GIANT MINE
Oversight Board

RESEARCH PROGRAM REPORT

November 2023

www.gmob.ca

The Giant Mine Oversight Board (GMOB) Research Program

Welcome to the first public meeting to share the results of the GMOB Research Program. As part of its mandate, GMOB has supported research to find a permanent solution to manage the toxic arsenic trioxide dust stored underground at the Giant Mine site.

237,000 tons of arsenic trioxide dust are currently stored in fourteen underground chambers. After evaluating a wide range of technical solutions to manage potential environmental and human health impacts associated with the dust, the Government of Canada and the Government of the Northwest Territories determined that the preferred method was to freeze the dust and the rock around each underground chamber. In 2013, the Mackenzie Valley Environmental Impact Review Board found that this was the most appropriate technical solution available at the time. However, it also determined that freezing should not be viewed as a permanent solution and that emerging technologies should continue to be investigated.

As a result, GMOB, through Article 7 of the 2014 Giant Mine Remediation Environmental Agreement, is tasked with supporting research into technical approaches that could serve as a permanent solution.

In 2017, GMOB released a report entitled, *"Giant Mine State of Knowledge Review: Arsenic Dust Management Strategies"* which considered the state of several remediation technologies that could be considered for future arsenic trioxide remediation. A subsequent gathering of research institution and program administrators to examine the requirements for development of a GMOB research program resulted in a recommendation to approach TERRE-NET to discuss establishment of a collaborative research program.

Headquartered at the University of Waterloo, TERRE-NET brings together leading experts from eight Canadian universities working in the fields of geochemistry, hydrogeology, mineralogy, biogeochemistry, mine effluent treatment, geotechnical engineering, nanotechnology, environmental microbiology, resource economics, environmental sociology, and interactions with Indigenous communities. Through an integrated approach, the network develops technically viable, cost-effective, and socially acceptable strategies for managing mine waste and mitigating contamination from mining operations.

GMOB hosted a number of workshops with TERRE-NET research leads prior to signing a Master Research Agreement in 2018. The Agreement guides the administration of the GMOB Research Program. There are now seven streams of active research under the agreement.

This research is funded by GMOB with additional funding leveraged by TERRE-NET through successful applications to the Natural Sciences and Engineering Research Council of Canada (NSERC) Alliance program and the Ontario Research Fund.

On behalf of GMOB, I thank you for attending this meeting. We look forward to the experts' presentations and your observations, comments, and questions.

Regards,

Marc Lange
GMOB Board Member
Research Lead

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The Giant Mine Oversight Board at a Glance

Purpose

The 2015 Giant Mine Remediation Project Environmental Agreement established the Giant Mine Oversight Board (GMOB). GMOB has two primary purposes:

1. Independently monitor, promote, advise, and support the responsible management of the remediation of the Giant Mine site; and
2. Manage a research program to seek a permanent solution to the arsenic trioxide dust stored underground at the Giant Mine.

Mandate

To achieve its purposes, GMOB's mandate is to:

- Monitor and report on the Giant Mine Remediation Project;
- Review, comment, and make recommendations on programs, research, and reports about the Project;
- Support research into a permanent solution for the arsenic trioxide dust stored underground at the Giant Mine site; and,
- Communicate to the public and Parties to the Environmental Agreement about GMOB's activities.

Vision

GMOB envisions that the remediation of the Giant Mine site, including the sub-surface, will be carried out in an environmentally sound, socially responsible, and culturally appropriate manner.

Governance

GMOB is governed by a six-member Board of Directors. The six Parties to the Giant Mine Remediation Project Environmental Agreement each appoint one member to the Board. Each Director acts independently from the Party making the appointment. The Parties are:

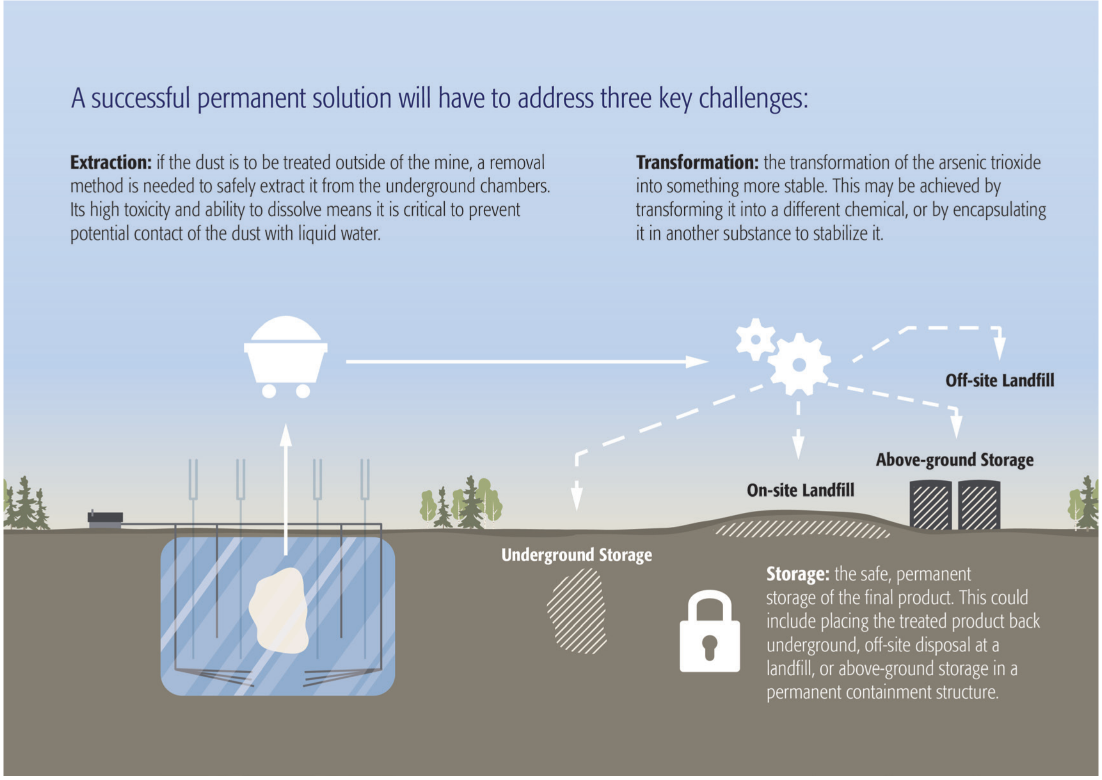
3. Government of Canada, Crown-Indigenous Relations and Northern Affairs Canada
4. Government of the Northwest Territories, Environment and Natural Resources
5. Yellowknives Dene First Nation
6. North Slave Métis Alliance
7. Alternatives North
8. City of Yellowknife

