Under Ice Treatment and Discharge Of A Tailings Impoundment – A Case Study From The Lupin Mine Nunavut, Canada

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Abstract Water management and treatment in cold regions faces many challenges, a core one being the limited open water season. In 2015, treatment and discharge of water stored in a tailings impoundment extended into the winter season under complete ice cover. Lime was added to raise the pH (4.7) of poorly buffered water (alkalinity <2.0 mg/L as CaCO3) into an acceptable range for discharge. In total 2,171,000 m3 were discharged to the environment in 2015 with an average pH of 7.0 (alkalinity 4.4 mg/L as CaCO3). Under ice water quality remained consistent during discharge and highlights the possibility for extending treatment programs when circumstances warrant it.

Key words Water Treatment, Under Ice, Lime, Neutralization, Adaptive Monitoring

Introduction

The Lupin Mine is located in Nunavut, Canada, 400 km north of Yellowknife, 1,400 km north of Edmonton, at 65° 46’ N latitude and 111° 14’ W longitude, and approximately 60 km south of the Arctic Circle. The site is accessed by a 1,950 m airstrip, which is Jet aircraft capable, and occasionally the winter road from the diamond mines east of Yellowknife is extended to Lupin. The Lupin Mine has been maintained in a care and maintenance status since 2005. Periodically water that accumulates in the tailings impoundment needs to be discharged. In 2015, treatment and discharge of water stored in a tailings impoundment extended into the winter season. The discharge quality objective was to raise the pH (4.7) of poorly buffered water (alkalinity <2.0 mg/L as $CaCO_3$) into the permitted pH range of 6.0 to 9.5.

The tailings impoundment is comprised of solids retention cells (Cells 1, 2, 3 and 5) and three liquid polishing ponds (Cell 4, Pond 1 and Pond 2) (Figure 1). All precipitation and runoff falling within the facility ultimately reports to Pond 2 (the Pond) (Figure 2). The Pond is contained by geomembrane lined perimeter dams, Dam 1A and Dam 2. The design allows for the aggradation of permafrost into the dam’s core. In order to maintain conservative operating freeboard levels at the perimeter dams, water needs to be treated and discharged every two to four years. The frequency, depends on cumulative runoff and precipitation as well as the amount discharged during the last treatment campaign.

Since the site has been maintained in a care and maintenance status, three treatment campaigns were carried out in 2005, 2009 and 2012. Only the total volume and water quality discharged to the environment was available from the 2005 and 2009 treatment programs. The operational data from the 2012 treatment program was not thoroughly documented, however all compliance data required by the water licence was. All treatment programs were carried out during the open water season, spanning from mid-July to early October.

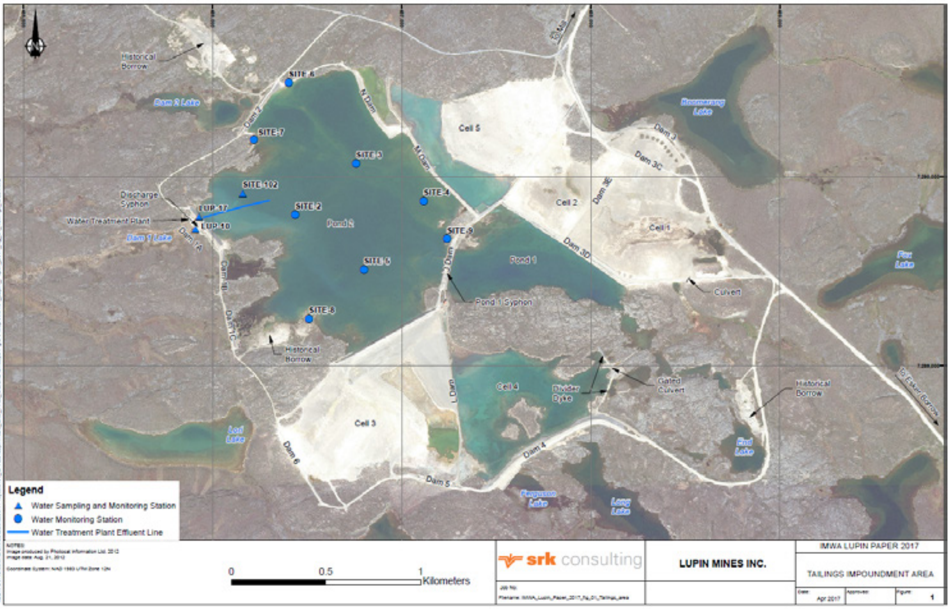

***Figure 1** Lupin Mine Tailings Impoundment and Sample Locations*

The buffering capacity of the Pond water is very low. Before treatment in 2012 and 2015 water quality data was collected and the alkalinity was <5.0 and <2.0 mg/L as $CaCO_3$, respectively. In order to raise the pH of the Pond hydrated lime was added (Pouw 2014). The introduction of OH^- ions into solution consumed acidity (Aubé 2003). Since there was very little alkalinity in solution to buffer the OH^- addition the pH of the solution increased dramatically with small doses of lime (Stumm 1996). The limited buffering capacity means the target pH for treatment can be easily overshot.

