Giant Mine State of Knowledge Review: Plain Language Summary

Toxic arsenic trioxide dust is currently stored underground at the former Giant Mine. The Giant Mine Oversight Board contracted Arcadis to research and assess technologies that could be used to manage the dust. The report that was produced is called a State of Knowledge Review. The following is a plain language summary of the Arcadis review.

Background

The former Giant Mine is on Great Slave Lake about five kilometres north of Yellowknife, in the Northwest Territories. Gold was mined from the site from 1948 until 1999, when the owner, Royal Oak Mines, declared bankruptcy. Indigenous and Northern Affairs Canada (INAC) and the Government of the Northwest Territories (GNWT) took on responsibility for managing the site, including the environmental risks. INAC and the GNWT are planning to manage those risks by implementing the Giant Mine Remediation Project.

The gold-bearing rock at Giant Mine includes arsenopyrite, a mineral that contains arsenic. Dust, made up mostly of arsenic trioxide, was created when the rock, or ore, was processed to produce gold. That dust has been stored underground in specially-built vaults or in previously mined-out chambers (known as stopes) at the mine site since the early 1950s.

During the 50 years of operation, the mine produced 237,000 tonnes of arsenic trioxide dust. The dust stored at the site would fill Yellowknife's Precambrian Building (an 11-storey high rise) seven times. The dust is, on average, about 60% arsenic trioxide by weight.

Arsenic trioxide can dissolve in water. If it was dissolved in water, the arsenic trioxide would be a risk to people and the environment if it makes its way to Great Slave Lake and Baker Creek, which runs through the mine site.

The Giant Mine Remediation Project Team began the process of evaluating approaches that could be used to manage the arsenic trioxide dust in 2000. After considering more than 50 technologies, the Project Team decided that the "frozen block method" was the best option. In 2013, the Mackenzie Valley Environmental Impact Review Board approved the frozen block option but there were several important conditions:

1. The frozen block option was approved for a maximum of 100 years;
2. An independent body was necessary to oversee the remediation project; and

3. The oversight body needed to initiate research into more permanent arsenic trioxide management solutions.

The Giant Mine Oversight Board (GMOB) was established in 2015 to oversee the remediation project. GMOB is also beginning the process of designing its arsenic trioxide research program. As a first step, it was decided that a State of Knowledge Review should be performed to evaluate the current status of methods that could be used to manage arsenic trioxide. GMOB contracted Arcadis to perform the State of Knowledge Review, which is summarized below.

Research Method

Arcadis reviewed various potential treatment solutions. It looked at the 50 technologies previously evaluated and the likelihood of success. It then looked more closely at a shorter list of potential ways to:

- manage the arsenic trioxide dust where it is now;
- remove the dust from underground at Giant mine;
- stabilize and process the dust; and
- store the dust.

To determine the most promising options, Arcadis considered several factors. It gave the most weight to such things as long-term effectiveness, safety for people and the environment, minimizing the risks and increasing the permanence of operation and maintenance.

Figure 1 shows all the different factors and the importance given to each one. Teams of experts scored the different solutions. Arcadis obtained information in Canada and elsewhere from government agencies, research organizations, universities and business.

