

DATE January 31, 2014**REFERENCE No.** 1314260010-093-TM-Rev0-5100**TO** Brad Thompson
Public Works and Government Services Canada**CC** Sue Longo**FROM** Steven Atkin**EMAIL** satkin@golder.com**PASTE BACKFILL GEOCHEMISTRY**

Golder Associates Ltd (Golder) has placed cemented paste backfill into open stope voids as part of the Giant Mine Underground Remediation project in Yellowknife, Northwest Territories. The paste backfill is composed of tailings from historic ore processing at the Giant Mine, along with Portland cement (and in some cases aggregate from local sources). As part of the backfilling program, Golder analysed two samples of the tailings feed materials and the resulting cemented paste for bleed water chemistry, mineralogy and major element composition. Results of the water chemical analysis showed that the concentrations of copper, lead and zinc in the bleed water exceeded the MMER water quality guidelines; while arsenic concentrations were below the guidelines. Unlike copper, lead and zinc which typically have low solubilities at alkaline pH values, arsenic becomes soluble at high pH. The objective of this data review is to address changes to mine water chemistry from the use of cemented paste backfill. For this reason, this memo reviews the results of these analyses with respect to the published literature on arsenic mobility because of the sensitivity of arsenic as an element of concern at the Giant Mine and the potential increases in solubility due to Portland cement binder in the cemented paste.

The use of cement as a binder for the backfill has several advantages (e.g., low permeability, additional alkalinity that will serve to buffer any acid released from sulphide mineral oxidation). However, owing to the presence of arsenic in the tailings, using cement as a binder results in a significant disadvantage. Cement is a strong base, and as a consequence, bleed water from the cemented paste, or water that comes in contact with the cement paste backfill will acquire a very alkaline pH. Values of pH above 11 are common in bleed water and water in contact with Portland cement; and at these elevated pH values, arsenic and other cations that form oxyanions (e.g., antimony, selenium) (Mehling 2006) can become mobile.

SRK (2001) reported that the sulphide mineralogy of the Giant tailings included pyrite (FeS_2), chalcopyrite (CuFeS_2), pyrrhotite (Fe_{1-x}S) and arsenopyrite (FeAsS). Arsenopyrite may be a source of soluble arsenic in the tailings however, the sulphide minerals represented only a small portion of the tailings. SRK noted that:

- iron oxide (e.g., hematite – Fe_2O_3) grains were common in the Giant tailings as they are common by-products of roasting of pyrite-bearing ores or calcine; and
- the soluble arsenic in the Giant tailings is associated with the calcine and occurs adsorbed onto hematite particles.



This is consistent with what is known about arsenic in natural settings where oxide minerals, and particularly iron oxides, are found to have a strong binding affinity for arsenic and are important adsorbents of both arsenite (As(III)) and arsenate (As(V)) in sandy aquifers (Smedley et al 2002). Further, Manning et al (1998) showed that the minimum adsorption of arsenate and arsenite to goethite (FeO(OH)), a common iron oxide mineral, occurred at pH values of 11 (Figure 1) - which is consistent with the Mehling findings.

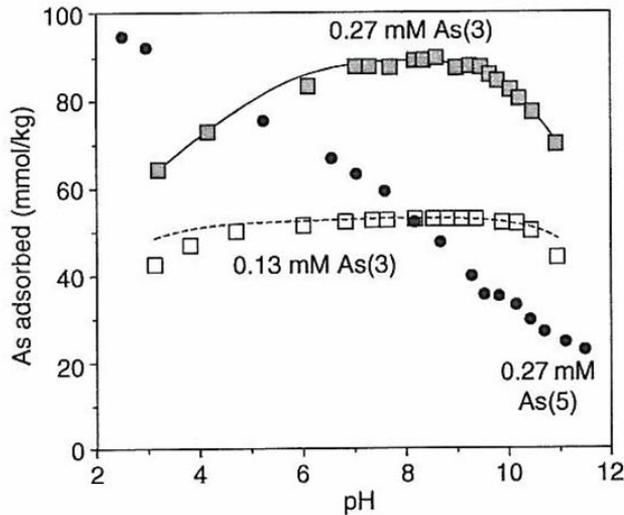


Figure 1: pH Dependent Sorption of As(III) and As(V) on Geothite (after Appelo and Postma 2010)

The two samples of paste backfill bleed water (1% binder and 3% binder) had alkaline pH values of 11.84 and 12.06, respectively. Total arsenic concentrations in the two water samples were also high (240 and 61.8 $\mu\text{g/L}$, respectively), but within the MMER Maximum Authorized Grab Sample concentration of 1000 $\mu\text{g/L}$. Neither sample however, contained sulphide or oxide minerals based on X-ray diffraction analyses. As a result, the actual source of the arsenic in the two cemented paste samples is unknown.

In order to better understand the impacts of the paste backfill on mine water and groundwater, additional sampling and testing may be required to better define the impact of Portland cement on the mobility of arsenic. The program should include:

- Chemical analysis of the water used to prepare the cemented paste.
- Additional sampling of the paste backfill and the tailings used for the paste backfill and laboratory testing to include elemental whole rock metals analysis to quantify the arsenic concentration, mineralogical analyses to identify reactive phases, and short and long-term leach tests to quantify leaching rates.
- Comparisons of the bleed water chemistry with ambient mine water or where possible, sampling of actual mine water from areas of paste backfill and uncemented areas of the mine of similar geology.

This data should identify the source of arsenic in the cemented paste, compare arsenic mobility of equivalent cemented and uncemented tailings, and provide empirical data on the impacts of paste backfill on mine water chemistry.

Please review this memorandum and if you have any questions, do not hesitate to contact me.

GOLDER ASSOCIATES LTD.

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