Results from the 2012 Treatment Campaign

In total 1,067,000 m^3 of treated water were discharged from Pond 2 in 2012. Five points within the lake were monitored for pH, temperature and conductivity during the treatment program: Site 1 through Site 5 as depicted in Figure 1 (Site 1 is water sampling and monitoring station Site-102). The treatment plant was located on Dam 1A (compliance sample point LUP-10 is downgradient of the siphons on this dam [Figure 1]). The 2012 program was designed to focus on treating water within a Bay area spanning from the sample point LUP-17 out to Site 2 in Figure 1 (Figure 3).

The treatment strategy was to remove water from the Pond, dose it with lime, and pump it back to the Pond and allow the treated water to mix with the untreated portion of pond water. The pond water was pumped to a 22 m^3 tank on Dam 1A. Once full, lime was added to the tank to create a lime slurry of roughly 1 to 10% (by weight). The lime slurry was then pumped back to the Pond via a perforated pipeline within the Bay. This cycle was repeated until the entire Pond was above the target pH. The water was then held in the Pond until it

Figure 2 *Lupin Mine Pond 2 of the Tailings Impoundment Area*

equilibrated with atmospheric carbon dioxide and mix with the portion of untreated Pond water. The pH decreased into the acceptable range for discharge. Pond water was transferred via two 20" siphons from a depth of 3 m off Dam 1A to Dam Lake, ultimately reporting to Contwoyto Lake.

The main conclusions from the 2012 program was that the Bay could not be treated in isolation, the Bay pH could be easily overshot, and the lime slurry needed to be dilute (<2% by weight). These findings were discovered during the initial treatment period before discharge. Initially more lime slurry was added to the Bay than required and a portion of the lime particles settled to the bottom. Also since the Pond water was so poorly buffered the pH was initially above the acceptable discharge criteria (pH >9.5). Treatment stopped and the Bay was left to mix with the remaining Pond water and to reach equilibrium with atmospheric carbon dioxide (Figure 3). The pH of the Bay eventually lowered back below 6.5 and treatment started again. pH was challenging to maintain within the range for discharge.

Results from the 2015 Treatment Campaign

For the 2015 treatment program a number of changes were made to use lessons learned by the mine operator in 2012.

- A longer pipeline extended out to Site 2 (500 m). The first 300 m was solid pipe, while the last 200 m had 1 inch holes drilled every 10 m. A plume of treated water spanned 200 m in the outer part of the Bay.
- The lime slurry concentration was maintained between 0.5 and 1% (by weight). Using a lower dosage allowed for greater control when treating the Pond. Especially once an ice layer formed on the Bay and wind assisted mixing and the diffusion of atmospheric carbon dioxide into the Pond was limited.

Figure 3 *The Bay area in Pond 2 during the 2012 Treatment Campaign*

- The process was changed to a continuous operations. When the treatment tank reached half empty, the intake pump was turned on. Once full, lime was added to the tank. The process was repeated throughout active treatment.
- Five shore sample points were added to the Pond. These locations were introduced to allow for data collection on days when the wind made Pond access by boat unsafe. These locations could still be monitored and provide some direction around the required lime dosage.

Throughout the 2015 treatment program, daily water quality readings were taken from Sites 1 through 9 and LUP-17 for pH, temperature and conductivity. For sites 1 through 5, readings were taken at 1 m, 2 m and 3 m depths on days when there were safe boating conditions. Once discharge commenced, compliance monitoring was conducted at the discharge point (LUP-10). All compliance monitoring and toxicity testing met the Lupin Mine water licence conditions.

