MANAGEMENT OF ARSENIC TRIOXIDE BEARING DUST AT GIANT MINE, YELLOWKNIFE, NORTHWEST TERRITORIES.

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Introduction

The Giant Mine, located in Yellowknife, Northwest Territories, Canada has been operating as a gold mine since 1948. Giant has been primarily an underground operation which used roaster technology to remove of gold from refractory arsenopyrite ore. The roasting process produced arsenic trioxide bearing dust as a waste product. This dust was pneumatically conveyed into underground storage chambers at a rate of 10-13 tons per day at peak production. Fifty years of operation have resulted in approximately 265,000 tons of roaster dust stored in 15 underground chambers. When underground storage began in 1951, it was considered the best option at the time, based the occurrence of permafrost in the bedrock. The first chambers were purpose built for dust storage in areas thought to be dry and surrounded by permafrost. From the 1960's through to the mid 1970's dust was placed in mined out stopes rather than purpose built chambers, however, the stopes were still located in dry permafrost zones.

In 1976 the mine once again began using purpose-built chambers to store the arsenic trioxide dust. These chambers were placed to utilize low permeability host rock rather than in permafrost for containment. As late as 1977, the Canadian Public Health Association recommended underground storage as the best option. The chambers are located in the zone that has been dewatered by mining activities (water table depression) but local flow does exist in the mine workings including the chamber areas. This flow is captured by the mine's collection system and treated prior to discharge to the environment. Open pit mining and extensive underground workings in the areas of the chambers have impacted the discontinuous permafrost in the area. The permeability of the host rock, decreasing permafrost, and a re-assessment of the rate of mine reflood has resulted in a review of permanent underground storage.

In 1999, Royal Oak Mines Inc., the former owner of Giant Mine, was placed in receivership and the property was purchased by an existing Yellowknife mine operator. However, in order to effect the sale, the federal government assumed liability for the pre-existing environmental conditions of the site, including the As_2O_3 bearing dust underground. The mine is located within Yellowknife city limits and potentially significant environmental, public health and safety concerns exist. The Department of Indian Affairs and Northern Development, in it's role as regulator and project manager, has been working with the mine's current and previous owners to assess options for managing the dust stored underground.

By October, 2001, the regulatory agency requires the submission of an Arsenic Trioxide Management Project Description outlining a management plan for the dust. The development of a management strategy for the 265,000 tons of As_2O_3 dust has focussed on five main areas: hydrogeology, underground geotechnical issues and in-situ management of dust, extraction of dust to surface, purification of the dust to a marketable product and stabilizing the dust through processing or encapsulation. These will be described further in the paper.

The objective of this paper is to provide an overview of the diversity and complexity of the various components in developing an Arsenic Trioxide Management Project Description. This project presents challenges posed by few other projects from both an arsenic management and government regulatory process perspective. The following paper summarizes approximately 25 reports on arsenic trioxide management issues produced for DIAND since 1997.

In 1997 and 1999, two technical workshops were held to discuss the engineering and scientific aspects of arsenic trioxide management, as well as environmental, health and safety issues. The workshops provided a forum to develop a common understanding of the arsenic trioxide problem, and to present potential options and management strategies. Results of the sessions included: the development of a common criteria for the evaluation of the various alternative processes, the understanding that this is a complex situation with no “quick fix”, and the realization that the solution, rather than being a single process, may be a combination of technologies. In January, 2000, DIAND retained a technical advisor to develop and recommend a management plan for the As_2O_3 dust. The technical advisor is currently completing a pre-feasibility study of the potential options, considering the following five areas.

1. Hydrogeology

Research on hydrogeology and geochemistry of the mine was initiated in January, 1998 by DIAND, in partnership with Royal Oak Mines, to characterize the groundwater flow regime and to assess the potential for seepage of arsenic trioxide from underground chambers. Due to elevated concentrations of dissolved arsenic found in several samples, recommendations were made for follow-up sampling and construction of a 3-D numerical model. This was completed in 1999. A meeting of experts in the fields of physical, chemical and isotopic hydrogeology was held in March, 2000 to review the current state of knowledge. Recommendations arising from the meeting included: collection of additional water samples to further define groundwater, arsenic sources and transport pathways within the mine; investigation of the arsenic trioxide dust stored within the chambers; and determination of the physical characteristics of the rock adjacent to the chambers.

A sampling program was implemented to characterize the geochemical and isotopic signatures of water sources in the mine workings. This information was used to define the flow pathways through the mine, as well as identify sources and pathways of arsenic within the mine. The main sources of arsenic bearing water include naturally occurring arsenic from arsenopyrite ore, drainage from the tailings pond due to drill holes into mine workings, surface water contaminated with arsenic, tailings backfill, and groundwater seepage from chambers The maximum concentration of arsenic observed in mine waters is on the order of 3,500 to 4,000 mg/L. Several samples collected from areas of the mine not influenced by the arsenic chambers were found to also contain significant concentrations of arsenic, indicating the effects from the other listed arsenic sources. Source inputs and arsenic loading from these sources are being evaluated to determine the contribution of each source to the overall arsenic balance in the mine.

