Eliminating Acid Rock Drainage (ARD) at Mine Doyon – Sustained Operations allow for New Possibilities

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Abstract

Mine Doyon, located in the Abitibi Region of Quebec, has been in operation since 1978. First operated as an open pit gold mine, the issue of ARD was not identified prior to operations and resulted in the construction of roads, dams, and waste rock piles with acid generating materials. The problem was intensely studied through the MEND program primarily by the Groupe de Recherche en Environnement et Géo-Ingénierie (GREGI), of Laval University from 1991 to 1994. As the operation moved to underground ore extraction, the open pit became available for disposal of materials and allowed commencing of the rehabilitation process. Operations at Doyon ended in 2010, but with the discovery of the nearby Westwood deposit, new ideas and opportunities are being explored to rehabilitate the Doyon waste disposal areas to reduce the risk of ARD and provide for the next years to further study rehabilitation options. As mining activities will continue, the bulk of the former waste disposal sites is not required to be restored now allowing for both new ideas and cost-effective implementation.This paper will discuss the use of the open pit for managing ARD wastes, de-pyritized tailings covers and the use of treatment plant sludge to evolve an improved closure strategy for Doyon Mine.

Key Words: Acid mine drainage; Desulphurization; Paste backfill;Desulphurized tailings, dry cover, paste backfill

Using the Doyon Open Pit for the Tailings Disposal of Project Westwood

The evaluation of the pit storage volume has shown that it could hold up to 14 million cubic meters of material; sufficient for the needs of Westwood.For the Westwood project, about 5 million tonnes of tailings must return underground as cemented backfill, 2 million will be used to restore the Doyon tailings ponds with the desulfurized tailings and the remainder, about 5M tonnes will be placed in the pit. Hydrogeological studies of the pit were conducted in the years 2009 and 2010. The results of these studies were that the pit is a sufficient hydraulic trap and complies with the criteria for percolation in the requirements of the Department of the Ministry of Sustainable Development, Environment and Parks of the province of Québec.

To achieve this mandate, an initial study at a cost of $ 500, 000 was launched in 2009. Eleven (11) monitoring wells were installed around the pit as well as downstream. The choice of the location of the wells was done according to the main faults location surrounding the pit. Percolation tests (packers) were performed in each well. In 2010, a further installation and study of six other wells was conducted in a section that was not well covered by downstream hydraulics. The cost of this mandate was $ 62, 000.

The results of the study shows that the Doyon open pit meets the criteria for percolation found in the requirements of the Department of the Ministry of Sustainable Development, Environment and Parks. The maximum level of the water table that may bereached during the flooding of the pit was lowered by4

meters to ensure the protection of the downstream water quality. This lowering decreasedthe capacity of the pit to a volumeof 12 million m3 which is more than the required volumeby the Westwood project.

As of 2008, 1.35 million m3 of acid generating rock from the north waste rock dump of Doyon have been stored in the open pit.An additional 450 000 m3 of Westwood projectwastehave also been disposed of in the pit.

The application has been submitted to the Department of Sustainable Development, Environment and Parks and the file is being studiedbygovernment authorities.

Environmental Desulphurization

Achieving optimal wastes management and site remediation is one of the main challenges facing the mining industry around the world. Management of acid mine drainage generating tailings is an important issue for operating mines.Environmental desulphurization is one of the most promising approaches and techniques proposed in recent years to limit the production of AMD from mine tailings. It consists of separating a sufficient quantity of sulphides (based on the neutralization potential) from the mine tailings. With this process, there are two different fractions to manage;a large quantity of desulphurized tailings which do not generate AMD and a small quantity of sulphide enriched tailings that are acid generating. With this approach, it is possible to substantially reduce the volume of problematic tailings to be managed at the surface, especially when the concentrate can be returned as cemented paste backfill (CPB) underground.The desulphurized tailings can then be used as construction material for an engineered cover to prevent acid mine drainage. This method is generally recommended for operating mines that are willing and able to add a flotation circuit at the end of the existing treatment process.

The Doyon mill can treat 3500 tpd of gold ore. After gold processing (cyanidation), the total tailings feed is split into two fractions having the same mineralogy. During the operation time of the Doyon mine, the biggest proportion (approximately 60%) was used to produce paste backfill for the underground operation. The remaining 40% was stored at the surface in tailings ponds. Two main constraints led the operator to evaluate the possible addition of environmental desulphurization to their paste backfill technology: the maximum storage capacity of the tailings pond will be reached in the near future, and the Doyon tailings acid generation potential.

