Presented at the Sudbury 2003, Mining and the Environment Conference

In-Pit Mine Drainage Treatment System in a Northern Climate

Bernard C. Aubé, P. Eng.
EnvirAubé
174 D. Lebeau, Ste-Anne-de-Bellevue
Québec, Canada, H9X 3Z9
aube@enviraube.com

Blandine Arseneault
Société minière Raglan du Québec ltée
120 avenue de l'Aéroport
Rouyn-Noranda (Québec)
J9X 5B7

Abstract

Société minière Raglan du Québec (SMRQ) is a nickel mine owned and operated by Falconbridge Limited in Northern Québec, Nunavik territory. Operations began in 1997 with ore extraction both from open pits and underground development. The property contains many small high-grade deposits scattered along its length. These deposits will be consecutively mined and reclaimed over the course of its mine life. During mine conception, a pond was designed to collect and, if necessary, treat drainage from waste rock. This pond, now collecting water from open pits as well, contains water with Ni and Cu concentrations above discharge limits. Prior to year 2000, treatment was completed within this pond by liming near a filter dyke, siphoning the high pH water, and decreasing pH with sulphuric acid to meet the maximum of 9.5. This perfunctory treatment system was challenging as high winds caused the accumulated sludges to re-suspend and could therefore make it difficult to attain the Ni limit of 0.5 mg/L. A hydrological investigation was completed, presenting an additional challenge as the spring runoff can occur quickly and contain large volumes of water. As exploitation of a small open pit was being completed, it was decided to use the decommissioned pit for treatment. A system of collection, pumping, raising pH, separating precipitates, and reducing pH prior to discharge was put into place. This paper describes the hydrological challenges and in-pit treatment system for removal of dissolved nickel from this neutral mine drainage.

Introduction

Société minière Raglan du Québec Ltée (SMRQ) is a nickel mining and processing operation situated in the Nunavik territory, Northern Quebec (see Figure 1). It includes mining operations, a mill, a port facility, an airstrip as well as lodging accommodations. Operations began in 1997 with ore extraction both from open pits and underground development. The property contains many small high-grade deposits scattered along its length. These deposits will be consecutively mined and reclaimed over the course of its mine life.

This paper deals specifically with one area of the property, about 7 km from the plant site. The area, as described in greater detail in the next section, includes 3 open pits, a waste rock pile and an ore pad. The area is designated as Zones 2 and 3.

Area Of Concern (Zones 2 And 3)

The first mineralised area to be exploited from surface was the Zone 2 Pit (Pit 2). Production from this pit began in 1997. At the same time, an ore pad and a waste rock disposal area were put into service. The ore pad was built immediately next to the pit, while the rock dump was constructed in nearby Zone 3, about 3 km west. The waste rock disposal area was placed adjoining a natural depression, which was used to build a containment pond. This large water body, the Zone 3 Pond, can hold up to 600,000 m^3 of water. Zone 3 Pond was built by construction of a single dam and, as described in greater detail in the next section, one internal dyke. All drainage from the rock dump reports to this pond by gravity. The general water management system is shown in Figure 2.

Drainage from the ore pad reports to Pit 2 by gravity. While Pit 2 was operating, dewatering pumps conveyed the mine water to the Zone 3 Pond. In 1999, as Pit 2 reserves were being depleted, a second pit was commissioned in Zone 3 (Pit 3). Champagne, a very small pit also located in Zone 3, was commissioned during the end of Pit 3 operation in 2001. Mine waters from Pit 3 and Champagne Pit report to the same pond, as shown in Figure 2. Table 1 shows the typical raw water quality and discharge criteria.

