framework for risk assessment

During the inception workshop and in several follow-up meetings a considerable allotment of time was spent elaborating on how the risk assessment could be conducted and what input data that was required. As the project has collected four distinctive sites in three different countries, the availability of information is varying. The presence and variety of sources, the different endpoints reported, and other site-specific variables introduce challenges for the comparability of the risk assessment. On the other hand, the inclusion of different sites with different characteristics will also allow testing the models and its explanatory power.

As described in the ARCRISK project proposal a risk assessment tool based on a probabilistic modelling framework will be adapted and applied to assess the risk of mercury pollution, in combination with other stressors such as climate change impacts, urbanization and industrialization. The project team agreed that a risk assessment framework such as the Bayesian Network Relative Risk Model (e.g. Landis et al. 2020), which was presented at the inception meeting, would be a good starting point. The project team will also consider aligning the conceptual framework with the DPSIR concept of the European Environment Agency, which is a causal framework for describing the interactions between society and the environment as Driving forces; Pressures; States; Impacts; and Responses.

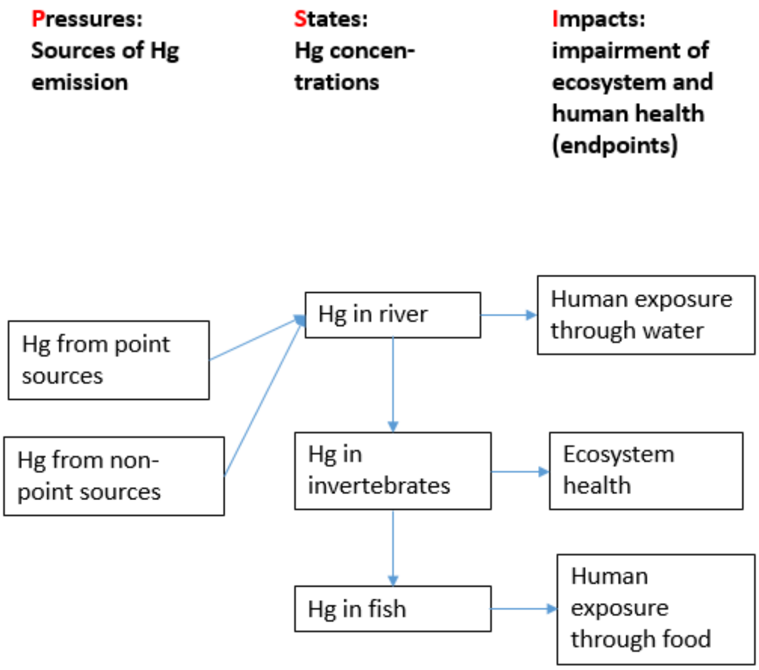

Figure 10. An example of the BN "current situation" for mercury in the Arctic, including Pressures; States; and Impacts. The boxes (nodes) represent variables and the arrows represent causal links.

To exemplify, a Bayesian network (BN) consists of nodes (variables) with probability distributions across discrete states, which are linked by conditional probability tables (CPTs). The model can integrate continuous data (e.g. concentrations), ranked data (e.g. ecological status), and categories (e.g. mitigation measures). For mercury in the Arctic, an example of the "current situation" is exemplified in Figure 11. Each node (represented by boxes in Figure 10) is defined as a limited number of discrete states, typically 3-5 intervals, and quantified by a discrete probability distribution across these states. A CPT determines the probability distribution of a child node (e.g. «Hg in river») depending on the probability distributions of its parent nodes (here: «Hg from point sources» and «Hg from non-point sources»).

In the inception phase the project team discussed how the ARCRISK project may quantify the specific variables (boxes) and the relationships (arrows), and that this should be carried out in close collaboration and through consultation with local stakeholders. Possible scenarios for future developments of external drivers such as climate change, industrial development, and urbanization will also be developed in collaboration with stakeholders and the impacts of such drivers on the risk associated with mercury will be quantified as far as possible (Figure 11). The local communities and indigenous people's perception of risk may also be integrated in the framework, for example by specification of adverse effects to human and ecological endpoints, and the probability of the occurrence such effects under different conditions. To ensure coherence in the different case studies a workshop will be arranged during fall 2020, to start developing conceptual models as a basis for BN models for each case study. During this workshop we will also specify the responsibility of different tasks and partners for the steps needed for further development of quantitative BN models for each site. These steps include the identification and quantification of mercury sources, concentrations and effect endpoints, and the quantification causal relationships either as equations or as conditional probability tables.