An integrated tailings management scenario for Westwood was proposed to reduce the costs associated with tailings management by, among others, the re-use of concentrator tailings. A sulphide flotation circuit before the concentrator tailings disposal in the tailings pond would produce a sulphide-rich concentrate and desulphurized (low sulphide) tailings. For the Westwood Mine project, the concentrate could be used as a component of cemented paste backfill and returned underground for ground support. The low sulphide tailings, (non acid generating), could be used for reclamation as a cover material to be placed overacid generating Doyon tailings.

A study was undertaken to evaluate the use of this newly proposed integrated method for sulphide tailings management for the specific case of the Doyon mine. The main objectives were; (i) to identify the flotation conditions that allow a good recovery of sulphide minerals using flotation tests at the laboratory and intermediate scales; (ii) to evaluate the acid generating potential of the desulphurized tailings using kinetic tests; and (iii) to verify if the addition of sulphide concentrate to the CPB would significantly modify its mechanical and environmental behaviors.

Desulphurization tests

Desulphurization tests were performed at the Doyon mine ore treatment plant on fresh tailings using batch and on-line testing. The process was first optimized with Denver cell laboratory tests before moving to an on-line flotation bank at pilot scale to validate the laboratory tests and to produce sufficient materials for the upcoming investigationas humidity cell and columns tests.

Pilot tests conditions

The URSTM (Unité de recherche et de service en technologie minérale) mobile flotation unit was used for this study (figures 1 and 2). The feed of the pilot scale flotation bank was connected to the total tailings pipeline at the Doyon plant. The flotation bank is made of six 10 L mechanical cells with an automated reagent addition system and a data acquisition system for on-line pH and Eh measurements.

Figure 1: Exterior view of the small scale pilot plant

Figure 2: Panoramic view of the small scale pilot plant

Acid Generation Potential after Desulphurization

Leaching tests

Humidity cell tests were conducted on the desulphurized tailings and totalDoyon tailings (reference sample). Plexiglas cells were filledwith 1 kg of solid material. Then, a repetition of 25 cycleswas performed, consisting in three (3) days of wet ventilation followed by three(3) days of dry ventilation, with the 7th day devoted to the rinsing of the solids with 500 ml of deionized water. The leachate was collected from the rinse water that extractedthe oxidation products from the solid samples, i.e. 4 h afterwater addition.

Columntests

Columntests with Doyon acid generating tailings with desulphurized tailings above were performed and monitored for more than one year. The leachate was collected and analyzed for metals, pH and other parameters.

Laboratory evaluationof the effectiveness ofa desulfurizedmonolayer covermade fromWestwood tailingsplaced onacid-generatingDoyon tailings was done. Thus,11instrumentedcolumnssimulatingacollectionofacid-generatingreleaseshave been put inplace. All of the columnscontained a30cm baseof acid generating Doyon tailings with a cover of Westwood tailings; the thickness of which was varied depending upon the column.(Figure 3).

Figure 3: Laboratory columns

Results

Flotation testing at laboratory scale (Denver tests) and at pilot scale

The objective of the first series of flotation tests was to determine the optimum flotation conditions for Doyon tailings desulphurization. The tailings are generated by a cyanidation circuit (gold processing) and contain a high cyanide residual concentration. The portion of tailings used for making CPB is treated to destroy cyanides using the Inco process (the corresponding proportion of sulphide concentrate is approximately 15 wt% of the total tailings).

Acid generation potential after desulphurization

Humidity cell tests were performed to study the long term geochemical behaviour of the Doyon desulphurized tailings and total tailings (used as an acid generating reference sample). The measured pH values were maintained above neutrality on the samples, except the one with the low water table, also containing Doyon acid generating tailings. The reference sample (total tailings) showed a larger sulphides oxidation rate (compared to the cell containing desulphurized tailings), as demonstrated by the sulphate release profile in the leachate which has higher values for the total tailings. Typically, the sulphate concentration was around 500 mg/L for the total tailings while for the desulphurized tailings sulphate release was negligible. This difference is explained by the higher sulphide content of the total tailings in comparison to the desulphurized tailings.
The metal concentrations were often lower than the detection limit of 0.01 mg/l for the laboratory and pilot tests. Even zinc (one of the most soluble and mobile metal elements) shows low concentrations in the leachate; zinc concentrations were usually between 0.10 and 0.02 mg/l for the Doyon tailings, and below 0.04 mg/l and detection limit for the desulphurized tailings. The desulphurization level reached is enough to avoid the acid generation for the Doyon tailings, containing less than 0.4 % of residual sulphur.

