Arsenic Mobility from Arsenopyrite-rich Gold Mine Waste, Snow Lake, Manitoba

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New Britannia Mine
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Many field and laboratory assistants
Nor - Acme Mine, Snow Lake (1949 – 1958)

- Reopened as New Britannia Mine 1995
- Arsenopyrite Residue Stockpile (ARS) and the Nor Acme Emergency Tailings (NATA) were designated as orphaned sites
- New Britannia Mine closed in 2002
Arsenic Contamination of Mine Watershed

MW 17
< 20 ppm As
Objectives of Research

• To determine the cause of the high arsenic in MW 17
• To determine the flow path of ground and surface water to predict the possibility of contamination of Snow Lake
• To determine the geochemical and mineralogical processes controlling the mobility and attenuation of arsenic in the mine watershed
Surface and Ground water Flow Path from Elevations and Water Table in Wells
Surface Water As (ppm)
Standards and Regulations

- Canadian natural background of As in soils: 5–14 ppm
  - ARS solid: 23 wt%

- Canadian standard for As in drinking water: 0.025 ppm
  - ARS pore water: 100 ppm
  - MW17: 20 ppm
  - Snow Lake: 0.004 ppm

- Standard for As in mining environments: 0.5 ppm
  - RA: <11 ppm
  - NATA: <9 ppm
Two Possible Sources of As Contamination

Nor-Acme Mine site (1954)
- Arsenopyrite Residue Stockpile
- Nor Acme Emergency Tailings Area
- MW17: 20 ppm As
THE ARSENOPYRITE STOCKPILE

Ore: Free gold overgrowing arsenopyrite & refractory gold in arsenopyrite. Beneficiation: Crushing and grinding, flotation and cyanidation. Recovery of gold only 81%

Cyanide treated residue stored in the 200 m x 100 m Stockpile 1949-1958
Covered by New Britannia Mine in 2000
Drilled and sampled in 2003

Extensive alteration of sulphides in top 1m released As from arsenopyrite
Solid Residue: 18% As
Pore water: 100 ppm As
Primary Mineralogy

**Sulfides**
- Arsenopyrite
- Pyrrhotite
- Pyrite
- Chalcopyrite

**Non-Sulfides**
- Quartz
- Plagioclase
- Orthoclase
- Amphibole
- Hydrobiotite
- Calcite

Gold: Free gold overgrowing arsenopyrite & “invisible” refractory gold in arsenopyrite
Extensive alteration of sulphides in upper 1m released As from arsenopyrite
Solid Residue: 23% As, Pore water: 100 ppm As

Note: Ground surface slopes down to the North
Clay Base of ARS slopes to the South
Alteration Minerals in the top 1 m of ARS from sample collected prior to capping

Amorphous iron sulfoarsenates (AISA)

22 - 26 wt % As
SCORODITE

\[ \text{FeAsO}_4 \cdot 2\text{H}_2\text{O} \]

Inclusions in AISA cement and forming cement

35 wt % As

Precipitation produces acid

JAROSITE

\[ (\text{K,}\text{H}_3\text{O}^+)\text{Fe}_3(\text{S,AsO}_4)_2(\text{OH})_6 \]

Incorporates < 5.6 wt % As.

Forms in acidic oxidizing conditions
Arsenopyrite Stockpile

Tailings

Clay

Sand

Unfractured bedrock

10^{-11} m/s

10^{-8} m/s

10^{-9} m/s

10^{-3} m/s
Before Capping in 2000:
Arsenopyrite oxidized producing acid (pH ~ 2)
Arsenic accumulated in secondary AISA, jarosite, scorodite
Infiltration through pile from rain and snow
Arsenic-rich acidic runoff to NE
Increasing As in MW 17

2000: Cap limits water and oxygen infiltration
Reducing conditions in pore water and now neutral pH prevent the production of stable secondary phases
Arsenic released in drainage water (100 ppm)
Infiltration has been eliminated but groundwater still flows through the base of the pile
Slight reduction in As in MW 17

Note: the difference in total As from NBM and my group
Prior to capping surface water flowed NE to Runoff Area

Underlying clay contains 0.9 wt % As in arsenopyrite
Nor Acme Emergency Tailings (NATA)

- Interface: oxidized
- Interface: reduced
- 5 – 15 cm
- 15 – 25 cm
- 25 – 35 cm
- 35 – 45 cm
- 48 – 58 cm
- 58 – 68 cm
- 68 – 78 cm
Concentration low, NATA not the major source of arsenic at MW17. Higher As in the interface zone. Removed by adsorption to FeOOH in oxidized zone.

Arsenic in pore water of NATA
Runoff Area

Boggy area
Runoff from ARS prior to capping and from mine area and old leach pad

Surface Water

- pH 7.2
- $\text{SO}_4$ 340 ppm
- Fe 0.5 ppm
- As (III) 3.5 ppm
- As (V) 6.9 ppm
Aquatic plants

Positive control

Negative control samples collected near Wekusko Lodge (WL) camp ground 40 km SW.
Accumulation of Arsenic in Cattails

Higher As content in roots (<1000 ppm) than shoots (< 90 ppm)
Arsenic accumulates in roots of plants both with Fe oxy-hydroxides and alone.

SEM backscatter images with EDX element scans.
The Source of Arsenic at Snow Lake Mine

1949-2000: Surface runoff from the Arsenopyrite Residue Pile, the Leach Pad and the Nor Acme Tailings area

2000: Leach Pad remediated and ARS capped preventing infiltration.

Arsenic still leaching through the base of the ARS to MW17 joins runoff from Nor Acme tailings area in the runoff area
Mechanisms of Attenuation of Arsenic

- In ARS, the formation of scorodite, jarosite, AISA in the oxidized residue prior to 2000
- Adsorption of arsenic to Fe oxy-hydroxide minerals in oxidized regions of soil and tailings
- Adsorption in the roots and shoots of plants with Fe or alone
Possible Future Contamination of New Britannia Mine Site

- Possibility for mobilization of As in groundwater if environment becomes reducing and Fe oxyhydroxides become unstable

- Plants in wetlands may release As

- Plants may be a passage of As into the food chain

- Arsenic in surface water will be attenuated by Fe-oxyhydroxides in oxygenated water before reaching Snow Lake