Uarctic Thematic network on

# Sustainable Strategies for Waste Removal and Restoration of Arctic Mine Waste Areas

Acronym: RAMWA

## Background

The Arctic region is a unique and fragile ecosystem that is currently undergoing significant environmental, cultural, political, and societal changes due to global warming and urbanization. The region is considered rich in natural resources, including minerals, oil, and gas, which have attracted the attention of many countries as well as industrial consortia and interest organizations. The geopolitical and economic implications of industrial development and Arctic mining are complex and multifaceted.

### Opportunities and challenges

The Arctic region politically represented by eight countries, i.e. Russia, Canada, Kingdom of Denmark (incl. Greenland and the Faroe Islands), Finland, Sweden, Iceland, Norway, and the United States, which may have competing territorial claims and interests in the region. The melting of the Arctic cryosphere has opened new shipping routes and will likely enable easier access to natural resources, potentially leading to increased competition for the economic and political control over the region. This has also led to concerns about risks for conflict and highlighted the need for international cooperation to manage the region's resources in a sustainable way.

While the extraction of natural resources in the Arctic has the potential to create jobs and stimulate economic growth in the region, it also carries the risk of environmental damage and disruption of traditional ways of life for Indigenous communities. The economic benefits of industrial development and Arctic mining must be balanced against the potential environmental and social costs in the region in question.

Therefore, industrial development of the Arctic including Arctic mining is a complex issue that requires knowledge of its potential consequences for the environment as well as local and Indigenous communities. The region's natural resources must be managed sustainably to ensure that they benefit the local communities and create minimal environmental impact. The fragile ecosystem of the Arctic requires protection and preservation for future generations.

### Arctic mining and waste handling

Sustainable strategies for Arctic mine waste removal and restoration of affected land areas are crucial for the preservation of the Arctic environment. Several examples exist of damaging

effects from uncontrolled industrial activities in the Arctic. The development of sustainable strategies includes mitigation actions for environmental impacts and respond to the overall goal of maintaining healthy ecosystems in the Arctic, for future generations.

Important elements of these sustainable strategies include environmental remediation and re-wilding practices to restore landscapes and natural water resources altered by extraction and waste storage including buried toxic wastes. These practices involve restoring the natural environment by removing waste and pollutants, planting vegetation, and reintroducing native species. This process is not only beneficial for the environment but also for the local communities that depend on the Arctic ecosystem for their livelihoods.

As reported in recent studies, large scale mining in arctic regions contributes to the increase of $CH_4$ (methane) emission due to elevated permafrost thawing and direct release. Another strategy is the use of microbially mediated carbon dioxide ($CO_2$) removal to reduce the carbon footprint of mining. This technique involves microbial communities that can degrade chemical residues in contaminated soil and contribute to the remediation of industrial waste sites. Also, the reduction and storage of $CO_2$ during mining operations will help to mitigate the negative effects of industrial operations on the Arctic climate.

Furthermore, bioremediation techniques can be applied to treat mine tailings. Bioremediation involves using living organisms such as microorganisms and plants to reduce the effects of acid mine tailings by turning waste into less harmful forms or even into fertile soil. These remediation techniques can reduce the environmental impacts of mining waste and ensure a healthier Arctic environment for future generations.

Thus, sustainable strategies for Arctic mine waste removal are essential tools for the preservation of the Arctic environment. The use of environmental remediation, re-wilding, restoration, and bioremediation techniques support international efforts to keep the Arctic region as a clean and healthy environment for future generations.

## Thematic Network on Arctic mine waste handling

Creating a thematic expert network of Arctic scientists aiming at the development of advanced scientific interdisciplinary methods for sustainable mine waste removal and remediation techniques is overdue considering the rapid growth of the mining industry throughout the Arctic. The use of sustainable strategies will help mitigate the environmental impact of mining waste and ensure that the Arctic remains a clean and healthy environment for future generations.