Covers with capillary barrier effects (CCBE) columns

With the aim of using desulphurizedwaste as single cover material, different column tests were conducted. They are used to test the influence of three key parameters: the sulfur content, the water table and the thickness of the cover toprevent the generation of acid mine drainage by Doyon tailings placed below. These tests allow for the comparison of a monolayer cover with more conventional methods such as water cover and multilayer cover. A series ofcolumns with different configurations of cover and positioning of the water table and control tests, were set up and monitored for over a year. Results of the CCBE columns are presented below in figures 4to 6.

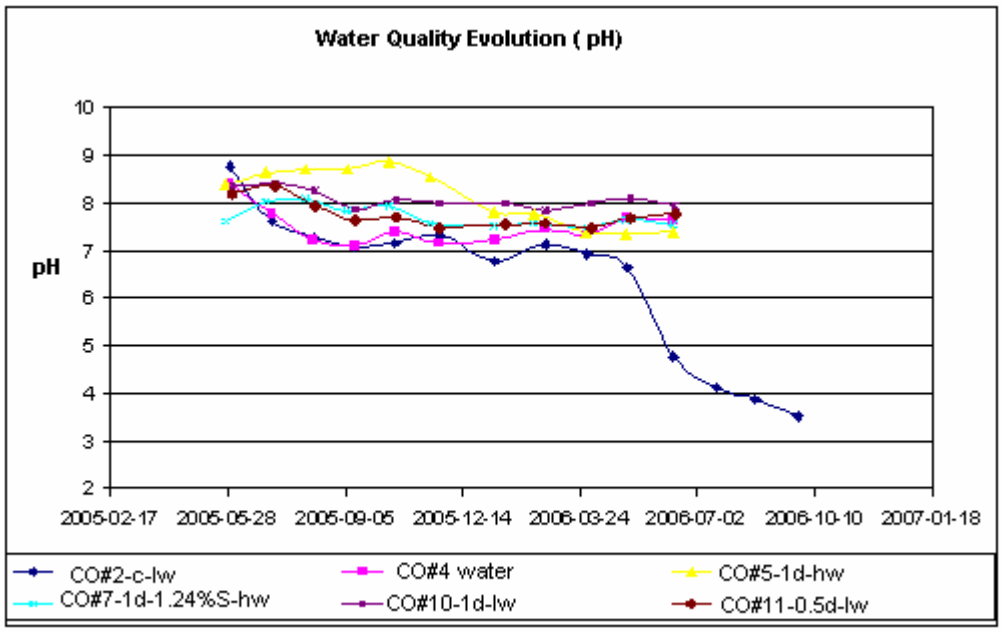

Figure 4: Water quality evolution (pH)

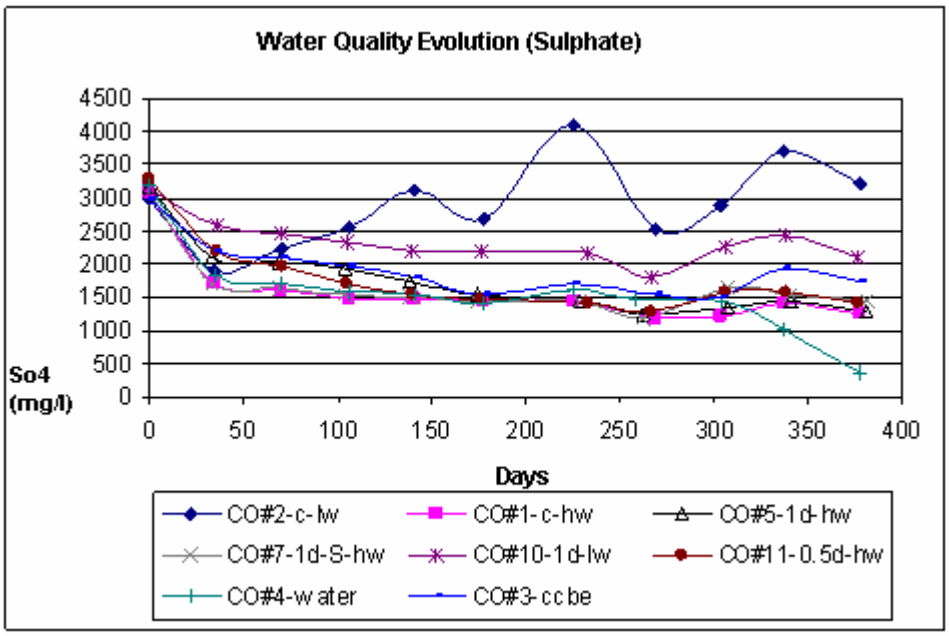

Figure 5: Water quality evolution (sulphate)