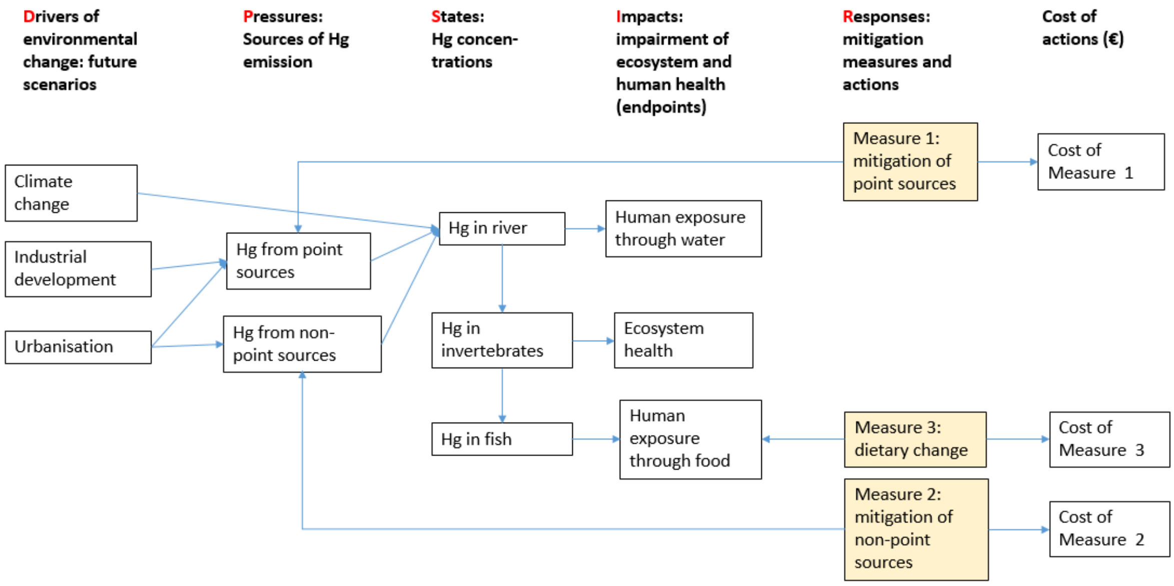

Figure 11. An example of the BN with future scenarios (i.e. Drivers); measures/actions (i.e. Responses); and cost of actions included for mercury in the Arctic. The boxes represent nodes and the arrows represent causal links.

Finally, depending on resource availability the BN models can be extended to include key actions (e.g. mitigation measures) and if feasible a costs/benefit influence diagram. At the inception meeting the BN experts emphasised the importance of agreeing on valorisation of the different variables, such as mitigation measures, costs of actions and benefits of impacts. The beforementioned project workshop will be instrumental in such case.

3.3 Stakeholders and local communities

Stakeholder outreach and involvement is essential for the implementation of ARCRISK and has been thoroughly examined in the inception phase. The stakeholders will be involved in at least four ways:

1. Providing information and local knowledge, project planning
2. In the assessment of risk and perception of risk
3. Evaluating the relevance and feasibility of reduction measures
4. Communicating and discussing project outcomes and results

Reviewing the four localities to be studied in ARCRISK the project team identified the following key stakeholders: government (local and national), indigenous groups and local communities, industrial enterprises, civil society groups and researchers (Annex D). The presence/composition of different stakeholder groups will differ between the study locations.

All of these listed stakeholder groups will be of relevance when collecting information, on existing knowledge about mercury pollution in the area, about the presences of sources or historic sources, about management issues and health implications, etc. Hence, this is why ARCRISK has been designed with early stakeholder meetings and outreach, to collect and review this often local knowledge, not published in any scientific journal.

When assessing risks, the local actors will have information on the history of the site: Whether it has been an issue prior to this, whether there are other issues that poses a risk to the local communities, how the locals themselves perceive any risk of environmental pollution, existing policies and measures, etc.