Table 1: Water Quality of Mine Drainage and Effluent Criteria

Parameter	Raw Water (average)	Effluent Limits
pH	7-8	6.5-9.5
Ni (mg/L)	25	0.5
Cu (mg/L)	1	0.3
Fe (mg/L)	0.1	3
Other		Non-toxic

Original Water Treatment System (1998-1999)

Prior to the start of operations, it was not certain that treatment would be necessary in this area. In case treatment became necessary, the Zone 3 Pond system was designed to remove Ni by raising the pH of the pond above 10 and allowing solids to settle to the bottom. The system is shown conceptually in Figure 3. An internal dyke, which divided the pond in two, was to filter any solids remaining in suspension before the ostensibly clean water is pumped out of the smaller section. This internal dyke was also meant to break the waves generated by winds and thereby prevent re-suspension of the precipitates. Sulphuric acid was to be used for pH control prior to release.

Operating Challenges Of Original Treatment System

The original treatment plan could not be followed as raising the pH of a pond this size (capacity of 600,000 m^3) is a considerable challenge. It was not feasible to lime the feed to the pond as drainage from the waste rock dump enters the pond at multiple points. Raising the pH of the entire pond would have required added infrastructure to dispense the alkali (hydrated lime) and distribute it throughout the pond. It is also very difficult to get an early start on treatment as the pond slowly thaws – considerably slower than the surrounding snow.

An added challenge was solids settling, as the high tundra winds and large shallow pond caused considerable wave action and wind currents. The filter dyke did not significantly help as suspended solids easily travelled through the coarse material and neither did it prevent the waves from stirring the bottom of the pond.

Treatment was quickly found to be only possible in the smaller section of the pond, which was originally supposed to be kept free of precipitates. The winds were still an important factor in this smaller section, as the hydroxide precipitates were re-suspended. Re-suspension was significant enough that it was often impossible to meet discharge requirements. Consequently, effluent release was intermittent and water inventory in the pond increased over the two year period this system was used. For proper operation of the system, the pond volume should be brought low in the fall in order to have the surge capacity required for the following spring.

Hydrology

A preliminary hydrology study of the Katinnik area was completed in 1999 (SNC-Lavalin, 1999). The runoff was modelled using data collected by SMRQ as well as historical information from meteorological stations in the same general area. The Raglan hydrology is special for two reasons: 1) precipitation is over 80% in the form of snow and ice and 2) the spring thaw reports entirely as runoff. In temperate climates, a significant fraction of the spring thaw infiltrates the ground and is stored there for a more gradual release. In this area, permafrost conditions do not allow for water infiltration, which means the snowmelt is essentially 100% runoff. The modelling results are displayed in Figure 4.

Figure 4 shows that more than half the water to be treated for a given year can report to the collection ponds within the first 2 weeks following the start of thaw. Contrary to most mines, this water cannot be largely treated as it is collected, but must first be stored. Once contained, the contaminated water can then be treated continuously to slowly bring down the volume stored in the containment area.

New Water Treatment System

Once the problems from the original treatment system were well understood and the hydrological evaluation complete, it was decided that the Zone 3 Pond could be better used solely as a containment area. The recently decommissioned Pit 2 was evaluated for use as a treatment system. With its greater depth and partial protection from the wind, the pit was thought to be a good alternative treatment site. Treatment would require raising the mine drainage pH to precipitate the Ni prior to discharge in the pit, where the solids could settle to the bottom.

The existing treatment system is shown in Figure 5. It was designed using a turnkey lime system and a mixing tank (Lime Reactor). The turnkey system uses 1-tonne bags of hydrated lime to form a slurry. Runoff collected in the Zone 3 Pond is pumped to the Lime Reactor where pH is controlled to a setpoint of 11-12 with this lime slurry. The Reactor has baffles designed to ensure that the mixture does not short-circuit. Ferric sulphate is also added in the Reactor to aid in coagulation. A flocculant is added in the reactor overflow line as the slurry flows by gravity into the pit. There the precipitates are allowed to settle and the clear supernatant is collected via a submerged pump installed on a floating barge at the opposite end of the pit. This pump transfers the clean effluent to a sulphuric acid addition system for final adjustment to pH 9.2 prior to release.

