

Spatial and temporal evolution of Cu-Zn mine tailings during dewatering

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Abstract

The Ruttan Cu-Zn Mine produced about 50 Mt of fine-grained tailings over 30 years. Since the closure of the mine in 2002, the tailings have been systematically dewatered through trenches draining into the open pit. This study evaluated the evolution of tailings that were underwater until 2002. Acid generation is dominated by the oxidation of the abundant pyrite and pyrrhotite comprising 25 wt.% of tailings. Metals are temporarily attenuated from waters associated with the tailings, either absorbed on Fe oxy-hydroxide precipitates or as evaporite minerals at the surface of the tailings. While some secondary phases are stable, evaporites are only temporary metal sinks as they can re-dissolve. The pH of pore water and shallow groundwater decreased first to 4.5 and then stabilised at values of 2–3. Metal contents of ground and surface water are increasing but Ruttan Lake is maintaining a constant composition.

1 Introduction

The dewatering of the tailings at Ruttan Cu-Zn Mine, Manitoba, Canada, after closure in 2002, provided an opportunity to observe potentially acid generating tailings during the first years of dewatering and oxidation in a subarctic-climate. The objectives of this study were to observe changes in mineralogy and geochemistry during oxidation of the previously submerged tailings, to predict their evolution as well as that of Ruttan Lake.

2 Study site

Ruttan mine site is 950 km north of Winnipeg, 30 km east of Leaf Rapids, Manitoba (Figure 1). From 1973 until 2002, Cu and Zn ore were extracted at Ruttan Mine. Flotation refinement removed sphalerite and chalcopyrite, producing over 50 million tonnes of fine-grained sulphide-rich tailings which were discharged into the tailings impoundment. Most of these tailings remained submerged after deposition but one area had been exposed to the atmosphere and oxidised for ~20 years. To improve the stability of the dams, tailings ponds are being systematically dewatered through a network of drainage trenches into Ruttan Lake. The onsite watershed including Ruttan Lake now drains into the open pit. The subarctic climate causes groundwater to be often frozen from October to July giving a short period for reactions in the tailings to occur at a significant rate and for drainage through the trenches.

3 Methods

Solid and water samples were collected from the oxidised and unoxidised tailings and from Ruttan Lake from 2003–2009. Pore water was extracted from the tailings. All samples were analysed for cations and anions, Eh, and pH. Mineralogy was determined with optical and scanning electron microscopy and powder x-ray diffraction. Samples of tailings underwent a sequential extraction process to determine the mobility of metals.