2. Leave the Dust Underground

The option to leave the arsenic trioxide in place underground, both for short term and long term, has been considered. In the short-term it is likely that this is the best option until a permanent solution can be implemented. This requires the mine water to be pumped to the surface and treated in an effluent treatment plant until the preferred, long term management strategy can be determined. In the long-term, the main issues associated with underground disposal are perpetual pumping and treatment and preventing the chambers from flooding. In addition to perpetual pumping and treating of contaminated minewater, the feasibility of containment by assisted ground freezing (re-establishment of permafrost) or establishment of other impermeable barriers, such as grouting, are being considered. The issue of arsenic dissolution and migration is a major issue for evaluation. Leaving the arsenic trioxide dust underground eliminates the difficulties associated with removal of the dust to surface, including increased occupational health and safety risks in its handling.

3. Extraction

Extraction options range from open pit to underground methods. Geometry of the chambers, wall and roof stability, and water content are key factors influencing the extraction of dust. An evaluation of the geometry of each chamber has been undertaken, indicating the extraction of dust is complicated by the use of old production stopes, which are irregular in shape. Over time, the dust has settled, resulting in variable densities and saturations throughout the chambers. Other challenges which must be overcome to bring the dust to the surface include: containing the dust during extraction to avoid health and environmental concerns; minimizing worker exposure; applying removal techniques to variable chamber geometries and material characteristics; cleaning the chambers to a state where it is acceptable for final abandonment; and surface storage of the dust. SRK Consulting conducted a geotechnical assessment of rock mass stability to determine the status of bulkheads, chambers and access tunnels in an effort to evaluate potential extraction methods.

4. Purification to a Marketable Product

Before arsenic trioxide can be successfully sold on the open market, it must be upgraded to 97-99% purity with low concentrations of contaminants such as antimony, iron and copper. Currently, the largest market for purified arsenic trioxide is in the wood preservative industry through the production of Chromated Copper Arsenate (CCA), which accounts for more than 90% of US consumption. At the current time, the market is stable and represents an annual US consumption of approximately 30,000 tons of arsenic trioxide compounds produced primarily by China (16,000 tons) and Chile (8,000 tons). (U.S. Geological Survey, Mineral Commodity Summaries, February 2000) Although the USEPA recently reviewed the use of CCA and has stated that CCA treated wood does not pose a significant risk to human health and the environment, public concerns exist over the use of CCA preservatives. For this reason, the future of the market is uncertain as alternatives may replace CCA.

The most promising purification technologies are re-sublimation or re-crystallization. Two pyrometallurgical, selective sublimation technologies have been subjected to a conceptual level evaluation as potential methods for upgrading the roaster dust at Giant to a saleable product. One, the WAROX (White Arsenic Oxide) process, was developed at Giant to a pilot plant level and the other, the El Indio Process, is used at full scale at the El Indio Mine in Chile. Both processes were developed to recover gold from dust while producing a marketable grade of arsenic trioxide. Hot water leaching involves using hot water to dissolve As_2O_3 selectively, purification of the solution and crystallization of an As_2O_3 product from the purified aqueous solution. CANMET did analysis on Giant dust to determine the applicability of the hot water leach process in purification of the dust. The composition of the dust differs depending on when the dust was deposited, with the older chambers containing lower concentrations of arsenic and higher gold content. There is an average of 60% arsenic and 0.534 ounces per ton of gold in the 15 chambers.

5. Stabilizing the Dust

Arsenic trioxide can be converted to less soluble arsenic forms such as amorphous ferric arsenate or scorodite using an autoclave or biological processes. It is likely that the autoclave option for stabilizing to scorodite is the most applicable to the Giant Mine situation, however, bench-scale tests have not been conducted pending the results of the pre-feasibility study being done by the technical advisor. A literature review of current arsenic disposal practices, focussing on production of insoluble amorphous ferric arsenate and crystalline scorodite ($FeAsO_4 \cong 2H_2O$), was conducted by CANMET to obtain information about arsenic disposal practises in the mining/metals industry and about the long-term stability of the stabilized arsenic compounds.

The resulting information will be evaluated to determine the applicability of current arsenic disposal technologies to the Giant Mine. Arsenic trioxide can also be encapsulated into a medium such as bitumen or cement to bind the dust and produce a stable solid product for long-term storage/disposal. Early leachate studies done by University of British Columbia identified either medium as a candidate for arsenic trioxide stabilization. Results indicate that cement is suitable for encapsulation of dust but only at low concentrations (approximately 5%). Bitumen has a much higher capacity for encapsulating roaster dust (approximately 40%), while maintaining low leachate values. Ongoing long term leaching test data (after 2 months) suggests bitumen/arsenic trioxide dust encapsulation is effective and durable. Due to the low loading capacity of cement/dust encapsulation, this method of stabilization was determined to be ineffective given the large volume of cement that would be required and the volume produced for disposal.

Conclusion

This project presents a multi-disciplinary challenge, with many fields of study working together to achieve a common goal. Additional factors in this project include the potentially high costs and the unique regulatory, political, legal and environmental situation surrounding the mine.