Surface Paste Disposal of High-Sulfide Tailings at Neves-Corvo – Evaluation of Environmental Stability and Operational Experience

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Abstract

The Neves-Corvo mine is a world-class underground copper-zinc mine located in the semi-arid south of Portugal. The mine has been operated since 1988 by Somincor (Sociedade Mineira de Neves-Corvo, SA), a subsidiary of Lundin Mining.

Pyritic tailings produced in the copper and zinc plants have a high acid generation potential and have historically been placed subaqueously since the startup of the mine. This disposal system at Somincor has provided safe and reliable storage of tailings. However, the tailings facility was predicted to reach full capacity in 2011 and alternatives for provision of sufficient tailings storage capacity were studied by Somincor. Surface disposal of paste was selected as the preferred alternative.

The feasibility of changing the tailings deposition method to sub-aerial placement of paste has been investigated since 2001. Work completed includes a laboratory screening program, a field cell monitoring program, a large-scale field trial, a feasibility study, basic engineering, detailed engineering, and commissioning of the paste plant, culminating in operational placement of paste commencing in late 2010. Co-placement of acid-generating waste rock occurs in the form of berms and dikes that contain the paste.

This paper summarizes the geochemical work conducted to evaluate the environmental stability of the paste. In addition, operational learnings and observations are presented.

Operational experience to date indicates that the environmental behavior of the paste is consistent with the predictions resulting from the field and laboratory geochemical testing programs, demonstrating the value of these extensive efforts. Despite the high acid generation potential of the paste, its surficial placement under controlled conditions results in responsible and reliable management of both tailings and waste rock.

Key words: Paste, tailings, surface, acid generation, operational, co-disposal, waste rock

Introduction

Environmental impacts resulting from surface disposal of acid generating waste are a common problem for base metal mines around the world. Sociedade Mineira de Neves-Corvo, S.A (Somincor), who own the Neves-Corvo underground copper-zinc mine and associated tailings facility in southern Portugal, have been investigating the possible application of paste technology since 2001 when a feasibility study indicated the potential for major long-term advantages. Given the long remaining mine life (current estimates indicate possible operations through 2034), the sub-aqueous disposal method would require substantial dam raises. In addition, the presence of a water cover in perpetuity as a closure option was considered a considerable challenge in the semi-arid and net evaporative climate of southern Portugal.

The Neves-Corvo deposit is a so-called volcanogenic massive sulfide (VMS) and, as such, the tailings contain significant quantities of pyrite (up to approximately 50 wt.%). Understanding the geochemical behavior of these sulfide-rich tailings was paramount as conventional sub-aerial disposal methods may facilitate and promote significant generation of acid rock drainage (ARD).

Evaluation of Environmental Stability

The geochemical investigation of the paste has had three principal objectives:

- Evaluation of the long-term environmental stability of the paste;
- Identification of operational constraints during operational placement of paste; and
- Assessment of closure options.

The program has included multiple phases, as follows:

- Laboratory bench-scale testing (2000);
- Field cell testing (2002 - 2005);
- Paste pilot program (2005 - 2010); and
- Operational monitoring (2011 - current).

The laboratory program was conducted in the Somincor laboratory (Figure 1) and involved a one-year screening-level assessment of different sub-aerial placement options, including wet paste (250-mm slump), stiff paste (150-mm slump) and filter cake, both with and without amendments (cement, lime, and bactericide). The results were consistent with expected relationships between moisture content, amendments, and sulfide oxidation. In summary, the best performance (i.e. the least oxidation) was observed for the samples with the highest moisture content (250-mm slump paste). Lime and cement amendments provided early buffering capacity, but not in the long term. Sulfide oxidation rates were not affected by the presence of lime or cement, while use of bactericide showed a short-term benefit only. More detail about this program can be found in Verburg et al. (2003).

Figure 1 *Laboratory Bench-Scale Testing of Paste.*

The geochemical study expanded to the field in 2002 with the construction of six field cells, each containing approximately 12 tons of tailings, to monitor the performance of the sub-aerial placement option. Based on the results of the laboratory testing, wet paste was selected for the field cell trials. The cells were monitored for three years, with routine collection and comprehensive chemical analysis of seepage and runoff (Figure 2).

Figure 2 *Field Cell Program.*

The field cell testing program provided data supporting the use of tailings paste as a viable disposal alternative. The results from this program demonstrated that, although sulfide oxidation occurred in the paste, due to the high degree of saturation of the paste, oxidation rates were reduced relative to those in dry tailings. In addition, due to its low permeability, contaminant transport was very slow, and the impact of sulfide oxidation on seepage quality was reduced through the presence of mineralogical controls that buffered pH. The results from the field cells further identified that, during active paste disposal, it would be the control of runoff, not seepage, which would govern the placement protocol. In particular, a lag time to acid generation was established that represented the operational window within which a previously-placed layer of paste needed to be covered by either a fresh paste layer, an interim cover, or a final cover to prevent an unacceptable degree of sulfide oxidation. More detail is provided in Verburg et al. (2006).