The creation of a thematic network on removal and remediation technologies for Arctic mine wastes will provide a platform for researchers to share knowledge and expertise, collaborate on interdisciplinary research projects, and develop new technologies for sustainable mine waste removal and remediation in the Arctic. The network will foster the development of advanced scientific interdisciplinary methods for sustainable environmentally friendly mine waste removal and remediation technologies in the Arctic. The network on Sustainable Strategies for Waste Removal and Restoration of Arctic Mine Waste Areas (RAMWA) will serve a platform for the development and establishment of advanced international research proposals and projects.

## Integration of Indigenous knowledge in mine remediation strategies

It is essential to involve Indigenous knowledge in the development of sustainable strategies in Arctic mine waste handling to ensure the best possible outcomes for the preservation of the Arctic environment for local and Indigenous communities. Locally adjustments in sustainable

strategies that are based on local and Indigenous knowledge and embrace the diversity of Arctic Indigenous cultures can help mitigate the environmental impact of mining waste at the local level.

Indigenous peoples have a deep understanding of the Arctic environment and have developed sustainable practices for living in harmony with the Arctic nature. Their knowledge and expertise can be leveraged to develop innovative solutions for sustainable mine waste removal and remediation in the Arctic. Involving Indigenous peoples in the development of sustainable strategies is essential to ensure that the strategies are culturally appropriate, socially acceptable, and environmentally sustainable.

The United Nations have recognized the importance of involving Indigenous peoples in the development of sustainable strategies and have called for their participation in the implementation of the 2030 Agenda for Sustainable Development.

## Network priorities and strategies

As previously outlined, Arctic mining waste including tailings and the need for remediation and restauration of affected areas is of major concern with respect to the regional environmental and people's health, culture, and livelihood. Acknowledging the general importance of appropriate mine waste handling in the Arctic region, a first expert workshop was held at Yukon University in September 2023 that brought together international and Indigenous experts on Arctic pollution issues for a 3-day meeting. Inspired by the open and substantial discussion, the concept for a UArctic Thematic Network (TN) was developed and further refined.

### Expertise

The RAMWA TN core group is composed of international Arctic experts with a variety of expertise including community administration, Indigenous knowledge, mining industry, pollution assessment, regulation, engineering, technology development and bioremediation (table 1). Among others, three currently active UArctic chairs will join the RAMWA team.

| Name | **Affiliation** | **Expertise** |
|---|---|---|
| Roland Kallenborn | Norwegian University of Life Sciences (NMBU) | Environmental pollution and environmental risk assessment, analysis of Chemicals of Emerging Arctic Concern (CEACs) |
| Wonjae Chang | University of Saskatchewan (USask) | Bioremediation, hybrid bioremediation, and salinity mitigation technology development, mine waste-to-valuables process development, contaminated cold-climate soils, contaminated Innovative environmental mineral development for remediation, reclamation, and waste recycling |
| Arja Rautio | University of Oulu | One health and human health risk assessment, epidemiology, collaboration with Indigenous Peoples |
| Daria Popugaeva | The University of Western Ontario & Core Geoscience Services Inc. | Water treatment research in the Arctic and Subarctic |
| Bing Chen | Memorial University of Newfoundland | Wastewater treatment and reuse, site remediation, environmental modeling, spill response and cleanup |
| Susan Baldwin | University of British Columbia | Bioprocess engineering, anaerobic fermentation, bioremediation, reactor modeling, biochemical reaction modeling, reaction kinetics |

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|---|---|---|
| Carmen Mihaela Neculita | University of Quebec en Abitibi-Témiscamingue (UQAT) | Environmental hydrogeochemistry, mine water treatment and management, mining rehabilitation |
| Yifan Li & Zifeng Zhang | Harbin Institute of Technology (HIT), School of Environment | Environmental pollution, Fate modelling, risk assessment, pollutant transport |
| Leo Yeung | Ørebro University | Organic pollutant, environmental chemistry, Fate assessment, analytical methods |
| Guillaume Nielsen | Yukon University | Bioremediation processes applied to mining contamination – passive treatments – mine restoration – Cold climate |
| Katrin Vorkamp | Aarhus University | Arctic pollution, chemical analyses, Chemicals of Emerging Arctic Concern (CEACs), environmental fate of organic chemicals, human exposure, risk assessment |
| Stephan Weinbruch | Technical University of Darmstadt | Emission profiling, pollutant distribution, aerosol characterization, Electron microscopy, |

## Main Activities

The here planned RAMWA project intend to create an open high profile thematic network as forum for scientific discussions and platform for large follow up scientific projects and collaborative networks also outside the Arctic.