Later in the project implementation, once the project has come up with a proposed list of key reduction measures, the integrated design of the project facilitates testing of the relevance, applicability and feasibility of the proposed actions and measures. All types of local stakeholders will be consulted as part of this component, as they all will provide different perspectives, thereby enhancing the chances of succeeding with various reduction measures, among governments. Once input has been provided and the reduction measures refined and finalized in an action plan for the investigated area, a pivotal part of the project will be dissemination of the project results and outcomes to a wider audience, both locally at each of the sites (beforementioned stakeholders), but also nationally, regionally and internationally. The latter will be done in close collaboration with the ACAP secretariat.

Related to the stakeholder outreach the project team discussed a risk factor that may affect project implementation – the access to indigenous groups and availability of data. Carrying out sampling and making physical analyses/assessment would warrant a formal and extensive procedure to obtain permission and access to the areas and people we study. However, the team reasoned that as long as the project does not carry out physical sampling, but will build on existing data and information, that will ease the access to these areas. Nevertheless, it may at some locations be necessary to obtain support on a national level, prior to engaging with local governments/industries.

4 Work plan and Budget

4.1 Work Plan

During the inception phase and based on deliberations at the inception workshop in Oslo, a workplan has been developed for the project. The workplan is designed to be a dynamic steering document that will be updated regularly during the project period. It provides an overview of timeline, responsibilities and clarifications made as the project progresses. The workplan is provided in **Attachment 1**, to the present report.

4.2 Budget

The ARCRISK budget is provided in **Attachment 2**. The budget corresponds to the original budget frame attached in the proposal package that was approved by ACAP in 2019, of which EUR 68 000 for work package 1 (the inception phase) has been assigned and financed by the PSI.

The attached and updated budget has been further divided into country allocations, reflecting the geographic distribution of funding needed to carry out the various activities within the project. Additional break down of the budget into institutional allocations was not considered sensible at this point of time, as the exact timeline of the ACAP/PSI approval procedure is not clear and to take height for any modifications that may occur in this period. Moreover, in recent months there has been considerable currency fluctuations and being a project that includes partners in four different countries we sustain some of the flexibility of balancing budget and responsibilities until WP2-6 is approved.

Adding to this, the budget distributions merit further elaboration of the following conditions:

- The project initiative, establishment, lead and management lie with NIVA.

- The Norway budget includes both activities carried out by NIVA, APN and WWU (US). The latter is not set up in a separate US budget, due to the fact that Prof. Landis will exclusively be working on the BN risk assessment, coordinated by NIVA (Dr. Moe), who also has the thematic coordination on this theme ("risk assessment"). NIVA also has the thematic coordination of the source mapping.
- The Russia budget includes allocations for four institutions, of which Mr. Romanov has the thematic responsibility of "reduction measures". Moreover, in contrast to the Norwegian and Canadian work packages that each include one river system only, the Russian includes two sites.
- The Canada budget covers two institutions and reflects the inclusion of the by far largest catchment in the project, Mackenzie, a site where it is more challenging to carry out fieldwork, as well as time and resource demanding.

5 Situation updates

5.1 Overview of changes in context

An important change in context since the inception phase was approved and commenced is the outbreak of the Covid-19 virus, that took place just after the ARCRISK inception workshop was organized in the beginning of March 2020. Starting in China and spreading to Europe, the virus has gradually also spread to the rest of the world, including Norway, Canada, Russia and USA. The outbreak gave an early test also to the ARCRISK project team, which were requested to work from home while our kids and families were all around – at least for some us. Within this context we also got thoroughly tested on the use of web conferencing and other electronic means of communication. Despite the situation we have managed to achieve a steady progression and been able to keep our final contracted deadline for this project inception phase.

That said, the true implications of the Covid-19 on the involved countries, on international collaborations and international travel remain uncertain and is very difficult to predict. NEFCO has indicated the possibility of PCOM processing the next phases of the ARCRISK project (WP2-6) between July and October 2020. If so, and endorsement is granted, the project team will be ready to start implementation of the project between August and October. A clear advantage in this circumstance is that the ARCRISK project team have highly competent partners in all countries we have case studies and are ready and able to carry out the planned work. Besides, we are as mentioned already fully operational using electronic means. Moreover, all partners will apply the highest standards when it comes to public standards and guidelines when it comes to minimise risk of spreading Covid-19.