The Government of Canada and the Government of the Northwest Territories are co-proponents of the Giant Mine Remediation Project. They work together as the Giant Mine Remediation Project Team. The co-proponents are referred to as the 'Project Team' throughout this report.

Overview of GMOB Funded Research

Article 7 of the Giant Mine Remediation Environmental Agreement tasks GMOB with undertaking research into technical approaches that do not require constant and forever care and maintenance of the arsenic trioxide at the mine site. As shown in the figure below, a permanent solution must tackle three key challenges: extraction of the dust, transformation to a much less toxic material, and safe storage of the final product.

Key Challenges to Address for a Permanent Solution to Arsenic Trioxide Dust Stored Underground at Giant Mine



Background

In 2018, GMOB partnered with TERRE-NET, an integrated network of leading academics from universities across Canada who work toward managing mine waste and mitigating contamination from mining operations.. One of TERRE-NET's goals is to find sustainable ways to deal with environmental challenges associated with the resource sector, including the management of hazardous wastes from mines. These experts work in various scientific and social science fields.

TERRE-NET is headquartered at the University of Waterloo. GMOB has asked TERRE-NET to focus on technology that will transform the arsenic trioxide into a stable, much less toxic material.

Understanding the makeup of the arsenic dust at Giant Mine

PRESENTED BY

- Matthew Lindsay, Associate Professor, Department of Geological Sciences, University of Saskatchewan
- Heather Jamieson, Professor Emerita, Department of Geological Sciences & Geological Engineering, Queen's University

The larger Giant Mine research program is exploring several different ways to stabilize the arsenic dust, and these projects include testing how well each stabilized product stands up to conditions that it might encounter in storage (for example, flooding by groundwater or lake water).

The arsenic dust currently stored underground at Giant Mine presents a serious environmental challenge. The dust is one of the by-products that were produced when rocks that naturally contained gold, arsenic and sulfur were mined and roasted at extremely high temperatures to extract the gold.

The dust contains large amounts of arsenic trioxide, a dangerous substance that dissolves in water, but it also contains iron, calcium, sulfur and more. These additional elements, which were present naturally in the mined rock, cause the dust to behave differently from pure arsenic trioxide. These differences affect how the dust can be treated so that it is stable for the long term.

This project has two goals. The first goal is to gain a clear picture of the dust's chemical and physical properties. The second goal is to learn how the dust dissolves in the different types of water that exist in and near the Giant Mine (e.g., lake water or groundwater).

The first step is to closely examine the arsenic dust using specialized equipment to gain a better picture of what exactly is in it. The dust's composition has implications for how it behaves and reacts, both in the environment and when it is transformed and stored for the long term.

The next step is to test how the arsenic dust dissolves in water under different environmental conditions such as fresh lake water or salty groundwater from deep underground. The results from these tests will help explain why the dust behaves the way it does, both in the environment and in potential remediated products (e.g., when mixed with cement or transformed to glass).

PROJECT UPDATE

RESEARCH PROGRESS: 90%

Where we are now: This was the first project initiated in this research program, and it is nearly complete. The first step, understanding the dust's properties, is complete and a scientific paper describing these results was recently published. The second step, examining how the dust dissolves in water, is nearing completion with ongoing efforts focused on data analysis and interpretation.

What comes next: The results of dissolving the dust in water under different conditions are currently being described in a second scientific paper that is being prepared for publication. Once published, this project will be complete.

PROJECT 2

Understanding the long-term stability of iron arsenic solids

PRESENTED BY

- Matthew Lindsay, Associate Professor, Department of Geological Sciences, University of Saskatchewan
- Heather Jamieson, Professor Emerita, Department of Geological Sciences & Geological Engineering, Queen's University

As the GMOB research program is exploring several different ways to stabilize the underground arsenic dust, one very common way of treating arsenic waste materials — specifically, arsenic dissolved in water — is to add an iron-rich compound. This process removes the arsenic from the water and forms iron-rich solids that contain the arsenic.

However, there are many knowledge gaps around the long-term stability of iron-arsenic solids, both when stored aboveground for decades and when conditions change through remediation (e.g., if they are covered in soil and planted over). These knowledge gaps have implications for not only potential treatments for the arsenic dust at Giant Mine, but also for any treatment process that produces these solids as a by-product.

The goal of this project is to learn more about the long-term stability of iron-arsenic solids by exposing them to a range of environmental conditions and studying what physical and chemical changes might occur.

The first step is to produce iron-arsenic solids in the lab, then examine them using special equipment such as the Canadian Light Source Synchrotron to understand their composition. The second step is to expose the solids to a range of conditions. These conditions include exposure to soil, water with different acidity levels, both oxygen-rich and oxygen-poor conditions, and microbes that occur naturally around the mine. These tests will shed light on how different possible reclamation scenarios might affect the long-term stability of the iron-arsenic solids.

PROJECT UPDATE

RESEARCH PROGRESS: 20%

Where we are now: The research team has produced iron-arsenic solids and performed initial tests to get a better picture of their chemical and physical makeup.