In 2005, a paste plant was commissioned in support of construction of a 50,000 cubic meter (m^3) pilot paste trial. This trial was initiated to investigate paste deposition techniques, co-disposal with acid-generating waste rock, and long-term performance of covers. Three cover scenarios were tested: 1) a low-flux cover without capillary break, 2) a low-flux cover with capillary break, and 3) a barrier cover (Figure 3). All three covers contained a component of acid generating waste rock. An exposed quadrant was present as a control cell. Monitoring continued for a duration of approximately five years and included collection of runoff and infiltration for chemical analysis. Data interpretation involved extensive geochemical modelling, unsaturated numerical flow modelling, and an impact assessment to evaluate seepage quality and quantity and potential associated effects on the receiving groundwater aquifer.

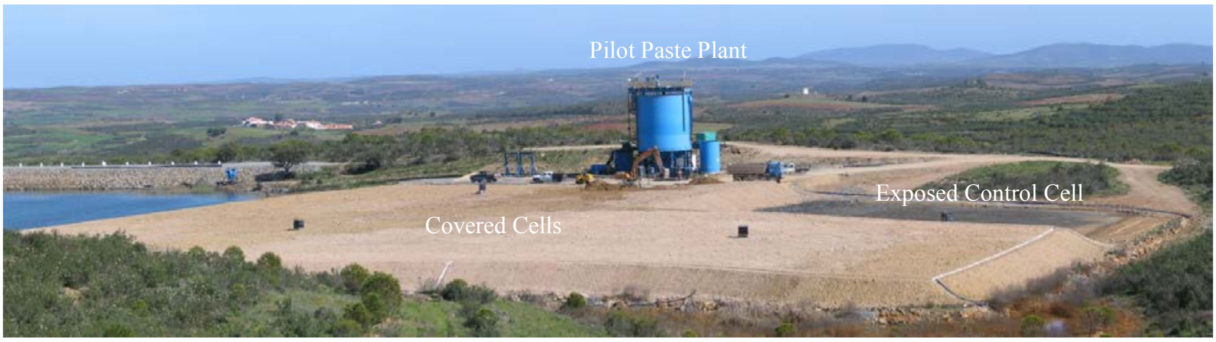

Figure 3 *Paste Trial after Construction.*

Monitoring results indicated significant reductions in sulfide oxidation in the covered cells relative to the control cell. Evaluation of draindown characteristics through unsaturated flow modeling identified that the highest degree of long-term saturation was achieved for the low-flux covers. This led to the conclusion that a cover system which strongly limits water infiltration, such as a barrier cover, is not always the best option for closure of acid generating tailings facilities located in arid and semi-arid climates. Instead, a cover that allows some infiltration was considered more reliable in terms of controlling ARD by maintaining a higher degree of saturation within the tailings. More detail on the geochemical findings of the program and draindown evaluation can be found in Verburg and Oliveira (2011) and Junqueira et al. (2009), respectively.

In late 2015, excavation of the covers in the paste trial provided an opportunity to conduct an informal assessment of cover performance. Based on visual observation, the extent of oxidation was limited to a few centimeters in all three cover designs, despite the presence of acid generating waste rock in the covers. It was further observed that the underlying paste had retained its moisture content.

Operational Monitoring and Experience

Operational paste placement commenced in late 2010. Paste is placed in cells separated by rock dikes constructed of acid generating waste rock (Figure 4). Alternating paste deposition between cells and limiting lift thicknesses promotes drying and densification of the deposited tailings. The sequential cell filling also provides for progressive closure and site restoration, as well as better control of acid generation and runoff during the operating years. An aerial overview of the paste placement scheme is presented in Figure 5. More detail on operational practices can be found in Oliveira et al. (2011) and Lopes et al. (2015).

Figure 4 *Operational Paste Placement.*

Figure 5 *Aerial View of Paste Placement Scheme.*

Operational monitoring includes visual observation, routine determination of paste pH in paste core samples, and collection and analysis of pond water. The paste pH measurements indicate that the depth of oxidation is limited to a few centimeters, even after extended exposure. Pond water quality is affected by this shallow oxidation, as evidenced by trends for pH and sulfate over time. The observed water quality is consistent with the predictions from the geochemical investigation program (Figure 6). Through 2014, pond water quality was amended by direct lime addition. This practice was discontinued in early 2015, and pond water is now routed to a collection pond prior to lime treatment in a water treatment facility.