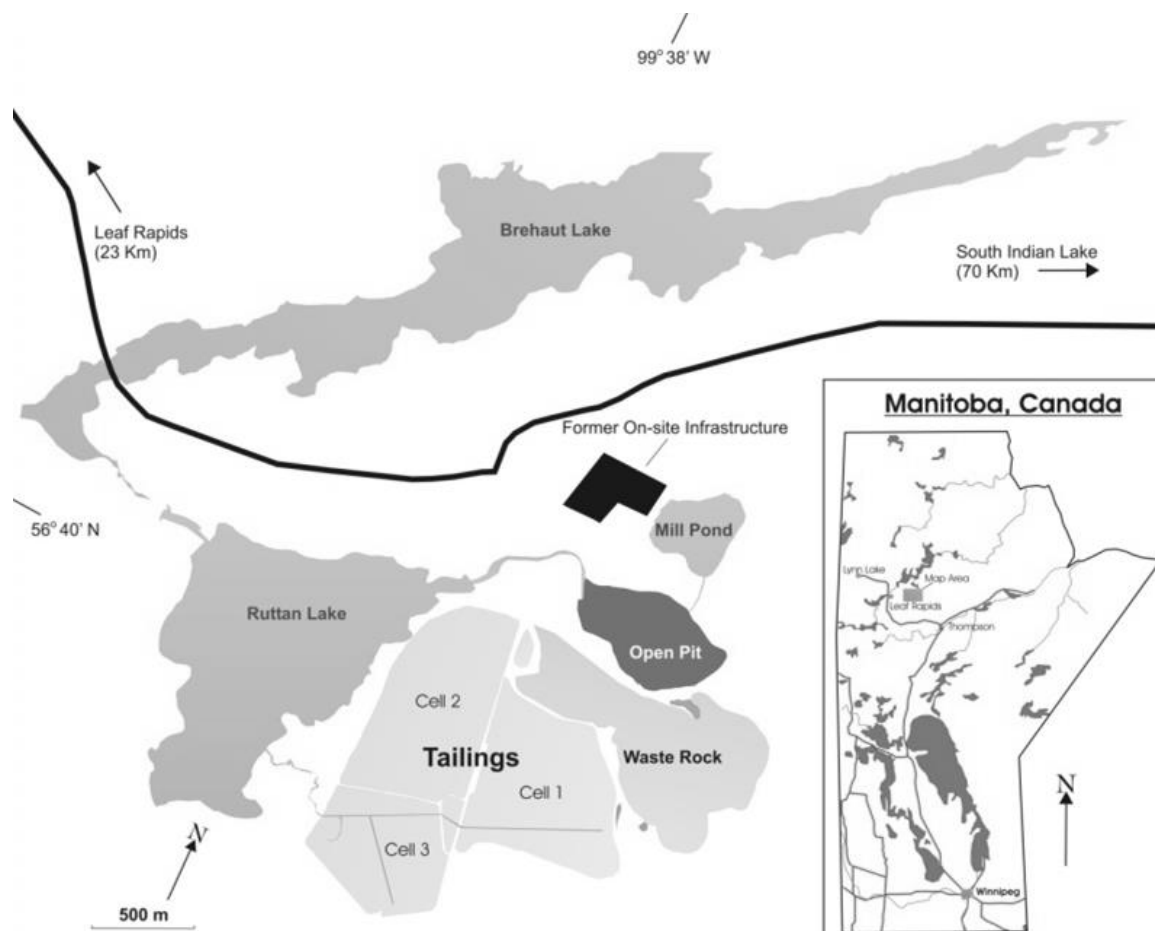


Figure 1 Location of Ruttan Mine and mine site plan showing tailings management cells and drainage trenches from these cells to Ruttan Lake

4 Mobility of metals

The unoxidised tailings at Ruttan have an average 2,200 mg/kg Zn which can be mobilised by oxidation of sphalerite producing < 10,000 mg/L Zn in near-surface pore water (Etcheverry, 2008). Pyrite and pyrrhotite release Fe and sulphate to the pore water.

Carbonates are only sufficient at Ruttan to maintain a neutral pH for a short period of time. Aluminium liberated from aluminosilicate minerals, and Fe^{3+} reacts with water to form Al and Fe oxy-hydroxide phases. A decrease in pH below 6 causes dissolution of these phases buffering the water at a pH of 4.3 for $\text{Al}(\text{OH})_3$ or 2–2.5 for FeOOH (Blowes and Jambor, 1990; Sherriff et al., 2007). In 2004, pore and groundwater at 0.8 m below grade had near neutral pH buffered by the dissolution of calcite. By 2005, the groundwater and pore water at about 1 m depth had stabilised at a pH of 4–4.5 controlled by the dissolution of $\text{Al}(\text{OH})_3$. Breakthrough of this acidic front correlates with increases in concentration of Fe, Al and Zn in solution. While Al hydroxides dissolve, Fe(II) can be oxidised and precipitated in form of Fe(III) oxy-hydroxides and hydroxy-sulphates at pH below 4.5. Most surface water including Ruttan Lake has stabilised at pH 2–3 due to the FeOOH buffers.

Pore water is in direct contact with sulphide grains and acts as the source of water for oxidation reactions and a conduit for metals released from these oxidation reactions. In 2004, maximum concentrations of metals and sulphate were measured in the upper 10 cm of the unoxidised tailings and rapidly decreased over the next 20 cm depth. Maximum concentrations were higher in 2005 and occurred between 20 and 30 cm depth. Once liberated from sphalerite, Zn is very mobile with a minor amount bound to FeOOH due to limited adsorption at $\text{pH} < 6$ (Dzombak and Morell, 1990). Initial high values of metals and sulphate in groundwater could have been due to the construction of the trench in 2002–2003 or to the oxidation of the very fine grained material from unoxidised tailings.

Acidic metal rich surface and shallow pore water evaporates to form Zn and Fe hydroxy-sulphate evaporite minerals. Metals that are temporarily attenuated on the surface of the tailings are released during periods of rain or snow melt.

Ruttan Lake acts as a reservoir for both contaminated water from the tailings and meteoric water. In 2004, the composition of the lake was found to be homogeneous with a pH of 2.8. By 2009, the pH had decreased slightly 2.6 but the sulphate and metal content had not increased despite a considerable increase at the input to the Lake.

As the unoxidised tailings continue to de-water and the water table drops, oxygen will continue to diffuse deeper into the tailings creating a deepening zone of oxidation. Modelling shows that sulphide-rich tailings with a deep water table can oxidise for centuries (Blowes and Jambor, 1990). A comparison of the conditions at Ruttan with their conceptual model of Blowes et al. (2003) suggests that the tailings were still in the early to moderate stage of oxidation in 2005. There is a minor depletion in solid metal concentrations near the surface and a peak in dissolved metal concentrations just below the surface. Pore water metal concentrations peak within the first meter of all the tailings, suggesting a juvenile oxidation stage. As the tailings are greater than 10 m thick they will be oxidising and releasing metals for many years.

The concentration of metals in Ruttan Lake may increase and pH levels decrease as oxidation in the tailings proceeds, however, the constant flow into the open pit and partial recharge by meteoric waters has a stabilising effect so that the Lake is unlikely to become as acidic as the ponds on the tailings surface.

This study has significance for mine closure as it shows the effect of allowing base metal tailings to dewater and drain into a body of water.

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