The temperature profiles at Sites 1 through 5 remained consistent with increasing depth and decreased from 14.5 to 4°C between August 15 and September 22, respectively. This indicates thermal stratification did not inhibit vertical mixing in the Pond to a depth of 3 m. The Pond was treated from August 18 until October 12. In total 26,000 m^3 of water was withdrawn from the impoundment and treated with 73 t of hydrated lime (<1% by weight slurry) and then pumped back into the tailings impoundment to neutralize the untreated portion of water. The Pond pH was indicative of the extent of treatment and used to provide instant feedback to the treatment program. The pH was a parameter easily monitored in the field through handheld Oakton pH meters calibrated daily before use.

Figure 4 shows the pH recorded at Sites 1 through 5. On September 8 and 9, the wind speed decreased to 1 km/hr and wind mixing was less vigorous. The pH at 3 m for Site 1 and 2 reached 9.1 and 7.5, respectively. Treatment was temporarily shut down. On September 10 the wind picked up again and the pH lowered back down to 6.3 and 5.7 for Site 1 and 2, respectively. Wind mixing also likely increased the rate of carbon dioxide transfer into the pond which also lowered the pH.

The poor buffering capacity of the pond was observed during the September no wind event. No discharge to the environment was occurring at the time, however the sensitivity of the system to active treatment is important for operational control. The adaptive operational approach was implemented. When setting target lime dosages for the day, wind strength and direction as well as the previous pond pH readings were all taken into consideration. The daily operating strategy was discussed with the operators before the start of each shift. Operators were also required to report no wind events to prevent a spike in the Bay pH.