What comes next: The work is continuing as researchers prepare to begin testing the samples under a range of environmental conditions, performing the microbial tests and closely studying any changes that might occur to the solids.

PROJECT 3

Turning arsenic dust into a mineral that won't dissolve in water

PRESENTED BY

- Tom Al, Professor, Department of Earth and Environmental Sciences, University of Ottawa

Arsenic sulfide is up to 10,000 times less soluble than arsenic trioxide and could provide a safe and permanent solution when stored underwater, deep in the mine.

The goal of this project is to "trap" the arsenic in a more stable mineral called "arsenic sulfide."

In its current form, the arsenic trioxide is simply arsenic "linked" to oxygen. The first step is to dissolve the arsenic trioxide in water to break the arsenic free from the oxygen. Like adding sugar to tea, heating the water is important to ensure it dissolves completely. **The most important challenge for the research team is figuring out how hot the water needs to be, and for how long, to completely dissolve all the arsenic trioxide.**

Next, the researchers add sulfides to the dissolved mixture. This process, called "sulfidation," traps the arsenic in arsenic sulfide. After dissolving the arsenic trioxide, a small amount of "residue" remains. Studying this residue is another important phase of this project to determine if it needs to be treated and how that could be done.

Should arsenic sulfide be used in a permanent solution, it would be important to keep it away from oxygen so new arsenic trioxide doesn't form, meaning it would need to be stored underwater in the deepest part of Giant Mine.

PROJECT UPDATE

RESEARCH PROGRESS: 60%

Where we are now: Researchers now have a good idea of the temperature and time needed to dissolve the arsenic dust in water. Their key finding is that the water will need to be 200°C or higher, and the time could range from 5 to 10 minutes (although these numbers may require adjustment for a full-scale operation). They have also begun studying the residue, which contains about 5–10% of the arsenic from the original sample, to better understand what extra treatment it might need.

What comes next: Researchers are putting the final touches on the process for dissolving the arsenic dust. Next, they will test the sulfidation process and finish studying the residue.

PROJECT 4

Using bacteria from the environment to produce an essential ingredient for stabilizing arsenic

PRESENTED BY

- Carol Ptacek, Professor, Department of Earth and Environmental Sciences, University of Waterloo

One potential option for safe, permanent storage is to dissolve the arsenic dust in water and combine the arsenic with sulfur, which will “bind” to the arsenic and trap it in a mineral form (arsenic sulfide) that can be safely stored deep underground (see Project 3 for more details).

Sulfur, in the form of sulfide minerals, occurs naturally in the rocks that were mined at Giant Mine. When mined and exposed to oxygen, sulfide minerals release sulfate, which can be found in the not-yet-treated wastewater at the mine. This form of sulfur *cannot be used to treat the arsenic dust* – but certain kinds of bacteria that live near Giant Mine may be harnessed to treat the water so it can. These bacteria "breathe" sulfate instead of oxygen in the wastewater to produce a form of sulfur, called “sulfide,” that *does bind with arsenic* to make a mineral that is not very soluble.

The goal of this project is to explore whether local bacteria can produce sulfide from not-yet-treated mine wastewater to treat arsenic dust at Giant Mine.

This project has three steps. First, researchers will collect bacteria from nearby wetlands and feed them nutrients (e.g., from local food waste) to help them grow and multiply. Second, they will use the bacteria to process untreated wastewater from the mine and produce sulfide. Finally, they will add the sulfide to dissolved arsenic dust to trap the arsenic in a much less soluble mineral.

By harnessing local bacteria to produce sulfide from locally available mine wastewater, it should be possible to treat the arsenic dust while also improving the quality of the mine wastewater before it goes on to further treatment.

PROJECT UPDATE

RESEARCH PROGRESS: 10%

Where we are now: A graduate student has just started on this project, beginning with a review of the existing scientific research and collection of samples from several wetland areas on the Giant Mine site. This work builds on the development of a process for dissolving the arsenic dust (Project 3).

What comes next: Soon work will begin on the three steps described above. The first step will be to “feed” the bacteria in a lab setting to increase their numbers and learn more about how much local waste/nutrients will be needed.

PROJECT 5

Testing the long-term safety of arsenic-containing glass

PRESENTED BY

- Alana Ou Wang, Post-doctoral Fellow, Department of Earth and Environmental Sciences, University of Waterloo

Arsenic-containing mine waste (dust) can be transformed into a highly stable glass, which has the potential to provide a safe, permanent storage option for the arsenic dust at Giant Mine. However, Giant Mine dust contains many impurities and may not always behave as expected.

The goal of this project is to stress-test arsenic glass samples, produced using arsenic dust from Giant Mine, and learn which conditions may cause arsenic to leak out. If the glass can withstand these tests, it may be strong enough to provide a safe long-term storage solution for the arsenic dust.

This project includes several steps. First, researchers will study the glass to learn its physical structure and chemical makeup. Next, they will test crushed and uncrushed glass samples with a wide range of liquids (water, acids, and more) to simulate extreme environments and learn what might cause the arsenic to leak from the glass. By studying crushed samples, they can learn whether potential physical damage would increase the likelihood of arsenic escaping from the glass.

Finally, they will subject the glass to environments that might occur in storage. They will pack uncrushed glass samples into plexiglass cylinders and pass three types of water through them to mimic exposure to Giant Mine groundwater, Great Slave Lake water, or acid rain.

These tests will reveal whether the glass can withstand exposure to different conditions or if the arsenic will eventually escape into the natural environment. This information will also help the researchers identify the safest storage conditions for the glass.

