Surface Disposal of High-Sulfide Thickened Tailings at the Neves Corvo Mine, Portugal – Operational Observations

Rens Verburg[1], Mafalda Oliveira[2]

[1]WSP USA, Redmond, WA 98077, USA, rens.verburg@wsp.com

[2]SOMINCOR – Sociedade Mineira de Neves-Corvo, S.A., Castro Verde, Portugal, mafalda.oliveira@lundinmining.com

Abstract

The Neves Corvo mine in Portugal makes use of surficial disposal of high-sulfide thickened tailings. The environmental behavior of the tailings is assessed through an extensive monitoring program of interstitial, surface and seepage water quality as well as the solids. The ongoing monitoring of the tailings mass and operational experience at Neves Corvo indicate that surficial deposition of high-sulfide thickened tailings in an arid climate represents a feasible alternative that enhances operational flexibility, facilitates concurrent reclamation and permits co-disposal with waste rock.

Keywords: Paste, tailings, sulfide, surface, operations

Introduction

Neves Corvo is a world-class underground copper-zinc mine located in the south of Portugal, owned at the time of paper preparation by Lunding Mining Corporation but currently owned by Boliden. The mine has been operated since 1988 by SOMINCOR. The pyritic tailings produced by the operation contain up to 45 weight% sulfide sulfur. Additionally, they have negligible neutralization potential (NP), resulting in a very high acid generation potential. Following mine startup, the tailings were placed subaqueously in the Barragem Cerro do Lobo tailings storage facility (TSF), a large tailings pond created by a rockfill dam across a natural river valley. However, due to the finite capacity of the impoundment, alternatives for provision of sufficient storage capacity were studied by SOMINCOR in the early 2000s. Surface disposal of thickened tailings was identified as the preferred option, which was considered a novel approach at the time given the high reactivity of the tailings and the arid climate at Neves Corvo. More detail on the geochemical and geotechnical investigations that were conducted in support of this decision as well as results from infiltration and geochemical modeling can be found in Junqueira *et al.* (2009), Lopes *et al.* (2015) and Verburg *et al.* (2003, 2009).

The tailings facility was originally developed for sub-aqueous tailings deposition, with an area of 191.5 hectares or 1.9 km^2, allowing for a total of 17 Mm^3 to be deposited. In 2010, the TSF was converted from a sub-aqueous to a thickened tailings deposition facility, without requiring any future raises of the main and perimeter rockfill embankments. The design included disposal of tailings with run-of-mine waste rock, which is potentially acid generating, in a co-disposal system. The waste rock is used for construction of peripheral berms and covers while use of waste rock for internal dikes formed part of an older depositional scheme which is no longer in use. Waste rock dikes nowadays have become encapsulated in the tailings.

The storage capacity of the facility using this method was increased to 33.3 Mm^3, based on a vertical expansion of five tiers. In 2022, SOMINCOR received approval to expand the footprint of the TSF to the south area, to allow for sufficient additional storage capacity through 2033. Construction of a new south containment embankment started in 2022 and the deposition of thickened tailings in the new area started in April 2024. Additional lifts to the expanded facility will be constructed in accordance with the mine plan. The expanded facility occupies a total area of approximately 210 hectares. With this expansion, the TSF storage capacity has increased in capacity from 33.3 to 50 Mm3 of extractive waste (tailings and waste rock), maintaining the current system of co-disposing thickened tailings and waste rock. Fig. 1 shows a recent aerial photo of the TSF.

Monitoring data collected since late 2010 include records of tailings production and thickened tailings densities, yield stress, particle size distribution, and specific gravity. Settlement, deposition slopes and piezometric levels in the thickened tailings and underlying subaqueous deposit are also routinely monitored. The environmental component of the monitoring program includes, among others, the determination of ponded water quality. Due to the acidic nature of the near-surface tailings, surficial contact water in the TSF is acidic as well, with elevated sulfate and metals concentrations. This water is directed to Cell 15 where it is mixed with process water from the tailings thickener. It is then treated by Fenton reaction plus a high-density sludge (HDS) process and reused in the industrial process, reducing the requirement for fresh makeup water.

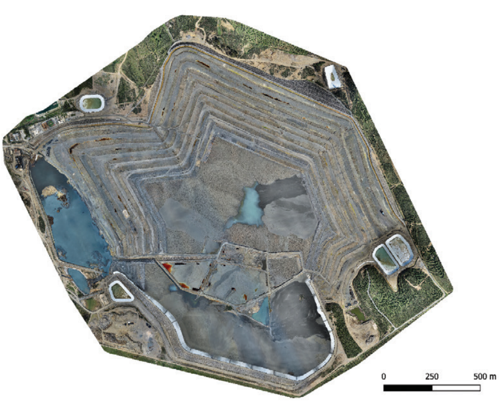

Figure 1 Aerial photo of the Barragem Cerro do Lobo TSF (image: IRCLLevantamento GW20Fev2025_100cm).

