## SCHEDULE "B-4"

RESEARCH PROJECT No. 4

Project Title: Stabilization of $As_2O_3$ dust in cemented paste backfill

RESEARCH TEAM:

Isabelle Demers (UQAT)
Nick Beier (University of Alberta)
Mostafa Benzaazoua (UQAT; collaborator)

PERIOD OF PERFORMANCE:

Start Date: July 1, 2019 End Date: June 30, 2022

PROJECT DESCRIPTION:

### 1. Introduction

This proposal addresses the incorporation of arsenic trioxide dust into cemented paste backfill for arsenic stabilization. Previous work performed on physical encapsulation of arsenic trioxide dust from the Giant Mine site was focused on cement and bitumen, in which arsenic dust was included in varying amounts (dry weight percentages; SRK, 2002). Unconfined compressive strength, leaching, and freeze/thaw tests were performed; the main results are highlighted below:

- For cement encapsulated samples, cylinders achieved full strength within 2 weeks of curing;
- Strength decreased as dust content increased, due to the higher water to cement ratio;
- Arsenic leaching rate decreased sharply over the first 3 days, then decreased gradually;
- Leachate As concentrations increased with time, and correlated with dust content; and
- Bitumen encapsulated samples leached very little As.

### 2. Background

Paste backfill, which consists of a mixture of tailings, cement, and water, was not specifically tested in the 2002 program. Work by Coussy et al. (2011, 2012) showed the possibility of stabilizing As from arsenopyrite tailings and As-contaminated water. Leaching behaviour was dependent on the type of As compound formed during cementation, which was related to the binder used, among other factors. This research could be extended to the issue of arsenic trioxide dust by combining the dust in various weight fractions to tailings during paste-backfill preparation. The backfill performance in terms of As stabilization will be investigated through appropriate mechanical and leaching tests of paste samples prepared using various dust content and binders. Binders for metal stabilization have been designed, and will be investigated through the proposed research project.

## 3. Objectives

The overall objective of the proposed research project is to evaluate the effectiveness of As stabilization through incorporation within paste backfill, which may provide an efficient option to safely and permanently attenuate the arsenic-trioxide dust. Previous studies on immobilization of the Giant Mine arsenic-trioxide dust have not included a detailed investigation on paste backfill. If incorporation into cemented paste backfill yields promising results, a future phase of this project could evaluate the stability of materials derived through other aspects of the research program (*e.g.*, sulfidation, commercial vitrification process) into cemented paste backfill.

Specific objectives are to:

- Identify efficient binders, with or without additives, suitable for long-term As dust stabilization;
- Optimize binder content within cemented paste backfill (CPB);
- Identify changes in As speciation after dust incorporation in CPB, and during cement hardening processes; and
- Identify and optimize dust content within CPB to provide robust environmental performance and mechanical durability.

## 4. Methodology

The proposed research project will involve one PhD student, co-supervised by Isabelle Demers, Nick Beier, and Mostafa Benzaazoua. The proposed laboratory experiments will be conducted at UQAT, although some characterization work (*e.g.*, As mineralogy, As speciation) will be conducted in collaboration with other TERRE-NET investigators and their HQP as part of Projects 1 and 2 of this proposal.

### *4.1 Initial characterization*

Representative arsenic trioxide dust samples from the Giant Mine identified and characterized in Project 1 of this proposal will be used in this study. Additionally, a homogenized sample of tailings from the site will be used in the paste backfill recipes (pending approval from CIRNAC) used to immobilize the arsenic trioxide dust. We will use the following tests to characterize and constrain the arsenic chemistry of the tailings and dust samples, and will utilize the results from Project 1 to minimize duplication of efforts:

- Chemical analysis by ICP-OES and X-ray fluorescence (XRF);
- Particle size distribution by laser particle size analyzer (Malvern Mastersizer);
- Density by helium pycnometer;
- Specific surface by BET method; and
- Mineralogical analysis by XRD, optical and scanning electron microscopy.

### *4.2 Paste backfill preparation*

Paste backfill samples will be prepared at UQAT's laboratory following appropriate health and safety considerations, including dust-collection systems, respiratory personal protective equipment, and other controls. Several recipes will be prepared using the robust methodology developed at UQAT over 25 years of experience, to test the following parameters:

- Weight percent of dust in the paste backfill;
- Binder type;
- Other As-fixing additives;
- Weight percent of binder; and
- Curing time.

Paste will be mixed to reach targeted consistency (*i.e.*, rheology), and will be poured into molds (5 cm diameter by 10 cm height) and allowed to cure in a humidity-controlled room to replicate underground conditions.

The Tagushi design of experiment (DOE) method will be used to reduce the number of recipes to be prepared. The estimated needs concerning samples are:

- Arsenic-trioxide dust: 50 kg equivalent dry material in sealed bags; and
- Tailings (to be used as aggregate material): 1 barrel of homogenized tailings for the purpose of mixing with the arsenic trioxide dust, with ~200 kg equivalent dry of tailings (if density less than 3), stored under water cover to minimize oxidation.