PROJECT UPDATE

RESEARCH PROGRESS: 70%

Where we are now: Researchers have finished analyzing the chemical and physical makeup of crushed and uncrushed glass. They have finished testing the samples that were exposed to different liquids and are currently preparing to report on the results. The water exposure tests using Giant Mine groundwater and Great Slave Lake water are ongoing, as the researchers want to be sure that the glass can withstand being exposed for a prolonged time.

What comes next: The researchers decided to add a third exposure test using acidic rainwater, which were started this summer. They will also study samples of both the glass, and the water that was in contact with the glass, to learn more about any changes may have occurred.

PROJECT 6

Trapping arsenic dust in a cement paste to be stored underground

PRESENTED BY

- Isabelle Demers, Professor, Research Institute on Mines and Environment, Université du Québec en Abitibi-Témiscamingue
- Nicholas Beier, Associate Professor, University of Alberta

Mixing the waste materials from mining ("tailings") with cement for underground storage is a common practice in mine reclamation. When wet, the mixture is a thick paste that can be transported and pumped into underground storage chambers. Unlike regular cement, which hardens into concrete, a cemented paste contains much more water and hardens to a consistency like a stiff soil.

Arsenic trioxide is not a typical ingredient in cemented paste, meaning the mixture could behave in unexpected ways. **The goal of this project is to test different cemented paste mixtures — and the conditions needed for the paste to harden — to learn the most stable "recipe" for trapping and permanently storing the arsenic underground.**

This project has two steps. The first step is to test different recipes to see which produces the strongest cemented paste once hardened. Researchers will then place hardened samples from each recipe in moving water to see if any arsenic leaks out from them. The second step is to subject the cemented paste to the extreme temperature changes that might occur at Giant Mine. These changes include freezing before the paste has hardened, freezing for long periods, or repeated freeze-thaw cycles, all of which might weaken the final hardened paste (like soils heaving as they freeze).

Together, these tests will allow researchers to see if there is a mixture that will withstand the eventual storage conditions at Giant Mine without leaking arsenic into the environment.

PROJECT UPDATE

RESEARCH PROGRESS: STEP 1 – 80%

Where we are now: The first step is nearly done. Researchers learned that adding arsenic dust causes the paste to behave differently than expected, and they were able to rule out several mixtures that were not strong enough. For example, they tried replacing some of the cement with lime kiln dust (a method for reducing costs), and the result was very unstable. They are analyzing the samples that performed poorly to better understand why this was happening. There are a few remaining tests required to identify the best recipe.

What comes next: Once the best recipe for the cemented paste is identified, step two involves subjecting the paste to different freezing scenarios (before, during and after it has hardened). Researchers will then look at the hardened paste through a powerful microscope to see if cracks form that could allow arsenic to escape.

PROJECT 7

Monitoring arsenic pollution using a stable isotope analysis of antimony

PRESENTED BY

- David Blowes, Professor, Department of Earth and Environmental Sciences, University of Waterloo

Understanding where arsenic came from on-site and how it moves through the environment is important for managing and treating it in the future. This kind of information can be learned using a method called "stable isotope analysis." However, this kind of analysis can only be performed using certain elements, and arsenic is not one of them.

Fortunately, arsenic has a close chemical cousin called "antimony" that can be used for stable isotope analysis. Antimony is found in the arsenic dust at Giant Mine and tends to "tag along" with arsenic. This means researchers can learn how arsenic behaves by studying the antimony that travels with it.

The first goal of this project is to develop and test a method that uses antimony to monitor arsenic pollution in the environment around Giant Mine. This work will make it possible to identify whether antimony (and thus arsenic) detected in a water sample came from the mine, and possibly even which storage chamber it came from. This could provide an early warning if arsenic enters the groundwater from any of the chambers, helping researchers quickly pinpoint the contamination source.

The second goal is to enable more detailed testing of the potential permanent storage options. The main challenge facing researchers is designing a method that is tailored to the arsenic dust and environment at Giant Mine. Stable isotope analysis using antimony is quite new, and researchers are breaking new ground by using it for this purpose.

Researchers will test samples from the other projects using stable isotope analysis and learn if there have been chemical changes that other methods could not detect. This is important because subtle chemical differences could impact a method's long-term stability.

PROJECT UPDATE

RESEARCH PROGRESS: 25%

Where we are now: There have been delays to date due to issues with the equipment needed to perform the stable isotope analysis. In the meantime, the researchers have prepared for the analysis, including collecting samples from Giant Mine surface water and groundwater monitoring stations and tailings ponds.

What comes next: The necessary equipment is now in place and researchers have begun the process of analyzing the samples.

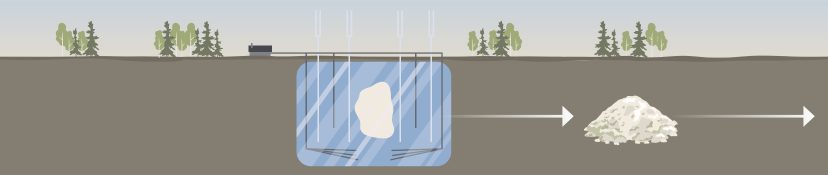
Working to permanently solve the problem of underground arsenic dust at Giant Mine

A multi-pronged research program to determine the safest way to store a dangerous waste product.

A legacy of waste

Giant Mine, located near Yellowknife in the Northwest Territories, produced 237,000 tonnes of toxic arsenic-containing dust during its 51 years of operation. This dust is currently stored underground, where several failsafe measures are in place to keep it contained.

A permanent storage solution for the dust — one that does not require constant maintenance — is needed to ensure the safety of surrounding communities for generations to come.