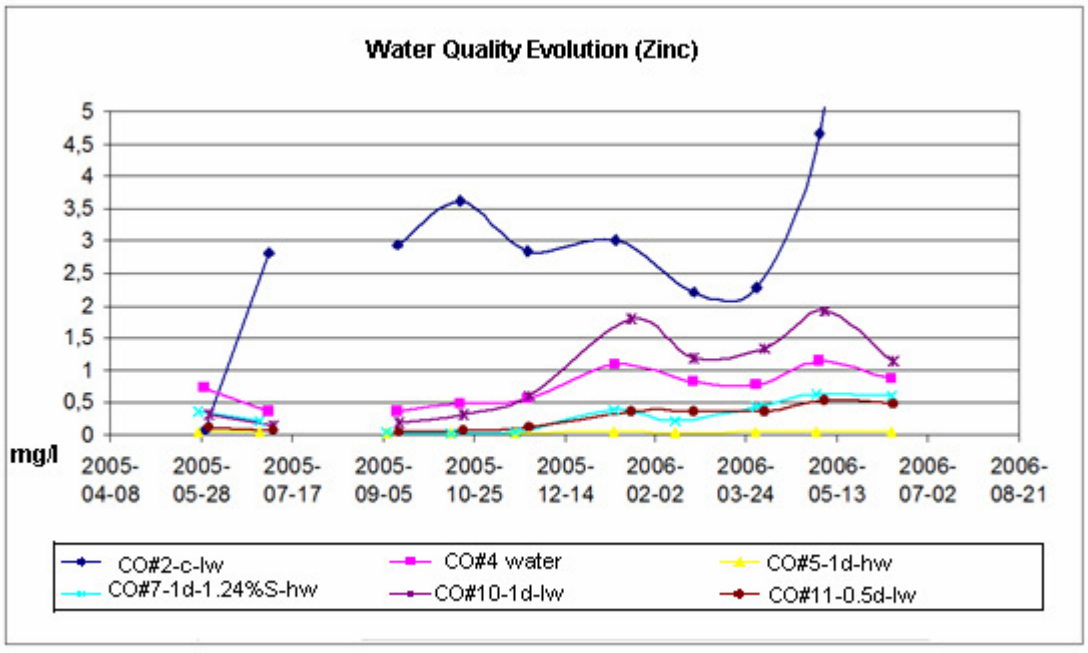

Figure 6: Water quality evolution (Zinc)

Desulphurization of a fraction of the tailings (partial desulphurization)

Under this scenario, the tailings are desulphurized only during the last years of mine operation.
The desulphurized tailings are used to cover the PAG tailings as aninert dry cover. The cover made of depyritized tailings is designed to maintain an elevated watertable, which will keep the PAG tailings deposited during the early years of operation in awater saturated condition to prevent sulphide oxidation. Since the foundation and the tailing dams arecharacterized by very low permeability, an elevated water table can be maintained in the PAGtailings with a layer of 1 to 2 meters of desulphurized tailings. The PAG tailings will act as anoxygen barrier by limiting oxygen diffusion because of the high degree of saturation in thetailings and the high water level. This approach is a variation of the previous scenario and requires the same capitalinvestment in a flotation circuit at the end of the plant circuit, but has lower operating costs sinceonly a fraction of the tailings need to be desulphurized. The use of desulphurized tailings as cover material would help to reduce the closure costs.

Laboratory work on the application of integrated tailings management for Doyon mine.

Pilot scale tests confirmed the feasibility of tailings desulphurization by flotation. A sulphide recovery of approximately 95% was achieved with amine collectors (insensitive to cyanide); the flotation tailings having approximately 0.3% S. The impact of the addition of sulphide concentrate into paste backfill was evaluated, and results confirmed that there is even a positive impact on mechanical strength. Leaching tests performed on paste backfill showed that paste made with sulphide tailings has a similar environmental behaviour as paste made with total tailings (before desulphurization). Finally, laboratory work confirmed that desulphurized tailings used as cover material over acid generating tailings can prevent the production of acid mine drainage.

Investigation on the recovery of treatment sludge for prevention and control of acid mine drainage.