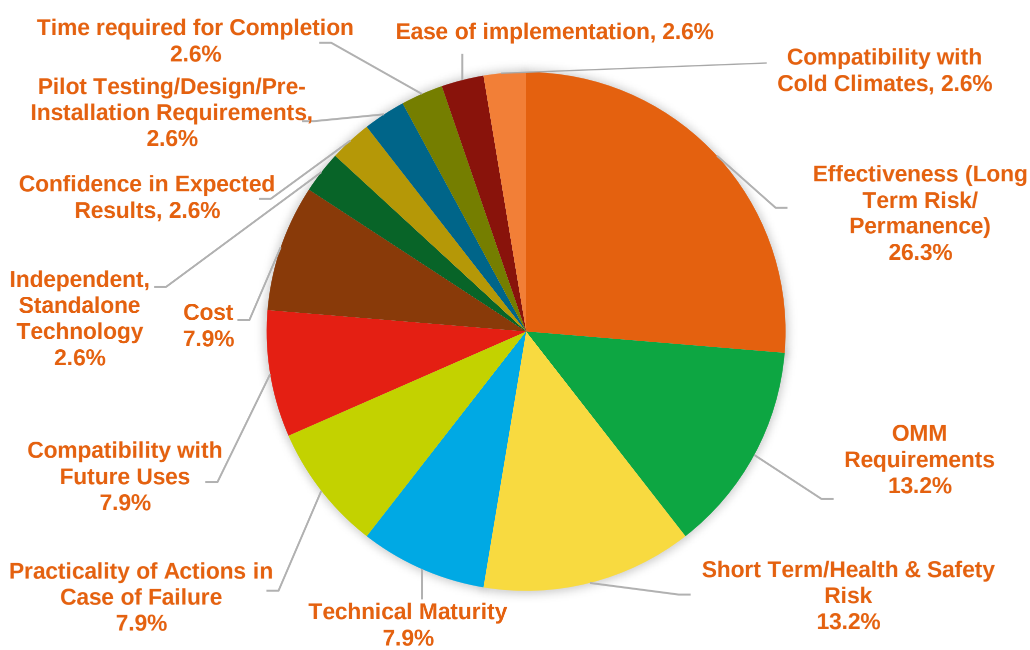

Figure 1: Scoring Criteria Contribution by Percent

Findings

Keeping the arsenic trioxide underground

Two methods for keeping the arsenic trioxide dust where it is now were examined.

Frozen Block

The frozen block method keeps the arsenic dust in place by freezing the ground around it. Because the ground is frozen, water is unable to dissolve the arsenic dust. The frozen block is the highest scoring method for keeping the arsenic trioxide dust in place and is now being applied at the mine site. This method scored well for both technical soundness and for safety.

Nano-Scale Zero-Valent Iron

Nano-scale zero-valent iron refers to very small iron particles that can potentially stop arsenic trioxide from escaping into groundwater. The particles would be mixed with a liquid and injected into the ground surrounding the dust storage areas. This would create a barrier to arsenic movement. While this technology has been used at other contaminated sites, the experts determined that it would be difficult to use for Giant Mine, and probably not work as the only solution.

Removing the arsenic trioxide dust from underground

Dust removal or mining would remove the arsenic trioxide dust from underground for processing. In the past 15 years, technology developments using remote-controlled mining equipment have made the mining option safer for workers.

Remote Mechanical Mining Methods

Due to the complexity of the stopes and chambers, it is likely that several different mining methods would be needed to effectively remove the arsenic trioxide dust from underground. While technology has made mining safer, it is still high-risk. Therefore, mining still scores low in the safety category.

Hydraulic Borehole Mining

Hydraulic borehole mining was scored separately because it might be able to remove nearly all of the dust. This process uses high-pressure liquid or steam to remove the dust in a safer way than other mining methods. It scored the highest of the mining methods, and highest overall. However, because this is only a removal method, it would need to be combined with a process to stabilize the dust.

Treating the arsenic trioxide dust once removed from underground

Once the arsenic trioxide dust is removed from underground, it would need to be made safe for people, the land and water. A number of ways to treat the dust were reviewed.

Vitrification

Vitrification is a process for encasing the arsenic trioxide dust in glass. The arsenic dust would be mixed with glass-making material and then heated in a furnace. The glass captures the dust so it can't dissolve into water (Figure 2).

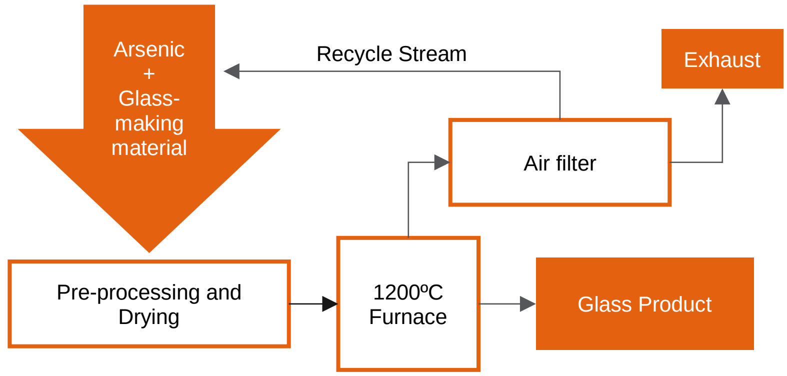

Figure 2: Vitrification Process

This method was the best performing treatment method for arsenic trioxide dust removed from underground. It scored well because the glass is expected to be very stable.

Cement Stabilization

Cement stabilization would combine cement with the dust to keep the arsenic trioxide from moving. Experts concluded that this method could work if the cement were stored in large blocks, keeping the arsenic away from groundwater and surface water. This method would use large amounts of cement, making it costly.