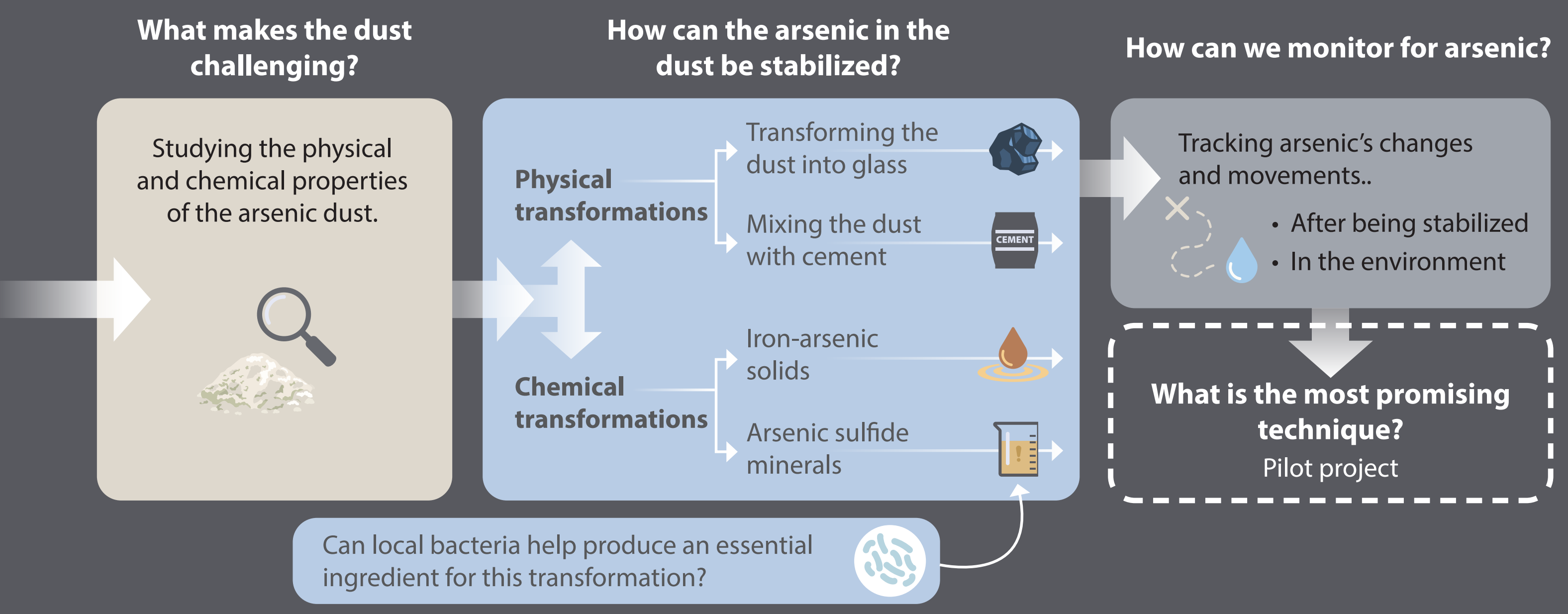
Exploring many options

The Giant Mine Oversight Board is funding seven research projects exploring different ways to stabilize, permanently store, and monitor the arsenic dust. These stabilization methods usually involve transforming the dust, either physically or chemically.

Rigorous research is needed to better understand both the dust and which methods will work to stabilize it.

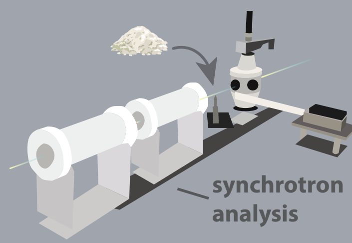
Laying the groundwork

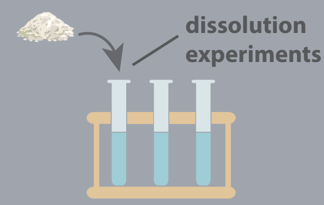
These research projects will build an essential foundation of knowledge to determine which techniques work the best. Each project will take a different amount of time to complete, and some started later because they built off the results of another. Future research will continue to explore the most promising solution(s). Once one is found a *pilot project* will then be proposed to test the solution on the Giant Mine site.



Q: What are the properties of the arsenic dust?

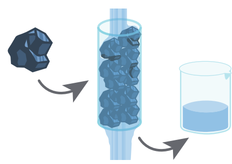
Highly specialized equipment and lab tests are used to gain a better understanding of what makes up the dust and how it dissolves in water.
(Project 1)



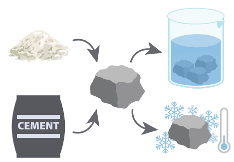


Q: What techniques will effectively stabilise the dust?

Physical transformations

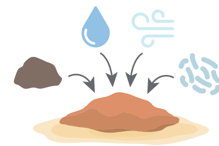


Arsenic glass: Exploring the properties of the glass and how it holds up when stored above or belowground.
(Project 5)

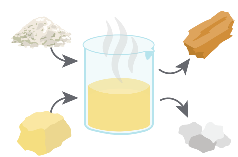


Cemented paste: Finding the best "recipe" and exploring its stability.
(Project 6)

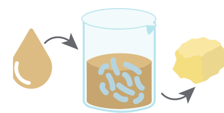
Chemical transformations



Iron-arsenic solids: Filling knowledge gaps around their long-term stability.
(Project 2)



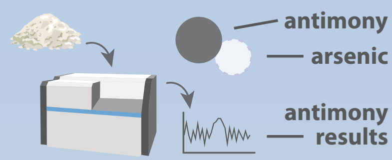
Arsenic sulfide minerals: Finding the best technique to transform arsenic into a stable mineral form.
(Project 3)

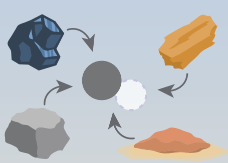


Can local bacteria help produce essential sulfides for this transformation?
(Project 4)

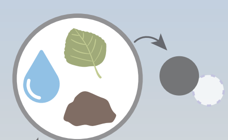
Q: How can we monitor for arsenic?

