

## The Mechanisms of Release and Attenuation of Arsenic in a Gold Mine Tailings Impoundment

Mei-Lin K. Stichbury (mkstichb@sciborg.uwaterloo.ca)<sup>1</sup>, Jeffrey G. Bain (jbain@sciborg.uwaterloo.ca)<sup>1</sup>,  
W. Douglas Gould (dgould@nrcan.gc.ca)<sup>2</sup> & David W. Blowes (blowes@sciborg.uwaterloo.ca)<sup>1</sup>

<sup>1</sup> Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, N2L 1W3, Canada

<sup>2</sup> CANMET, Natural Resources Canada, 555 Booth St., Ottawa, Ontario, Canada

In many ore deposits, gold is associated with arsenopyrite. Arsenopyrite is commonly oxidized during processing and the residual arsenic oxides are disposed of in dedicated facilities or mixed with mill tailings and discharged to tailings impoundments. Arsenic(As) is toxic, carcinogenic and teratogenic. Therefore, an understanding of the potential for arsenic release and attenuation is an important aspect of the design of tailings management programs. The release and attenuation of arsenic was investigated at the Campbell Gold Mine, Balmertown, Ontario. At the Campbell Mine, sulfide-roaster tailings containing arsenic-bearing ferric oxides, were disposed of with the flotation tailings from 1951 until 1991. In 1991, the roaster was decommissioned and replaced with a pressure-oxidation autoclave circuit. The autoclave tailings are co-disposed with the flotation tailings. High concentrations of dissolved As were observed at the base of the tailings impoundments, in close proximity to an organic carbon-rich peat layer. The highest concentration of As (113 mg/L) was observed immediately above the peat layer. These high concentrations of As were associated with high concentrations of dissolved Fe(II) and dissolved organic carbon (DOC), suggesting that As was released by the reductive dissolution of As-bearing Fe(III)-oxides derived from the roaster tailings. High MPN values of iron-reducing bacteria (IRB) were detected throughout the impoundments (greater than 10<sup>6</sup> IRB/g sediment). Enzyme activity measurements indicated that greater microbial activity occurred near zones of organic-carbon and high dissolved Fe. Dissolved As concentrations decrease sharply

in clay and sand units which underlie the tailings. Near the tailings-peat contact, the dissolved As concentrations decreased to near-detection levels. The decrease in dissolved As concentrations is attributed to bacterially-mediated sulfate reduction, and sulfide-mineral precipitation. Sulfate reduction was indicated by a large decrease in the concentration of dissolved SO<sub>4</sub> and by detectable concentrations of H<sub>2</sub>S (>0.01 mg/L). Sulfur isotopic ratios determined on sulfate (<sup>34</sup>S-SO<sub>4</sub>) were enriched compared to ambient SO<sub>4</sub>, also indicating that sulfate reduction occurred. Significant numbers of sulfate-reducing bacteria (SRB) were detected throughout the impoundments, with the highest numbers (MPN greater than 10<sup>6</sup> SRB/g sediment) occurring at the tailings-peat interface. The decrease in As, and Fe, concentrations in the zone of greatest SO<sub>4</sub> reduction suggested these constituents were removed from solution by metal sulfide precipitation. Solid-phase sulfur speciation showed that mono-sulfide accumulated at the tailings/organic carbon interface. Near surface analysis of tailings material from the base of the tailings impoundment, by X-ray photoelectron spectroscopy (XPS), indicated that As is bound as a sulfide at this depth. The binding energy for As obtained by XPS was 43.9 eV which corresponds to literature values for the mineral As<sub>2</sub>S<sub>3</sub>. Dissolved organic carbon (DOC) is the probable electron donor for the reductive reactions. Carbon isotopic signatures on dissolved inorganic carbon, taken from the vicinity of the peat (-19), were similar to the δ<sup>13</sup>C signatures on organic matter from the peat (-20).