The project, in partnership with the MDEIE (Ministère du Développement économique, Innovation et Exportation), Golder and Associates, MISA (Mine, Innovation, Solutions, Applications), UQAT (Université du Québec en Abitibi-Témiscamingue), URSTM (Unité de recherche et de service en technologie minérale) and Iamgold Corporation, aims to evaluate the potential use of a mixture of sludge-natural soil, sludge-mine tailings and sludge-waste rock, for mine reclamation to control acid mine drainage.

The main objective of this project is to establish, from an experimental program, the potential use of sludge as a component used to cover waste during the rehabilitation of mining sites. Several scenarioswere considered: sludge alone, sludgemixed with tailings,waste rocks and natural soil, and theseoptionswith or without cement.

The project includes a series of studies to be conducted in the laboratory of the URSTM at UQAT (characterizations, column tests), and partly on the site of the Doyon mine (experimental cells). The part of the project on the use of mixtures (with and without binder) began with the study of chemical stability of these mixtures using kinetic tests in columns and humidity cells.Once the right mixtures are chosen, chemical stability will be studied in columns and finally the optimal mix will be selected.

The project started in August 2010 by geotechnical drilling in the sludge pond. A geotechnical characterization, geochemical and chemical stability of sludge and the different mixtures were performed during winter and spring 2011. Static testsfor predicting thepotential foracid mine drainage were done. The chemical stability of mixtures, sludge-tailings and sludge-waste rocks are being studied to determine the behaviour of mixtures (hydraulic conductivity, shrinkage, cracking, freezing, etc.). The results to date show good potential for sludge reuse. Kinetic columntestsand wet celltestsare being conducted.

Figure 7: Humidity cells tests

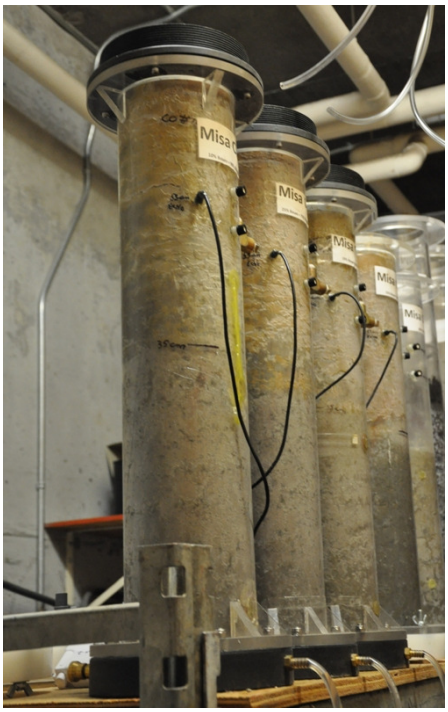

Figure 8: Columns tests

Humidity cells tests (Figure 7) started in May 2011 and will be monitored for 30 weeks, column tests (Figure 8) began in July 2011 for one year. Experimental cells in the field will be implemented in spring 2012 to validate the potential mining reclamation at an intermediate scale.

Conclusions

The studies demonstrated that for the case of the Doyon mine, it would be possible to use environmental desulphurization to produce non-acid generating low sulphide tailings and a sulphide concentrate. The sulphide concentrate could then be used in cemented paste backfill; in some cases, this could help improve the strength acquisition process. Doyon desulphurized tailings can be an efficient cover material to rehabilitate the existing acid generating tailings storage areas.

The desulphurization techniques, particularly when combined with paste backfill, should beconsidered as an integrated management technique throughout the mine life, and to facilitate therehabilitation at the end of mine life.

The preliminary restoration scenario proposed for the Doyon mine (normal conditions) was:

- Covering the Doyon acid generating tailings with 1m desulfurized tailings from 0.3 to 0.8% S, and
- Ensuring a high water table (75cm or less from the ground surface) to maintain the flow of oxygen at 10 mol/m2/an.

Also, the use of the Doyon open pit provides a good optionto reduce the footprint of the Westwood project and manage the waste rock and tailings.

The recovery of treatment sludge can prevent and control acid mine drainage. Depending on theresults of studies thatare underway and ongoing, this project results could include the following:

- Substantial reduction in Doyon site rehabilitation costs
- Substantial reduction in environmental footprint of mining operations
- Improvement in environmental management practices
- Increase is mining industry performance
- Contributing to ensuring the sustainability of a major motor for economic growth the mining industry
- Positive gesture toward harmonious cohabitation of land users and social acceptability
- Others.

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