Arsenic likes to stay close to antimony, and antimony can be tracked closely using a technique called "**stable isotope analysis**," opening the door to additional tests.
(Project 7)

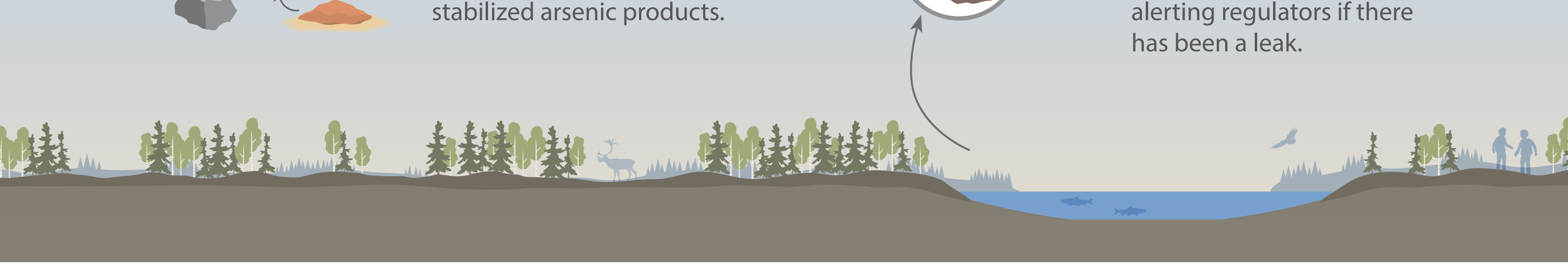




An extra way to assess whether lab tests have affected the stability of stabilized arsenic products.



Can be used to test for arsenic and antimony in the environment and learn where they came from, alerting regulators if there has been a leak.



WHERE WE ARE NOW

Each of these research projects will build a deeper understanding of the most promising permanent storage solutions for the arsenic dust at Giant Mine. By testing many avenues, it will be possible for the Giant Mine Oversight Board to focus their efforts on whichever approach is found to be most feasible.

Individual summaries and progress updates are available for each of the seven research projects. To learn more, visit **www.gmob.ca**

Biographies

Scientific Research Investigators

David Blowes, Professor, Department of Earth and Environmental Sciences, University of Waterloo

David Blowes is a Professor of Earth and Environmental Sciences and University Research Chair at UW and has more than 35 years of experience in contaminant hydrogeology and groundwater geochemistry. His research program includes three key components: mechanistic studies of contaminant release, transport, and attenuation, with emphasis on the environmental impacts associated with mine-waste management and disposal; development and application of numerical models to describe these processes; and development of new techniques for the prevention of contamination and remediation of mine sites. He has led numerous research projects focused on mine-waste geochemistry and hydrogeology, and on remediation of mine-waste storage areas. Dr. Blowes received an NSERC Synergy Award for Innovation in 1999 for his research on innovative approaches for managing mine wastes. Dr. Blowes is a Fellow of the Royal Society of Canada and a Fellow of the Geological Society of America. In 2015, Dr. Blowes and his research team received, with Diavik Diamond Mines (2012) Inc., the NSERC Synergy Award for Innovation for research focused on cover strategies for the long-term management of acid-generating waste rock.

Carol Ptacek, Professor, Department of Earth and Environmental Sciences, University of Waterloo

Carol Ptacek has been a Professor in Geochemistry and Contaminant Hydrogeology and University Research Chair at UW since 2006. Her research program is focused on mechanisms controlling the fate of metal(loid)s, nutrients, pathogens, and organic contaminants in groundwater, surface water, and sediments. She integrates laboratory, field, and modelling techniques to gain an improved understanding of physical and biogeochemical processes occurring at contaminated sites, including mine sites. This information is used to develop passive and active remediation systems to remove or stabilize contaminants to minimize ecosystem exposure. Prior to joining UW, she was employed for 14 years as a Research Scientist and subsequently Section Head for Groundwater Remediation at the National Water Research Institute, Environment Canada. Dr. Ptacek received an NSERC Synergy Award for Innovation in 1999 for her research on innovative approaches for managing mine wastes.

Heather Jamieson, Professor Emerita, Department of Geological Sciences & Geological Engineering, Queen's University

Heather Jamieson is a Professor Emerita at Queen's University in Geological Sciences & Geological Engineering. Dr. Jamieson is an environmental geochemist and her research has focused on the mineralogical controls on the release of elements to the environment. Dr. Jamieson has conducted research on the environmental mobility of arsenic and antimony in tailings, dust, soils and lake sediments in the Yellowknife area since 1999 and supervised 14 graduate theses on these topics. In addition to her collaboration with Drs. Lindsay, McBeth and Schoepfer on the Giant Mine Oversight Board-sponsored projects, she is part of a study on Yellowknife garden soils and vegetables, and leads another project on the recovery of the landscape following mining contamination.

Isabelle Demers, Professor, Research Institute on Mines and Environment, Université du Québec en Abitibi-Témiscamingue

Isabelle Demers is a professor at the Research Institute on Mines and Environment at Université du Québec en Abitibi-Témiscamingue (UQAT) in Rouyn-Noranda, Quebec. She is holder of the Canada Research Chair in Integration of environment in the mine life cycle. Her research work focuses on mine waste management, including engineered cover systems to prevent acid mine drainage, environmental desulfurization by flotation, and cemented paste backfill for contaminant stabilization. She also works on geoenvironmental characterization and modeling to help anticipate environmental issues associated with mine waste at the exploration and early operation stages. Isabelle is a member of the Order of Engineers of Quebec, obtained a B. Eng and M. Eng in metallurgical engineering from McGill University and a PhD in Environmental Sciences from UQAT.