On-Going Treatment Challenges

Although the current treatment system meets discharge requirements and is considerably more efficient than the original system, many challenges were encountered and some remain. The primary constraint for the system is meeting the regulated 0.5 mg/L Ni concentration. Time is also an important constraint, as the treatment window for the plant is of 90 to 120 days. It is important to release all the runoff from the year in this window, in order to provide the surge capacity for the following spring. Surge capacity is critical to compliance as 200,000 m^3 of runoff can be collected in the Zone 3 Pond in a single week (as demonstrated in Figure 4).

Pumping from Zone 3 Pond can typically start in early June and effluent can be discharged about 3 weeks later. Due to the high risk of freezing, pumping from Zone 3 ends at the beginning of October.

Initial Pit Water

The first difficulty encountered was treating the Ni already contained in the pit. The water in the pit contained dissolved Ni in neutral pH conditions, issuing from pit walls, the pit access ramp, and the adjacent ore pad. This problem was resolved by recirculating the pit water in a closed loop to the Lime Reactor until the pH of the entire pit volume was sufficiently increased to precipitate all the dissolved Ni as hydroxides. This procedure is shown by the dotted line in Figure 5.

This procedure must be repeated each spring, as the initial thaw brings dissolved Ni into the pit lake prior to treatment. Due to the urgency in decreasing the level in Zone 3 Pond, water is simultaneously pumped and treated from this Zone. This method of operation can continue for up to three weeks before discharge from the pit can start. This has an important impact on the already small treatment window.

Uncontrolled Ni Sources

The highly mineralised pit walls and run-off from surrounding areas represent a constant addition of dissolved Ni to the pit. In order to compensate for these extra inputs, the pH set point at the lime plant is adjusted to 11-12 to reach a sufficient pH in the entire pit.

The largest of these inputs is a neutral, high Ni-content stream that runs down the pit ramp. Throughout the treatment season, a 1-tonne hydrated lime bag is placed in the ramp stream in an attempt to precipitate most of the Ni in this source prior to contact with the pit water.

Another large input is the runoff from the adjacent ore pad. Some of this water seeps in through the fractured surface rock and can be seen entering the pit through the walls. The rest of the watershed reporting to the pit can also contain some Ni. This runoff flows not only on surface but also through the shallow crevices in the fractured rock

These uncontrolled sources represent the most important remaining problem for effective treatment. Even though controlling treatment pH to above 11 provides sufficient buffering capacity, these sources are not adequately treated. This Ni contacts the high pH pit water, precipitates as $Ni(OH)_2$ but does not settle. The problem is that the precipitates are formed individually as tiny particles. For the precipitates to settle, they must be agglomerated.

Pit Lake "Zones"

This method of treatment creates a "clear zone" in the upper section of the pit lake and a lower "precipitation zone" where solids slowly settle to the bottom. This lower zone contains too much $Ni(OH)_2$ in suspension to meet discharge requirements. It is therefore important that the pump intake be maintained in the clear zone at all times. To minimise disturbance of the clear zone, the Lime Reactor outlet (pit feed) pipe was extended into the pit lake at 2 meters from the bottom.

Pump rates can also affect the depth of the clear zone: if the pit outflow rate exceeds the inflow rate, the clear zone tends to disappear. As the pumps do not have any flow control (single speed pumps, no control valves), the barge pump is periodically shut down when this occurs. This method of operation prevents Ni exceedances.

Weather Effects

The weather can also affect the treatment efficiency. As the pit is maintained about half full, the pit walls serve to partially protect the pit lake from the wind, but extreme winds (not rare on the tundra) can eliminate the clear zone. Heavy rain can also cause turbulence and increase the inflow of contaminated run-off. When these events occur, samples can be taken as often as three times daily to ensure compliance. During extreme events, the discharge is sometimes discontinued as the effluent Ni concentrations can increase quickly.

In the early part of the treatment season as well as near the end, the water temperature is approximately 2 to 4 ^{o}C. Mixing the 40% sulphuric acid at these times is like mixing syrup with ice-cold water. Consequently, a longer mixing period is necessary to obtain a homogenous solution. Acid addition is automatically controlled by a feedback loop using a downstream pH measurement.