## Research cooperation priorities

The RAMWA network will be established to foster and initiate thematic collaboration among the individual partners and their respective institutions. Through regular meetings, digital communication, and thematic seminars, the RAMWA group will develop an inter- and cross-disciplinary research platform for international research coordination and academic educational interaction within the field of Arctic mining. The RAMWA team will focus on sustainable operational strategies in mining including waste handling. Communication and documentation of RAMWA findings will be organized through a joint digital platform accessible for all TN contacts. Priority topics including Bioprocess Engineering, Anaerobic Fermentation, Bioremediation, Reactor Modeling, Biochemical Reaction Modeling, Reaction Kinetics will be discussed and implemented in strategies of the RAMWA team aiming at suitable recommendations and research priorities for sustainable handling and regulations of mine operations and mine waste handling (regardless of type or resource to be extracted). Essential for all UArctic TNs, the RAMWA core group will establish an open network structure allowing external experts with complementary expertise to join and contribute. RAMWA will aim to provide guidance and advice to regulators, scientists, industries, and educators. To achieve this challenging balance, the following communication and information tools will actively be applied:

1. Joint research workshops/conferences
2. Digital communication platforms
3. International working groups /joint publications
4. Close connections to the Arctic Monitoring Assessment Programme (AMAP) and the International Arctic Science Committee (IASC).
5. Joint Academic educational program
6. Exchange program for Master/Ph.D students, support of Master/Ph.D theses
7. Collaboration/sharing data archives.

## Joint education programs/ Knowledge sharing in education

The RAMWA network considers the education on science-based solutions and strategies for sustainable mining operations in the Arctic as a prerequisite for improving the environmental status of affected regions. Ultimately, the education of the Arctic mining experts of tomorrow is an important task that should include environmental aspects and a basis understanding of Indigenous culture to ensure a small environmental footprint of these operations in the future. The educational efforts of the RAMWMA collaboration will address students at high school level and professionals as well as academic/university level education including specialization and practical training-based education. For this purpose, the following tools will be applied:

1. Joint training workshop for Arctic sample treatment and analysis
2. International specialized credited seminars on sustainable maintenance, operation and waste handling in Arctic mining
3. Sharing existing courses and study programs
4. Development of new joint courses and training programs
5. Exchange program and specializing program of professionals including undergraduate and graduate school program.

## Current activities

The RAMWA group is already active in various joint activities which can form the basis for and provide knowledge to feed into collaborations on sustainable mining operations and waste handling in the Arctic. The following examples illustrate the already established collaboration among the partners:

1. Joint conferences and seminars: PEOPLE, UArctic, ArticNet, ASSW, and ICCE Conference series
2. Summer and Winter school in Arctic Pollution Research (Harbin Institute of Technology & DTU Sisimiut)
3. Specialized seminars on mine waste bioremediation at Yukon University (2023)
4. Nordic Master Program on Arctic Environmental Forensics (jointly organized by NMBU, Örebro University, University of Southern Denmark)
5. Joint Education and Research in Arctic Environmental Forensics and Pollutant Remediation (JAF)
6. Collaborations on AMAP assessments on persistent organic pollutants (POPs) and chemicals of emerging Arctic concern (CEACs)

## Planned activities

For the initial period of our network and to attract external expertise for strengthening the scientific relevance of our work, we intend to focus our work on outreach and establishing a solid scientific platform for scientific knowledge exchange and harmonization of educational activities. In order to achieve these goals, we intend to use the following tools:

1. Joint research workshops/publications
2. Collaboration/sharing data archives.
3. Identification of funding sources for joint research proposals
4. Joint graduate study program
5. Development of specialized university courses
6. International Project applications (EU, NSF, ERC)

## Indigenous issues included in the Project

As indicated in our proposal, our partner organizations include relevant local representatives connected to international Indigenous organizations (Canada, Finland), which will be instrumental in addressing resilience can be increased to the impacts of mining activities and which mitigation strategies will be promising. Furthermore, The RAMWA team is closely connected to AMAP and will establish contacts to the Permanent Participants in AMAP for including Indigenous and local expertise in the work, which will be particularly important for recommendations to industries, scientists, and regulators.