Joyce McBeth, Assistant Professor, Department of Geology, University of Regina

Joyce McBeth is an assistant professor in the Department of Geology at University of Regina. Dr McBeth's expertise is in microbial interactions with the geosphere including metal(loid) and hydrocarbon contaminant remediation and metal transformations mediated by microbes in mine wastes. Her current research includes studies of microbes in mine tailings and ores and wastewater treatment systems and synchrotron approaches applied to mine-related remediation. Prior to joining the University of Regina, Dr. McBeth was an Assistant Professor at the University of Saskatchewan (2015-2020), a Research Scientist at the Canadian Light Source synchrotron (2012-2015), and a Postdoctoral Researcher at Bigelow Laboratory for Ocean Sciences (2008-2012).

Matthew Lindsay, Associate Professor, Department of Geological Sciences, University of Saskatchewan

Matthew Lindsay is an Associate Professor in the Department of Geological Sciences at the University of Saskatchewan and the NSERC Industrial Research Chair in Mine Closure Geochemistry. His research in environmental geochemistry and applied mineralogy emphasizes (i) mine waste characterization, management, and reclamation, (ii) mine drainage generation, transport, and treatment, and (iii) metal(loid)-mineral interactions in groundwater systems. Support from government agencies, industry partners, community organizations, and research facilities has enabled this fundamental and applied research. Overall, Dr. Lindsay's research program has helped advance understanding of complex interconnected process controlling water chemistry in mining environments and, more broadly, terrestrial waters impacted by anthropogenic or geogenic contamination.

Tom Al, Professor, Department of Earth and Environmental Sciences, University of Ottawa

Tom Al is a Professor in the Department of Earth & Environmental Science at the University of Ottawa. Dr. Al has over 25 years of experience with research focused primarily on groundwater geochemistry related to waste management in the mining and nuclear-energy sectors and is internationally recognized as an expert in hydrogeochemistry as it relates to these sectors. He is the lead investigator in the hydrogeochemistry research program supported by the Canadian Nuclear Waste Management Organization and was a principal contributor to the geoscience research program that formed the basis of the safety assessment for the proposed deep geological repository for low- and intermediate-level radioactive waste at the Bruce nuclear site.

Alana Ou Wang, Post-doctoral Fellow, Department of Earth and Environmental Sciences, University of Waterloo

Alana Ou Wang is a postdoctoral researcher in the Department of Earth and Environmental Sciences, University of Waterloo. Alana had her bachelor's degree in Earth Sciences (Hydrogeology) at the University of Waterloo. Then, Alana continued her PhD research in Earth Science (Water) at University of Waterloo which focused on remediation of mercury-contaminated riverine environment using biochar. Currently, Alana's research focuses on evaluating the stability of vitrified arsenical glass as potential solution to stabilize arsenic trioxide roaster waste at the Giant Mine with supervision of Dr. David Blowes and Dr. Carol Ptacek.

Valerie Schoepfer, Post-doctoral Fellow, Department of Geological Sciences, University of Saskatchewan

Valerie Schoepfer is a post-doctoral fellow at the University of Saskatchewan. Her work broadly focuses on dynamics of metal-mineral interactions with implications for metal mobility in both modern and paleo- environments. Dr. Schoepfer integrates synchrotron techniques, electron microscopy, and experimental approaches to address both fundamental and applied scientific questions with implications for environmental change through geologic time and for mine waste management and site remediation. Dr. Schoepfer earned her PhD in Environmental Geochemistry and Mineralogy under the supervision of Dr. Ed Burton (2019; Southern Cross University, Australia). Her MSc (2014; University of Nebraska-Lincoln, USA) and BSc (2010; University of New Hampshire, USA) are both in Natural Resources with a focus on aquatic biogeochemistry.

Amirhossein Mohammadi, PhD candidate, Research Institute on Mines and Environment, Université du Québec en Abitibi-Témiscamingue

Amirhossein Mohammadi is a final-year PhD student at the Research Institute on Mines and the Environment (RIME), at Université du Québec en Abitibi-Témiscamingue (UQAT). Amirhossein earned his bachelor's degree in civil engineering from the University of Tehran, Iran, and went on to complete a master's degree in civil engineering-environment at Amirkabir University of Technology in Tehran, Iran which focused on studying the geomechanical behavior of oil-contaminated soils and their interactions with structural surfaces. Currently, Amirhossein's research is centered on the stabilization of arsenic trioxide roaster waste dusts from the Giant Mine within cemented paste backfills. This research is conducted under the supervision of Professor Isabelle Demers (RIME/UQAT), and co-supervision of Professor Mostafa Benzaazoua (RIME/UQAT) and Professor Nicholas Beier (University of Alberta).

Kevin White, PhD Candidate, Department of Earth and Environmental Sciences, University of Waterloo

Kevin White is a chemist and toxicologist interested in the transport and remediation of contaminants and the risks they pose to environmental and human health. He holds a BSc in Toxicology from the University of Guelph and an MSc in Toxicology from the University of Saskatchewan, focused on the impacts of surface mining and remediation on water quality in the Alberta oil sands. Prior to starting his PhD, Kevin worked at RECETOX in the Czech Republic conducting research on persistent organic pollutants in the atmosphere across Europe and Africa. He has also worked in the federal government, industry, and environmental consulting. Kevin is currently a PhD candidate in the Groundwater Geochemistry & Remediation Research Group led by David Blowes and Carol Ptacek at the University of Waterloo where his research is focused on developing stable isotope analytical techniques to improve characterization of contamination and remediation at Giant Mine in Yellowknife, NT.

Nicholas Beier, Associate Professor, Department of Civil and Environmental Engineering, University of Alberta

Nicholas Beier is an Associate Professor of Geoenvironmental Engineering and the Principal Investigator of the Oil Sands Tailings Research Facility. His areas of expertise include characterizing the engineering behaviour of oil sand tailings, tailings dewatering technology development, simulation modelling for evaluation of mine waste management technologies, freeze-thaw dynamics of mining wastes, frozen ground engineering and waste management in cold regions. He also conducts research into the long-term management and closure of mine waste structures, tailings dam safety for the Alberta Energy Regulator and the reclamation of lands disturbed by mining activities. Dr. Beier has over 15 years of industrial engineering experience, including acting as a Technical Advisor for COSIA.