Shock Treatments

When treatment becomes difficult, either because of weather conditions or high uncontrolled runoff, a shock treatment can be used to quickly restore the clear zone. This is completed by manual addition of ferric sulphate distributed throughout the surface of the pond. The iron sulphate quickly dissolves and causes the iron to re-precipitate as ferric hydroxide. This serves to agglomerate the nickel hydroxide precipitates and also to partially adsorb any Ni remaining in solution. The larger particles formed by the combination with ferric hydroxides then settle much faster than the smaller $Ni(OH)_2$ particles alone. Discharge is usually possible within 24 hours of a shock treatment.

Raw Water Transfer

As previously mentioned, the raw water feed line from the Zone 3 Pond to the Lime Reactor is approximately 3 km long. Line failures occurred during commissioning of the new water treatment system resulting in Ni contaminated water spills that were not recoverable due to the nature of the terrain. The pipeline's lack of flexibility (lack of freedom to stretch due to temperature variations) was identified as a cause of failure.

The entire 8" pipeline between Zone 3 and Zone 2 was replaced by a 10" Sclairpipe line. The lack of flexibility was addressed by adding extra lengths of pipe to allow the pipe to stretch and shrink. The fused joints were tested by ultrasound prior to start-up and any weak joints were replaced.

Another potential problem is line freezing, particularly at the beginning and end of the treatment season. The most troublesome areas are the pump suction and some low points along the line.

As treatment is often intermittent, pumping must be halted in early October to prevent freezing. As soon as the raw water transfer is stopped, the lines are drained and cleared. Both ends of the line are sealed to prevent moisture from entering the pipe.

Conclusions

In-pit treatment is a feasible, low capital cost alternative when conditions allow.

Significant challenges must be overcome when treating water in a Northern Climate. These include potential freezing problems and a very high influx of water during spring thaw.

When treating mine drainage using this method, it is critical to minimise the uncontrolled inflow of contaminated runoff to the system.

Acknowledgements

The authors wish to acknowledge the help of Sophie Bergeron, SMRQ mining engineer, who completed a detailed technical review of this paper.

References

SNC-Lavalin, 1999. Flood volumes at Raglan Mine. Report prepared by B. Massé, C. Guillaud, and L. Macphie for SMRQ.