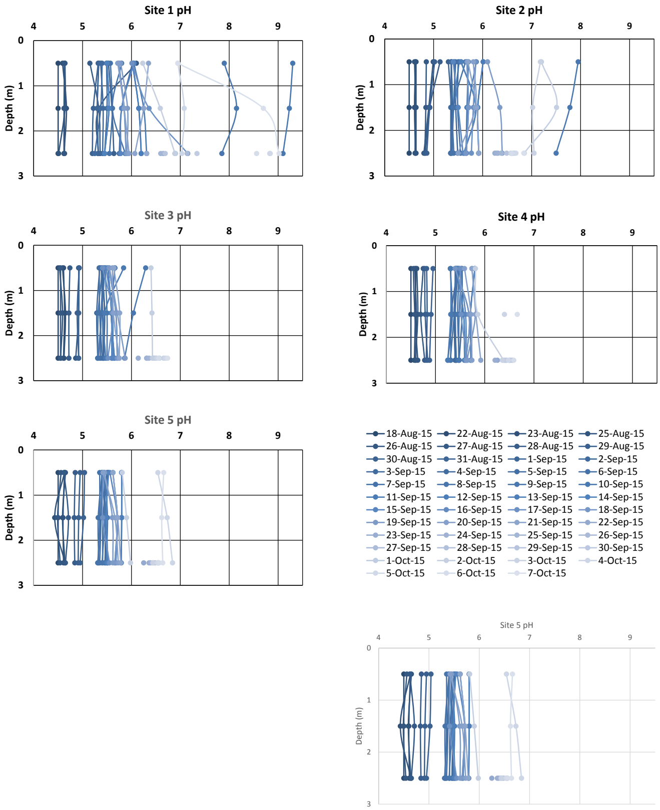

***Figure 4** Pond pH Readings throughout the 2015 Treatment Campaign*

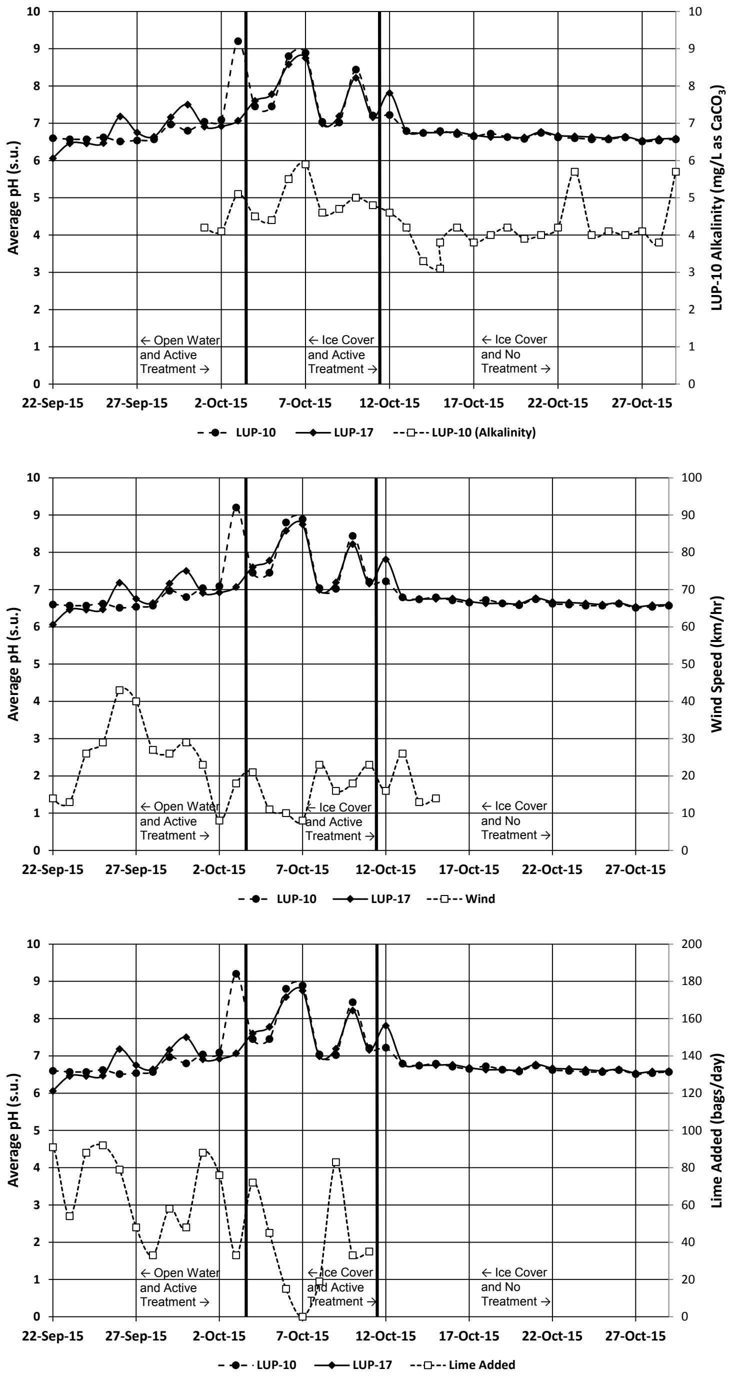

Figure 5 *Discharge Alkalinity, Wind Speed and Lime Added with respect to LUP-17 and LUP-10 pH*

Discharge to the environment commenced on September 23 and continued until October 29. Three distinct operational conditions occurred during discharge:

- Active treatment and open water
- Active treatment and ice cover
- No treatment and ice cover

During discharge, water quality was monitored at the effluent compliance point (LUP-10). Daily pH, temperature and conductivity readings were recorded in field, and samples were sent to ALS in Yellowknife for additional analysis. Daily alkalinity and pH values recorded at LUP-10 were compared to pH values observed at Sites 1 and 2 (Figure 5). The pH readings were also compared to wind speed to see how wind speed could affect the pH. Additionally, the lime dosage rate was also plotted to see how the dosage was lowered based on observation.

For the open water active treatment period, the water quality observed was largely driven by wind mixing. The average pH and alkalinity were 7.0 and 4.4 mg/L as $CaCO_3$, respectively. Once ice formation started on the Pond, carbon dioxide diffusion and wind mixing were limited, making lime dosage control more critical. For under ice treatment and discharge, the average discharge pH and alkalinity were 7.8 and 4.9 mg/L as $CaCO_3$, respectively. Finally for under ice discharge and treatment, the lake chemistry was observed to be fairly consistent. When the Pond water was isolated from the atmosphere, mixing with the untreated water could lower the pH and alkalinity. For under ice discharge without treatment, the average pH and alkalinity steadily dropped to 6.6 and 3.8 mg/L as $CaCO_3$, respectively.

Conclusions

In total 2,171,000 m^3 were discharged to the environment in 2015 with an average pH and alkalinity of 7.0 and 4.4 mg/L as $CaCO_3$, respectively. The overall treatment program was successful even when extended into the winter. Though winter treatment presents many practical operating issues, especially in an isolated north climate, consistent water quality was maintained throughout under ice discharge.

For similar seasonal treatment programs, there is a possibility to extend the treatment season into the winter. Although this is not a preferred or often planned approach, there are certain circumstances where this could prove beneficial for operations to maintain safe water levels in a tailings impoundment or other holding reservoirs. Once treatment finished, the under ice pond pH and alkalinity decreased suggesting that discharge could not be sustained for long periods without treatment. The treatment program was successful due to the adaptive nature of the monitoring program and constant feedback with the treatment plant operators. Although under ice treatment programs face a number of operational issues, successful execution is possible when extended discharge is required.

Acknowledgements

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