5.2 Updates on project related information

Considering the fact that the ARCRISK project has been established over a time span of three years, taking into account various rounds of reviews and contributions from ACAP and other stakeholders, there has not been need for any major revisions of the project framework. However, in comparison to the original proposal some modifications and further specification of the framework has been made:

- Locations – Originally it was planned to study three locations, one in each country. However, in the inception workshop it became clear that there are distinctive differences between the three Arctic regions. For Russia, it was deemed important to include to river systems: one small that would facilitate a more capillary and detailed understanding of sources, fluxes and management options, and a large catchment that would include a broader range of potential release sources, a broader spectrum of climatic and urban influences, and a greater potential for comparison (and extrapolation) with the larger river catchment systems in Russia.

- Advisory group – The ARCRISK project will have an advisory group. Already when preparing the original project proposal in 2017 relevant experts and stakeholders were contacted and invited. However, due to the project proposal processing time since 2017, several of the individuals contacted have either left or quit their job. Thus, as part of the inception phase, it was agreed that the project team will wait with defining the role and composition of a potential advisory group until the remaining project phases (WP2-6) has been approved by the PCOM. Anyhow, all partners have been asked to identify potential expertise within the study locations, that may also be relevant as advisors for the project. This information has been submitted to the project leads. Furthermore, since a normal procedure is to set up an ad-hoc advisory group within the EG, the ARCRISK team invite the EG to discuss an appropriate advisory structure, that would facilitate valuable input from external experts and stakeholders, while avoiding a too arduous, complex and bureaucratic organizational structure and reporting scheme.

- Risk assessment –step-wise - The project will, as thoroughly described, apply the Bayesian Network (BN) Relative Risk Model as our preferred tool for risk assessment and management. The applicability and strength of the methodology will depend on the availability of data at the four case study locations. More detailed and broad range of variables and better quality of data, in combination with stakeholder and local expert knowledge, will give better analytical and explanatory power. Hence, based on recommendations from the BN experts it was decided that the BN activities will start at one of the four locations (to be decided depending on the availability of data and information), where it will be set up applying a detailed and thorough analysis. A comparative assessment of the additional three sites will subsequently be carried out, if resources are sufficient. The scope and scale of the analysis of the additional three sites will however depend on the outcome and applicability of the first case study.

- Contracting – Contracts have been set up between the PSI/NEFCO and NIVA for the inception phase. Furthermore, NIVA has set up sub-contracts with all eight partners, also covering the inception phase. These contracts will be used as a basis for further contracting. However, it was not found sensible to establish additional contracts for WP2-6, until the PCOM process has been finalized. That said, since the partners have already formalized our collaboration, the foundation has been made and further contracting will be smooth.

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Annex A: Terms of Reference

Annex 3

TERMS OF REFERENCE

Mercury risk evaluation, risk management and risk reduction measures in the Arctic

PHASE I. Work Package 1. Inception

1. BACKGROUND

The Arctic Council is the leading intergovernmental forum promoting cooperation, coordination and interaction among the Arctic States, Arctic indigenous communities and other Arctic inhabitants on common Arctic issues, in particular on issues of sustainable development and environmental protection in the Arctic.The objective of Arctic Council's working group, the Arctic Contaminants Action Program (ACAP), is to prevent adverse effects from, reduce, and ultimately eliminate pollution of the Arctic environment. ACAP addresses Arctic pollution sources and acts as a strengthening and supporting mechanism to encourage national actions to reduce emissions and other releases of pollutants that are relevant in the Arctic.

Mercury has caused a variety of documented, significant adverse impacts to human health and the environment throughout the Arctic and the world. Human activities have significantly increased the amount of mercury that is available in the atmosphere, in soils and sediments, and in lakes, streams, and oceans.

The Arctic Council Project Support Instrument (PSI) finances activities aimed at preventing and mitigating pollution with the Arctic region. The fund is managed by NEFCO. The decision making body for PSI is PSI Committee consisting of the representatives of the contributors to the PSI fund.