A second component of the environmental monitoring program consisted of periodic compositional profiling of the thickened tailings and underlying slurry tailings with depth, which is the focus of this paper. The aim of this effort was to develop a better understanding of the depth of oxidation as a function of location in the TSF, with special focus on locations near waste rock dikes vs. locations at some distance from the dikes as well as locations underneath waste rock covers vs. locations where thickened tailings were exposed.

Methods

The sampling program of the thickened tailings took place during two campaigns in 2021. A total of 70 thickened tailings samples were collected from different depths at 40 locations throughout the TSF.

The first campaign involved collection of 40 deeper samples at 10 locations up to depths of approximately 35 m using a piston sampler as part of a geotechnical program. A second campaign consisted of collection of 30 shallow core samples up to approximately 1 m deep at the same locations (each generating 10 subsamples corresponding to different depths within each sample core). The samples were collected along transects to support assessment of different aspects related to depositional age of the thickened tailings, exposure duration, and the presence or absence of a waste rock cover.

Samples obtained during the first campaign underwent comprehensive geochemical characterization and were analyzed for paste pH and electrical conductivity (EC), acid base accounting (ABA), net acid generation (NAG) testing, chemical composition, and short-term leach testing by the shake flask extraction (SFE) method. The second campaign focused on the determination of paste pH and EC for the assessment of oxidation of shallow thickened tailings either exposed or encapsulated by the waste rock cover.

Concentration profiles with depth (not shown) indicate that the composition of the tailings has been relatively consistent over time, with both the deeper, subaqueous tailings and the overlying, subaerial thickened tailings reporting similar overall compositions. Where compositional differences are observed, they occur in the shallower, near-surface samples. Differences between the shallower and deeper samples are most pronounced for the following parameters: sulfate sulfur (highest concentrations in shallow samples), total inorganic carbon (TIC) and NP (lowest concentrations in shallow samples), paste pH (lowest values of approximately pH 2 in shallow samples) and paste EC (highest values in shallow samples). Also, for some trace metals (e.g., cobalt, copper), the shallowest samples contain some of the lowest concentrations observed throughout the depth profile.

Discussion

The observed trends in the solids profiles are consistent with sulfide oxidation occurring. This process results in generation of sulfate and acidic conditions, an increase in paste EC, and depletion of TIC, NP and the trace metals mentioned due to their increased mobility under acidic conditions. The SFE results support the observed trace metal trends and are in good agreement with geochemical principles, with leaching of cationic trace metals (e.g., cadmium, cobalt, nickel, zinc) more pronounced under acidic conditions and leaching of anionic parameters (e.g., antimony, arsenic, molybdenum selenium) more pronounced under circumneutral to alkaline conditions.

Due to the high sulfide sulfur content of the tailings of up to 45 weight%, its depletion is not apparent in the shallow samples. Also, in the presence of elevated sulfide sulfur contents, the quantities of near-surface sulfur available for reaction with oxygen are such that an oxidation front typically does not extend to great depths. In the absence of a cover, the oxidation front typically extends to a depth of approximately 30 cm. Figure 2 shows a typical oxidation front of an uncovered tailings surface that has been exposed for four years. Oxidation is most pronounced along fractures and cracks.

The effects of the near-surface sulfide oxidation (e.g., depletion of TIC, NP and/or trace metals) reach a depth of up to approximately 1 to 1.5 m, with the greater depths typically associated with desiccation cracks or discontinuities related to, for instance, the presence of waste rock dikes. These effects are considered the result of downward percolation of acidic solutions resulting from the near-surface sulfide oxidation.

The effect of the presence of waste rock dikes is illustrated in Fig. 3. This figure shows that paste pH is typically lower in the vicinity of those dikes than some distance away. Paste EC (not shown) exhibits the opposite trend, with higher values found closer to the dikes.