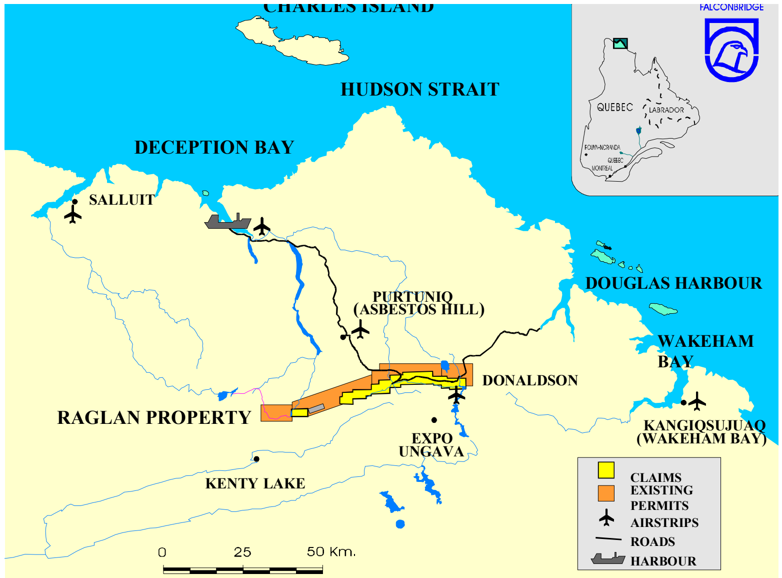

Figure 1: SMRQ Geographic Location

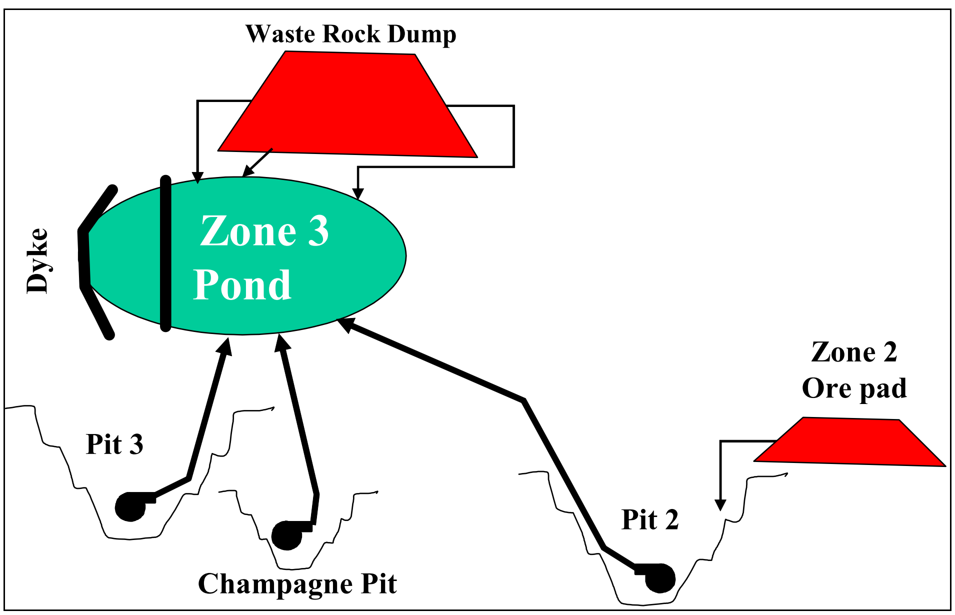

Figure 2: Water Management in 1999

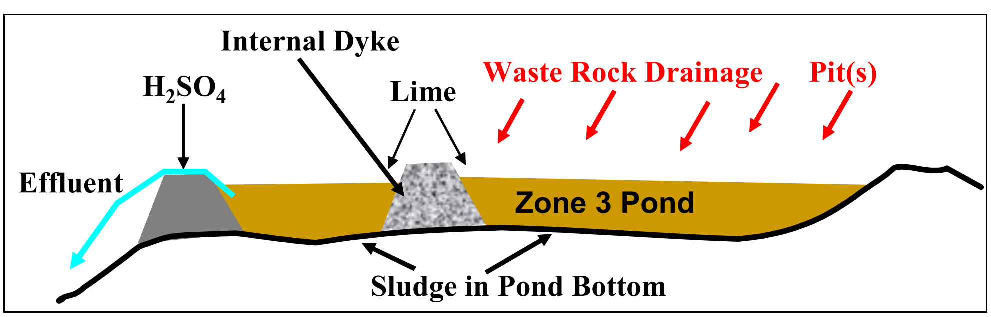

Figure 3: Conceptual Workings of Original Zone 3 Pond Treatment System