2. PROJECT

PSI Committee has approved the financing of the inception phase of the **Mercury risk evaluation, risk management and risk reduction measures in the Arctic** later called as **Program.** The Phase I is called as Work Package 1. Inception and referred later as **Project.** The entire program consist of 6 work packages and described in more detail in the attached Project proposal document.

3. OBJECTIVES

The objective of the Program is to identify key sources of mercury in selected catchments and assess the risk to local communities and the surrounding environment (water and soil). Based on this, the project will develop an action plan with risk reduction measures for mercury releases in the Arctic.

3. ISSUES TO BE STUDIED UNDER THE PROGRAM

First step is to identify key release sources of mercury in selected catchments and assess its risk to local communities and the surrounding environment. Action plan will be a prioritised list of effective actions and investments for reduction of mercury risks to the Arctic populations and environment. The action plans will include policy measures for local government, technical measures for industries, and sound investment options.

4. PLAN OF WORK

The Program is structured in 8 work packages: Financing has been approved for **WP1: Inception** only.

WP1: Inception: Preparation of a final project framework including work plans, budget details and organizational set-up with key stakeholders (including mandates for advisory and project management groups, and necessary contracts and sub-contracts). The project group will collaborate closely with AMAP and other AC WGs to set up a detailed project baseline in the initial four phases of the project (WP1-4), to ensure synergies and avoid duplicating efforts.

Provided successful completion of WP1. and approval of PCOM for the financing of consequent follow up phases, WP2-WP6 will be implemented. At this point, the work under those packages is described below to guide the work under WP1 and for information only.

WP2: Identify the sources of mercury to the Arctic: Identify and map point and non-point sources of mercury to the Arctic environment and assess its significance, with a focus on Arctic rivers. The review will include both known release sources and non-point sources in hotspot areas.
WP3: Risk evaluation of mercury and multiple stressor impacts: Assess the risk of mercury to the local community and environment at the three study locations, based on a systematic compilation and assessment of data.
WP4: Develop action plans (Demonstration of sound reduction measures for industry and government): Identify targeted and effective measures for risk reduction of mercury releases from key sources to the Arctic environment and its impact on local communities. Provide a targeted risk-reduction action plan for key sources at the selected study locations.
WP5: Stakeholder involvement, capacity building and dissemination: Promote a broad dissemination of project outcome and deliverables to targeted audiences. The project will ensure strong involvement of stakeholders at all governance levels, relevance for decision-making and risk management throughout the project.
WP6: Project management: Ensure appropriate management and administration of the comprehensive project work in very remote areas in five Arctic countries, including coordination of fieldwork, consultation, and dissemination activities.

5. REQUIRED EXPERTIZE

Program needs sound representation of researchers and policy experts, including representatives from the countries of investigation. Professionals are especially needed in mercury pollution issues, environmental modelling, risk management, risk governance, catchment processes, industrial processes, environmental policy and regulations. Local expertise and networks at all program sites are needed to carry out project activities at the sites.

Project shall work in close collaboration with relevant AC WGs, including AMAP, PAME and SDWG to ensure cross-fertilization, synergies, and exchange of experiences.

6. TIMETABLE AND REPORTING

A status report will be shared at least quarterly with ACAP expert group and NEFCO. Final Inception report to be provided in three months form singing the Contract.

Attachment: "Project proposal for an ACAP Artic Council Project: Mercury risk evaluation, risk management and risk reduction measures in the Arctic"

June 18, 2019 /KHO, AVA

Annex B: Project Inception Workshop - Agenda

Mercury risk evaluation, risk management and risk reduction measures in the Arctic (ARCRISK)

Inception workshop, Oslo, March 3-4, 2020
Detailed programme

Day 1 – Tuesday March 3rd

10.00: Welcome remarks and plan for the workshop
(Cathrine Brecke Gundersen and Eirik Hovland Steindal, NIVA)
10:15: Information and formalities NEFCO (Annukka Valkeapää, NEFCO, phone/email)
10.20: ARCRISK project introduction (Cathrine Brecke Gundersen, NIVA)
11.00: Short presentations of all project partners and experience/expertise
11.45: Coffee break
12.00: Short presentations of all project partners and experience/expertise, continued
13.00: Lunch
14.00: Introduction to mercury risk modelling (Jannicke Moe, NIVA, Wayne Landis, WWU)
15.00: Presentation of suggested study sites followed by discussion
(Norwegian, Canadian, Russian partners present suggestions)
16.00: Mercury pollution in the Barents region - experiences from an ongoing project (Cathrine Gundersen, NIVA)
16.30: Discussion and wrap-up day 1
17.00: End of meeting day