Hailey Jack, MSc Candidate, Department of Earth and Environmental Sciences, University of Waterloo

Hailey Jack is a 2nd-year MSc student in the Department of Earth and Environmental Sciences at the University of Waterloo. Hailey earned her BSc in Microbiology from the University of Guelph, where she first developed an interest in the interdisciplinary topic of using environmental microorganisms to bioremediate heavy metal-contaminated environments. Hailey then worked in an analytical biological toxicology laboratory for two years, developing her laboratory management and hands-on laboratory skills as a Team Lead. Hailey is currently an MSc candidate at the University of Waterloo conducting research that focuses on enhancing naturally occurring bacteria from Giant Mine for arsenic trioxide biotransformation and arsenic and antimony sequestration in biogenic insoluble sulfide minerals. This research is conducted under the supervision of Professor David Blowes (UW) and Professor Carol Ptacek (UW).

GMOB Board Members

David Livingstone, Chair

David Livingstone
Chairperson
Yellowknife, NT

David Livingstone has worked in the North for almost fifty years and has made Yellowknife his home since 1987. He worked in several departments during his 33-year career with the federal government holding different responsibilities but always focused on Northern environmental and resource development issues in the north. Since leaving the federal government in 2009, he has been engaged in a wide range of environmental stewardship projects and programs in the NWT, Nunavut and internationally. He was instrumental in creating the Tsá Tué International Biosphere Reserve in 2016 and currently chairs the Inuvialuit Environmental Impact Screening Committee, among other things. In 2011, he was awarded the Royal Canadian Geographical Society's Massey Medal for outstanding achievement in Canadian geography, specifically his work in the NWT.

Marc Lange

Marc Lange
Director
Yellowknife, NT

Marc has resided in northern Canada for the past twenty years. An ecologist by training, he is currently the Principle of NorthbyNorth Corp, an environmental and business services consultancy supporting community-based, private, and government initiatives. He has experience with analysis of monitoring results, cumulative effects monitoring, and regulatory decision-making with specific areas of expertise in policy development (e.g., recreational land use framework), strategic planning (e.g., accountability framework for CIMP and Lands Sustainability), program development & implementation related to environment and natural resource stewardship; land use planning; conservation planning; environmental assessment and regulatory processes in the Yukon, NWT, and Nunavut; and Indigenous engagement in program planning and research and monitoring initiatives including community-based research and monitoring.

Ken Hall

Ken Hall
Director
Yellowknife, NT

Ken was born in Yellowknife and grew up out at the Giant campsite. His family has a long history of working and living at Giant. Ken holds diplomas in Ecology and Environmental Sciences from the Northern Alberta Institute of Technology and was the first environmental technician at Giant in the 1970's. His career included time with Fisheries and Oceans when he travelled and worked throughout the Central Arctic spending time in many small communities. He went on to become a hazardous substance/contaminated site specialist with the GNWT then managed the environmental protection services until he retired in 2011. Working in both industry and public service with people from across the North has helped him develop a balanced perspective.

Graeme Clinton
Director
Yellowknife, NT

Graeme Clinton

Graeme is an economist with more than 25 years of experience. His first look at Canada's northern economies came in the early 2000's while working as a senior economist with the Conference Board of Canada when he studied the economic future of Nunavut and the NWT after the territories separated. Graeme has studied economies in Canada, South America, and Eastern Europe, but after moving to Yellowknife in 2002, has focussed primarily on the growth and development of the NWT and Nunavut. Graeme views economics as the study of choices, specifically, how our individual and collective wellbeing is determined by our ability to understand, assess, and make the most of the choices available to us.

Dr. Ken Froese
Director
Yellowknife, NT

Dr. Ken Froese

Dr. Froese is an environmental health scientist with more than 22 years of professional experience since completing his PhD in Germany. He is designated as a Professional Chemist in Alberta and British Columbia. Dr. Froese is the owner and principal consultant of GatePost Risk Analysis; he also an Adjunct professor in Community Health Sciences at the University of Calgary where he teaches Environmental Health. Dr. Froese's experience includes environmental chemistry and drinking water research, teaching, and numerous scientific publications and conference presentations. He has led and performed simple to complex risk assessments, critical reviews, research and policy development, serving First Nations, community groups, provincial and federal governments, and various clients in oil and gas, mining, and utilities. He approaches community environmental health from a broad perspective combining risk-based methods with systems thinking, because the issues are typically complex and require different solutions for different communities.

Mark Palmer
Director
Edmonton, AB

Mark Palmer

Mark has over thirty years of experience working in the Federal Government. He started his career in Yellowknife focusing on water quality issues and has since worked for different departments in various locations on a wide range of national and international environmental issues. His work over the last twenty-nine years focused on remediation of contaminated sites across Canada's north. He brings to the Board his experience with site and risk assessments, the development of remediation options, regulatory processes, contracting and socio-economic strategies.

Ben Nind
Executive Director

Ben Nind, Executive Director

Ben is a long-time resident of the NWT. He holds a B.A. in Law and Political Science and is currently the Executive Director of the Giant Mine Oversight Board. He has many years of experience in community engagement, facilitation and cross-cultural communications. He has held positions in both the territorial and federal government, as well as in the profit and non-profit sector.

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THANK YOU
FOR ATTENDING!

CONTACT

IN PERSON Giant Mine Oversight Board
5014-50th Avenue
Yellowknife, NT

MAIL Box 1602
Yellowknife, NT X1A 2P2

TELEPHONE 867.675.0788
EMAIL ed@gmob.ca

Or visit our website www.gmob.ca

GIANT MINE
Oversight Board