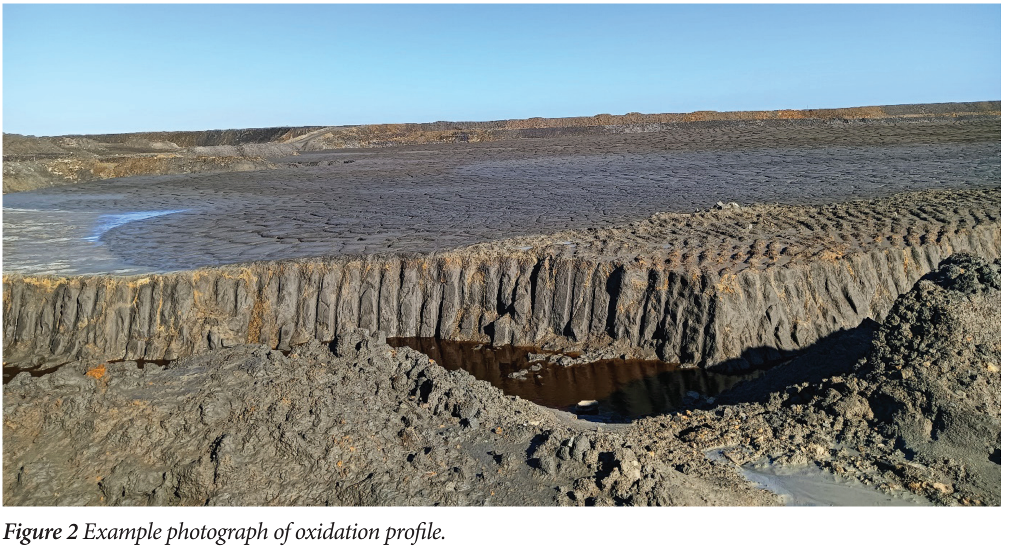

Figure 2 Example photograph of oxidation profile.

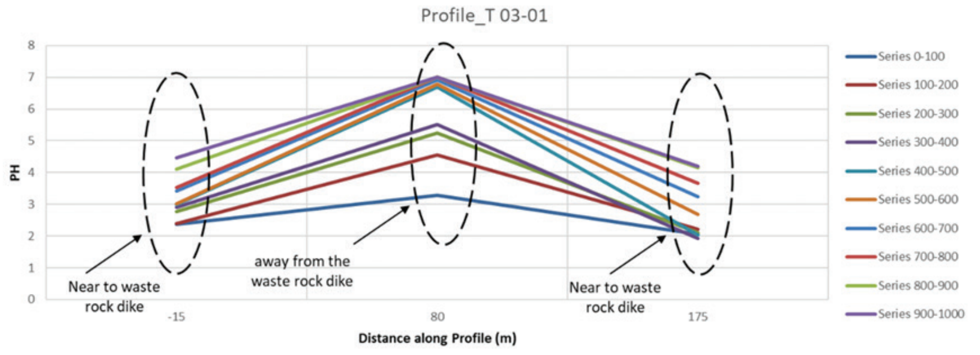

Figure 3 *Example cross section of paste pH near and away from waste rock dikes. Values in the legend refer to 100-mm depth increments of each sample below ground surface.*

This indicates that the dikes enhance sulfide oxidation relative to the regular thickened tailings surface, likely through promoting horizontal drainage and depression of the water table in the vicinity of the dikes, thereby reducing the moisture content of the thickened tailings and/or enhancing oxygen ingress by providing preferential pathways through cracking of the tailings. Sulfide oxidation is very sensitive to moisture content, with oxygen diffusion declining by approximately three to four orders of magnitude as the degree of saturation increases above 85% (INAP 2009). The effect of the dikes is typically more pronounced for the deeper samples, while shallower samples within the 1-m depth interval generally report lower paste pH than the deeper samples.

The effect of the presence of a waste rock cover is noticeable as well. Fig. 4 and 5 show paste pH trends for an uncovered and covered transect, respectively. Whereas paste pH in uncovered transects typically ranges from 2 to 6 (depending on depth), this range generally is 6 to 8 for covered thickened tailings, indicating that the waste rock cover has been effective at reducing sulfide oxidation. The average thickness of the waste rock cover is 1 m. The waste rock cover is applied as soon as the maximum tailings level defined for each lift has been reached.

Conclusions

In summary, the results obtained from the geochemical characterization program have demonstrated the following:

- Away from waste rock dikes and in the absence of a cover, the oxidation front reaches a depth of approximately 30 cm. The zone of oxidation is characterized by lower paste pH, higher paste EC, an increase in sulfate sulfur content, and depletion of TIC, NP and select trace metals. At greater depths (up to 1 to 1.5 m), infiltration of acidic solutions may result in depletion of TIC, NP and/or trace metals as well.
- The waste rock dikes promote sulfide oxidation relative to the regular thickened tailings surface, likely through increasing horizontal drainage and depression of the water table, thereby reducing the moisture content of the thickened tailings and/or enhancing oxygen ingress by providing preferential pathways.
- The waste rock cover has been effective at reducing sulfide oxidation relative to exposed conditions.