Day 2 – Wednesday March 4th

09.00: Presentation of draft work plan (Cathrine Brecke Gundersen, NIVA)
09.20: Discussion of draft work plan and suggested changes
12.00: Lunch
13.00: Presentation of draft budget (Cathrine Brecke Gundersen, NIVA)
13.20: Discussion of draft budget and suggested changes
15.30: Summary and wrap-up

Annex C: List of Workshop Participants

Invited project partners - ARCRISK			
Name	**Organisation**	**Area of Expertise**	**Contact information**
Hans Fredrik Veiteberg Braaten*	NIVA	Mercury contamination, Arctic, international collaboration projects	hbr@niva.no
Cathrine Brecke Gundersen	NIVA	Catchment biogeochemical processes, anthropogenic pollutants, natural organic matter	cbg@niva.no
Eirik H. Steindal	NIVA	Global conventions, international collaborations, policy and governance in science	ehs@niva.no
Marianne** Karlsson	NIVA	Arctic studies, risk analysis, adaption processes in local communities	mka@niva.no
Evgeniy Yakushev	NIVA	Marine biogeochemical processes, distribution of contaminants in waters	eya@niva.no
Jannicke Moe	NIVA	Statistical modelling, ecological responses to environmental stressors	jmo@niva.no
Guttorm Christensen	Akvaplan-niva	Monitoring and surveys of contaminants in the Arctic, impact assessments	guttorm.christensen@akvaplan.niva.no
Jane Kirk	Environment and Climate Change Canada	Biogeochemical cycling of elements, deposition, transformation, accumulation of mercury	Jane.Kirk@canada.ca
Sarah Roberts	Environment and Climate Change Canada	Biogeochemical cycling of elements, deposition, transformation, accumulation of mercury	sarahlilyroberts@gmail.com
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Igor Semiletov	Il'ichev Pacific Oceanological Institute	Aquatic ecosystems, biogeochemistry, Arctic ocean	ipsemiletov@alaska.edu
Natalia Frolova	Moscow State University	Contaminants, hydrology, rivers, limnology	frolova_nl@mail.ru
Wayne Landis	Western Washington University	Ecological risk frameworks, Bayesian modelling, risk assessment	landis@wwu.edu
Annukka Valkeapää***	NEFCO	Fund Manager	Annukka.Valkeapaa@nefco.fi

* Mr. Braaten, NIVA, was absent due to paternity leave.
** Ms. Karlsson, NIVA, was absent due to project travels.
*** Annukka Valkeapää, NEFCO, was invited to join parts of the workshop via video conference. Unfortunately, due to technical difficulties we were not able to connect, and she thus communicated with the project team by email.

Annex D: Identified Stakeholders at the selected Case Study Sites

Russia, Niva River

- Municipal authorities
- Central government
- Civil society organisations
- Indigenous groups
- Industrial enterprises

Russia, Northern Dvina River

- Local government
- Central government¨
- Civil society organisations
- Indigenous groups
- Industry actors
- Northern arctic federal university
- Northern department of rosyhydromet

Canada, Mackenzie River

- Provincial and federal ministries (of the environment, ECCC, DFO)
- Indigenous communities
- Scientists
- Northern college or university

Norway, The Pasvik River

- Ministry of climate and environment
- County governor of Troms and Finnmark
- Sør-Varanger municipality
- Local reindeer herders
- Local game and fishing association
- National NGOs
- National researchers

NIVA: Norway's leading centre of competence in aquatic environments

NIVA provides government, business and the public with a basis for preferred water management through its contracted research, reports and development work. A characteristic of NIVA is its broad scope of professional disciplines and extensive contact network in Norway and abroad. Our solid professionalism, interdisciplinary working methods and holistic approach are key elements that make us an excellent advisor for government and society.

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