Mineral Precipitation

Arcadis evaluated the possibility of converting the arsenic trioxide into stable natural arsenic minerals that do not easily dissolve in water. Mineral precipitation is used to process arsenic waste at other mines around the world using different methods. The treatment would occur above ground in a treatment plant. Two different groups evaluated this technology as a way to confirm quality control of the research method and findings.

Cement Paste Backfill

Cement paste backfill is a type of cement stabilization where a paste of cement and dust is made. This paste can be pumped, which helps move the dust safely. The cement paste would not be as strong as the solid blocks created through cement stabilization. It was assumed that after stabilization the arsenic trioxide dust would be pumped back underground.

Biological Arsenic Precipitation

Bacteria can make stable arsenic minerals under the right conditions. This technology is newer and not as well studied as mineral precipitation. It would also require an above-ground treatment plant. Some minerals formed in this way are not as stable as the ones formed using mineral precipitation and new processes are being developed. Arcadis examined this method under both low, or no, oxygen (reductive) and higher oxygen (oxidative) conditions.

Underground Disposal

Only one method of underground storage of the processed arsenic trioxide dust was studied.

Sand Shell Purpose-Built Vault

The sand shell purpose-built vault was evaluated as a possible underground storage option. The treated dust would be moved to new underground concrete vaults surrounded by sand and/or gravel to provide protection from ground movement (Figure 3).

This method scored well but needs to be combined with an extraction and treatment method to be effective. A large number of these vaults would be needed to handle the amount of treated dust.

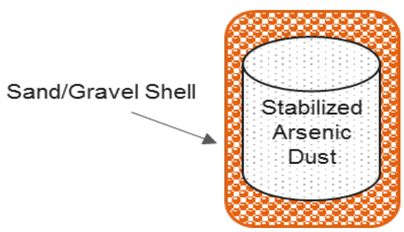

Figure 3: Sand Shell Purpose-Built Vault

Gold Recovery

The arsenic trioxide dust contains small quantities of gold. Previous evaluations determined that processing the dust to remove the gold was not justified. However, the price of gold has increased significantly since those evaluations were performed. As a result, there may be opportunities to partially offset remediation costs by including gold extraction as part of the management strategy.

Ranking of Reviewed Technologies

The frozen block method was the highest-scoring method for keeping the dust in the current location underground. It also got the second-highest score for the stabilization/treatment methods. The highest-ranking dust removal method was hydraulic borehole mining, and the highest-scoring treatment method was vitrification, or encasing the dust in glass.

The overall scores are summarized in Figure 4. Arcadis gave each method a score on a scale of 1 to 10.

Rank	Method	Normalized Score
Mining and Storage Methods		
1	Hydraulic Borehole Mining	10
2	Sand Shell Storage Chamber	7.9
3	Remote Mechanical Mining	7.8
Stabilization and Treatment Methods		
1	Vitrification	10
2	Frozen Block	9.6
3	Mineral Precipitation 1	9.0
4	Cement Stabilization	8.9
5	Mineral Precipitation 2	8.0
6	Cement Paste Backfill	7.8
7	Biological Oxidation	6.8
8	Nano Iron/ZVI	6.7
9	Biological Reduction	6.2

Figure 4: Method Score Summary

Analysis and Quality Control

As part of the study, two tests were done to check the results. First, Arcadis changed the importance of some of the scoring criteria to see if different methods would score better. Second, it had two different groups of experts score the exact same method.

The results of the first test showed little change in the scores of the best methods. The second test, on the mineral precipitation method, showed that the two groups of experts gave similar scores. However, the scores are based on the opinions of individual experts. Different experts might change the relative order of methods that have similar scores.

CONCLUSION

Long-term management of the arsenic trioxide dust at Giant Mine is complex. Arcadis suggested that a combination of methods may be needed to manage the arsenic trioxide dust.

The individual high-scoring methods were combined into possible alternatives.

- Frozen Block (currently used);
- Vitrification (encasing with glass) with mining, gold processing and storage;
- Cement stabilization/cement paste backfill with mining and storage; and
- Mineral precipitation with mining and storage.

More detailed studies are needed before the alternatives to the frozen block method could be considered for the Giant Mine site. Information from the State of Knowledge Review will be used by the GMOB to help define research priorities for a permanent solution for the arsenic trioxide dust that may be implemented in future.

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