Currently many mine activities are reported in the Arctic where Indigenous communities are affected (e.g., Canada, US-Alaska, Greenland, Finland). The RAMWA network will, hence, identify representative communities effected by local mining and will invite indigenous community and local mining experts explicitly to the planned meetings and future project planning. Potential funding for travel support and project contribution will be sought for Indigenous experts.

## Quality control of the application

For this project, quality means having reliable monitoring data and research findings as foundation of the RAMWA recommendations. The scientific expertise and integrity of the RAMWA experts is an important prerequisite for reliable decision making on science-based recommendations and research prioritization. Transparency in science and communication is a key aspect of the collaboration, enhancing internal quality control. External peer-review will be sought wherever possible. Quality control is, hence, an integrated tool for the here planned assessments for sustainable research and educational priorities.

### Integration into already established TN networks.

The RAMWA network will benefit from communication with and expertise of already established UArctic TNs. The RAMWA core group will, therefore, coordinate the network with relevant other UArctic TNs in operation. The following TNs have been identified as relevant for co-operation and knowledge exchange:

1. Arctic and Northern Governance
2. Arctic Economic Science
3. Arctic extraction Industries
4. Arctic Law
5. Arctic Plastic pollution
6. Arctic Sustainable Resources and Social Responsibility
7. Health and Well-being in the Arctic
8. Local scale planning, Climate Change and Resilience
9. POPs and Chemicals of emerging Concern in the Asian Arctic
10. SmartNorth

## Has network already been awarded some funding?

Except for the initial UArctic funding for the *"Fredrik Paulsen seminar on Mine Bioremediation in the Arctic (Sept. 18 – 20th, 2023)"* no direct funding has been provided. In addition to the UA support (after the TN is initiated), we expect that the proposed network

will work towards securing additional funds to support its planned activities for years two and three, including field work, educational collaboration, and meetings.

Lead: Roland Kallenborn, NMBU/KBM

*Partners:*

- Guillaume Nielsen, Yukon University, Canada
- Stephan Weinbruch, Technical University Darmstadt, Germany
- Bing Chen, Memorial University, Canada
- Wonjae Chang, University of Saskatchewan, Canada
- Elain Baker, University of Sydney, Australia
- Susan Baldwin, University of British Columbia, Canada
- Carmen Neculita, Université du Quebec en Abitibi Temiscamingue, Canada
- Kristina Thygesen, GRID Ahrendal, Norway
- Daria Popugaeva, Western University & Core Geoscience Services Inc., Canada
- Yifan Li, Harbin institute of Technology, China
- Zifeng Zhang, Harbin institute of Technology. China
- Katrin Vorkamp, Århus University, Denmark
- Arja Rautio, Oulo University, Finland
- Leo Yeung, Örebro University, Sweden

Norwegian University of Life Sciences

University of the Arctic
UArctic Thematic Networks
Leadership Office
Thule Institute
P.O.Box 7300
FIN-90014 University of Oulu,

Date
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**Letter of Support**

This is to confirm support by the Norwegian University of Life Sciences (NMBU) and its Faculty of Chemistry, Biotechnology and Food Science (KBM) of Prof. Dr. Roland Kallenborn's application to establish a new thematic network under the University of the Arctic tentatively called "Sustainable Strategies for Waste Removal and Restauration of Arctic Mine Waste Areas (RAMWA)". Should the application be successful, NMBU/KBM will allocate work hours for Prof. Kallenborn to lead this thematic network, including related activities and travel.

As a university member of UArctic hosting this proposed new network is deemed important for NMBU.

Siri Fjellheim
Rector

Sigrid Gåseidnes
Dean, Faculty of Chemistry,
Biotechnology and Food Science

P.O. Box 5003
NO-1432 Ås, NORWAY

www.nmbu.no
post@nmbu.no

+47 67 23 00 00