The ongoing monitoring of the tailings mass and operational experience at Neves Corvo indicate that surficial deposition of high-sulfide thickened tailings in an arid climate represents a feasible alternative that enhances operational flexibility, facilitates concurrent

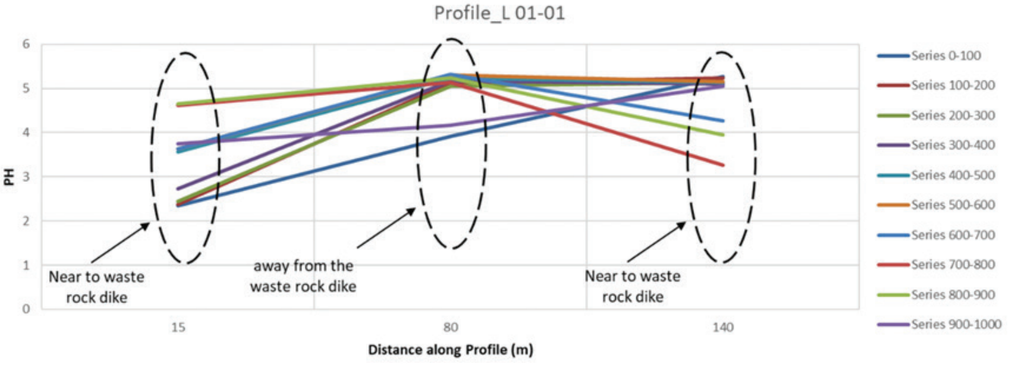

Figure 4 *Example cross section of paste pH in uncovered thickened tailings. Values in the legend refer to 100-mm depth increments of each sample below ground surface.*

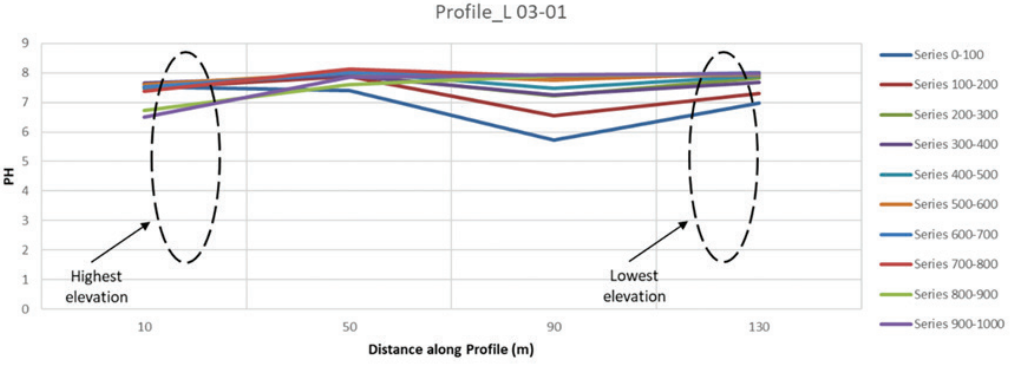

Figure 5 *Example cross section of paste pH in thickened tailings underneath waste rock cover. Values in the legend refer to 100-mm depth increments of each sample below ground surface.*

reclamation and permits co-disposal with waste rock.

Acknowledgments

The authors thank SOMINCOR for permission to present the results of the thickened tailings investigative program and Ricardo Bahia and Eduardo Afonso (WSP Portugal) for their support in paper preparation.

References

International Network for Acid Prevention (INAP) (2009) The Global Acid Rock Drainage (GARD) Guide. www.gardguide.com

Junqueira F, Wilson G, Oliveira M (2009) Surface Paste Disposal of High-Sulphide Tailings at the Neves Corvo Mine in Portugal. Part 1: Estimation of Tailings Desaturation and Implications for ARD Generation. Proc of the 8th Int Conf on Acid Rock Drainage, Skellefteå, Sweden, June 23–26, 2009

Lopes R, Bahia R, Jefferies M, Oliveira M. (2015) Upstream Stacking of Thickened Tailings at Neves Corvo. Proc of the 18th Int Seminar on Paste and Thickened Tailings, Cairns, QLD, May 5–7, 2015

Verburg R, Johnson B, Fordham M, Logsdon M (2003) A Rapid and Cost-Effective Method for Bench Screening of Geochemical Performance and Disposal Options for High-Sulfide Tailings. Proc of the 6th Int Conf on Acid Rock Drainage, Cairns, QLD, July 12-18, 2003

Verburg R, Ross C, Oliveira M (2009) Surface Paste Disposal of High-Sulphide Tailings at the Neves Corvo Mine in Portugal. Part 2: Field Trials, Cover Performance Monitoring, and Impact Assessment. Proc of the 8th Int Conf on Acid Rock Drainage, Skellefteå, Sweden, June 23–26, 2009