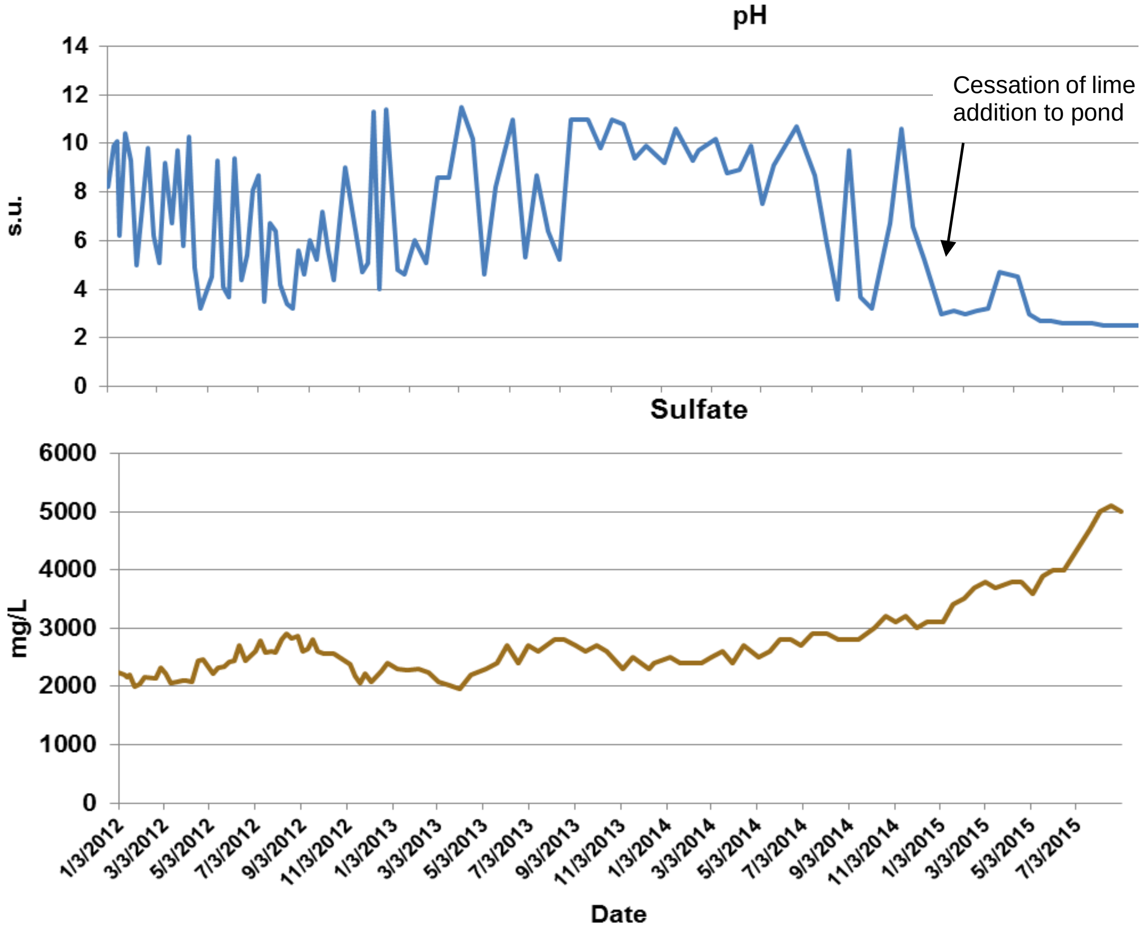

Figure 6 *Trends of pH and Sulfate Concentrations over Time in Pond Water.*

Placement of interim covers for operational purposes has provided an opportunity for qualitative evaluation of cover performance. Minor oxidation is observed at the base of the covers themselves, which consist of waste rock, but the underlying paste shows no visual signs of oxidation and has retained its moisture content. Future long-term cover testing, on a quasi-operational scale, is planned for quantitative demonstration of cover performance, while also presenting opportunity for gaining experience with cover construction. Additional ongoing operational learnings relate to berm construction, sequencing of paste placement, and water management.

Future Considerations

Somincor's 2014 life-of-mine (LOM) studies have established additional reserves and related demand for additional storage of tailings and waste rock beyond the current design. This LOM plan envisions two future scenarios:

- Base Case: operation until 2024; and
- Expansion Scenario: operation until 2034.

Both scenarios require evaluation of paste disposal options. A trade-off study is presently being conducted that evaluates the relative merits of higher stacking of paste tailings versus raising the perimeter dam.

Conclusions

Operational experience to date at Somincor's Neves-Corvo facility indicates that the environmental behavior of the paste is consistent with the predictions resulting from the laboratory and field geochemical testing programs, demonstrating the value of this decade-long, rigorous proof-of-concept effort. Despite the high acid generation potential of the paste, its surficial placement under controlled conditions results in predictable, responsible and reliable management of paste tailings. Co-placement of acid generating waste rock has proven feasible as well.

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