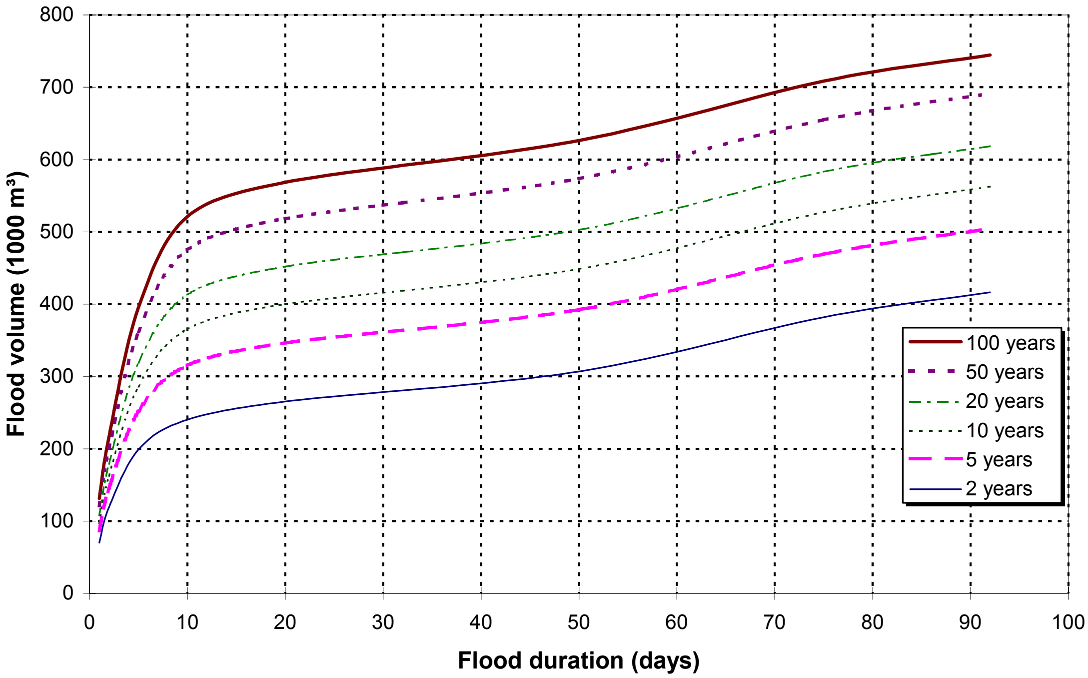

Figure 4: Flood Volumes at SMRQ for One Square Kilometer (from SNC-Lavalin, 1999)

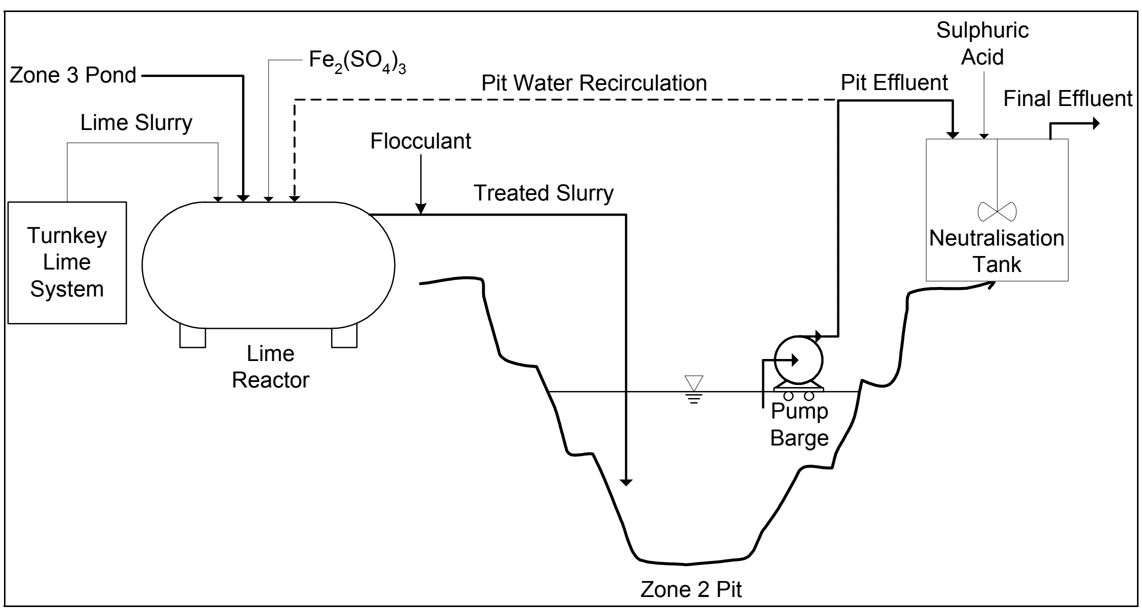

Figure 5: Current In-Pit Treatment System