### *4.3 Mechanical and rheological behaviour*

Mechanical strength will be evaluated to determine the strength acquisition of CPB. Uniaxial compression strength (UCS) tests will be performed on paste samples after 7, 14, 28, and 56 days of curing, using a MTS press machine 50 kN.

Rheology of the paste mixtures will be evaluated to determine how the dust content (%) impacts hydraulic transport properties of the paste. This information is necessary to determine whether the paste can be pumped in the underground stopes. The slump test will be performed for all recipes made during the project. The rheological properties will be determined for the three optimal recipes in terms of UCS behaviour.

### *4.4 Environmental behaviour and characterization*

Leaching protocols will be performed to evaluate the extent of As stabilization in the paste-backfill matrix, and to evaluate the long-term durability of the optimal CPB formulation. Monolithic leaching tests will be performed on paste-hardened samples after 28, 56, and 90 days of curing to evaluate As leaching rates with time.

Humidity cells of disaggregated CPB samples after 90 days of curing will be also performed on the optimal recipes to simulate behaviour of paste backfill when it loses structural integrity (*i.e.*, weak durability).

Finally the optimized cured recipes (after 90 days of curing) will be submitted to an acid-neutralizing capacity test series. The test will provide understanding of As stability and leaching behaviour under varying pH conditions.

In parallel, characterization of As compounds in paste will be performed using advanced mineralogical techniques, such as XPS and XAFS techniques, through collaborations with other TERRE-NET co-investigators.

## 5. Potential Benefits

Paste backfill has several advantages, and is a proven technology used previously to stabilize arsenic associated with mill tailings. Incorporation of $As_2O_3$ dust in paste backfill is expected to stabilize the As and prevent further exposure through As release to groundwater. Additional benefits of this approach are that cemented paste backfill can be used to enhance stability of underground mine workings, and can reduce the volume of tailings to be stored in surface facilities.

## BUDGET

The total proposed budget for this research is $150,305, including $130,700 for direct research costs plus 15% overhead ($19,605) charged by UQAT (Table 4).

The budget includes PhD salary support totalling $72,000 over three years.

| Category | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| **Salaries and Benefits** | $ 28,900 | $ 28,900 | $ 28,900 | $ 86,700 |
| a) PhD students | $ 24,000 | $ 24,000 | $ 24,000 | $ 72,000 |
| b) Master's students | $ - | $ - | $ - | $ - |
| c) Undergraduate students | $ - | $ - | $ - | $ - |
| d) Postdoctoral fellows | $ - | $ - | $ - | $ - |
| e) Technical/Professional Assistants | $ 4,900 | $ 4,900 | $ 4,900 | $ 14,700 |
| **Equipment** | $ 6,250 | $ 20,000 | $ 10,000 | $ 36,250 |
| a) Purchase or rental | $ 1,250 | $ - | $ - | $ 1,250 |
| b) Operation and maintenance costs | $ - | $ - | $ - | $ - |
| c) User Fees | $ - | $ - | $ - | $ - |
| d) Analytical Costs | $ 5,000 | $ 20,000 | $ 10,000 | $ 35,000 |
| **Materials and Supplies** | $ 250 | $ 250 | $ 250 | $ 750 |
| a) Laboratory supplies, reagents | $ 250 | $ 250 | $ 250 | $ 750 |
| b) Machining costs | $ - | $ - | $ - | $ - |
| **Travel** | $ - | $ 3,000 | $ 3,000 | $ 6,000 |
| a) Conferences and Workshops | $ - | $ 3,000 | $ 3,000 | $ 6,000 |
| b) Field Work | $ - | $ - | $ - | $ - |
| **Dissemination** | $ - | $ 500 | $ 500 | $ 1,000 |
| a) Publication costs | $ - | $ 500 | $ 500 | $ 1,000 |
| b) Communication costs (teleconference) | $ - | $ - | $ - | $ - |
| ***Subtotal*** | $ 35,400 | $ 52,650 | $ 42,650 | $ 130,700 |
| ***University Overhead (15%)*** | $ 5,310 | $ 7,898 | $ 6,398 | $ 19,605 |
| **Grand Total** | $ 40,710 | $ 60,548 | $ 49,048 | $ 150,305 |

BACKGROUND INTELLECTUAL PROPERTY:

(a) UW Background Intellectual Property:

None:

(b) Third Party Background Intellectual Property

None

(a) GMOB Background Intellectual Property:

None

**GIANT MINE OVERSIGHT BOARD**

Per: [signature]

Name: Kathleen Racher

Title: Chair of GMOB

I have the authority to bind GMOB

July 9, 2019

Date

**UNIVERSITY OF WATERLOO**

Per: [signature]

Name: ~~Leslie J.~~ Copp

Title: Director, Funding Agencies & Non-profit Sponsors, University of Waterloo

I have the authority to bind the institution

July 15, 2019

Date

**Acknowledgement and Consent of Principal Investigator**

I, having read this Agreement, hereby agree to comply with all the terms and conditions contained herein and further agree to ensure that all participants who are involved in the Research Project are informed of their obligations under the provisions of this Agreement.

By: [signature]

Name: David Blowes,

Title: Professor

Date: July 10, 2019