Original Article

Influence of pyrite depressant reagents on the flotation efficiency of lead and zinc sulfides

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Abstract

Pyrite (FeS_2) is a sulfide mineral that acts as gangue in the flotation of lead and zinc ores due to its propensity to float alongside galena (PbS) and sphalerite (ZnS), compromising the selectivity and efficiency of the process. This study investigated the impact of two pyrite depressants, sodium metabisulfite (MBS) and quebracho, on the selectivity of the flotation process for lead (Pb) and zinc (Zn) sulfide ore. Bench-scale flotation tests were performed using diferent dosages of each reagent. A dosage of 200 g/t of MBS achieved 91.73% Zn recovery, reducing the iron content in the zinc concentrate (Fe content of 2.89%). Quebracho, at the same dosage, provided 94.33% Pb recovery, with a reduction in the iron content in the zinc concentrate to 1.17%, although with a slight decrease in the Pb grade of the concentrate. Both depressants lowered Zn and Pb contents in the final tailings, meeting industrial specifications and demonstrating their potential to enhance the efficiency of the flotation circuit at the studied mine.

Keywords: Sulfide flotation; Depressants; Pyrite; Sphalerite; Galena.

1 Introduction

Lead (Pb) and zinc (Zn) metals are widely used in strategic sectors, including the electrical, mechanical, military, chemical, medical, and lighting industries [1]. Galena (PbS) and sphalerite (ZnS), the primary mineral sources of these elements, have significant economic relevance [2], but they are often associated with other sulfide minerals, such as pyrite (FeS_2) and chalcopyrite ($CuFeS_2$), which makes their efficient separation challenging [3,4].

Flotation is the main concentration technique for these ores, enabling the selective separation of galena (PbS) from sphalerite (ZnS) [5,6] based on differences in the surface hydrophobicity of the minerals [7]. For Pb-Zn sulfide ores, two common approaches are used: depressing sphalerite to float galena or performing a collective flotation of both minerals followed by their separation [2,8]. However, the presence of pyrite, due to its high floatability, compromises selectivity and reduces the quality of the final concentrates.

The reagent system used in flotation for treating lead-zinc ores varies considerably depending on the ore's nature and mineralogy [9]. Therefore, the development of optimized reagents and systems is crucial to overcome these limitations. Over the past decades, several studies have investigated methods to optimize the flotation separation of Pb-Zn sulfide ores [10,11].

This study aims to evaluate and compare the efficiency of two depressants, sodium metabisulfite (MBS) and quebracho, in reducing pyrite floatability in a Pb-Zn ore flotation circuit. Through this analysis, the research seeks to enhance the selectivity and quality of the produced concentrates, contributing to the overall performance of the beneficiation process in the studied company

2 Materials and methods

The tests utilized run-of-mine (ROM) material, which was sampled from the undersize stream of the second deck of the tertiary crushing circuit screen with a 10mm opening. Additionally, reprocessed material was collected from different points of a tailing dam. The test mixture was composed of 80% ROM and 20% reprocessed material.

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2.1 Particle size characterization

The particle size characterization tests were conducted to ensure the feed met the flotation plant's specifications. As shown in Table 1, the target particle size distribution was 65% passing 44 µm. To achieve this, a 2 kg sample (80% ROM and 20% reprocessed material) was wet-ground in a rod mill with 1 L of water.

The flowchart in Figure 1 summarizes the grinding and classification process, illustrating the steps undertaken to produce material suitable for the bench flotation tests.

2.2 Flotation process specifications of the mine

For the analysis of the flotation test results, the following parameters were considered: the zinc (Zn) grade in the zinc sulfide concentrate, the lead (Pb) grade in the lead sulfide concentrate, the recovery rates of Pb and Zn, the iron (Fe) grade in the zinc concentrate, and the grades of Zn, Pb, and Fe in the final tailings. These parameters are defined according to the specifications presented in Table 2.

2.3 Chemical analysis

The chemical composition of the flotation feed and products was determined using X-ray fluorescence (XRF) via the powder method. The analysis was carried out with an EDX 720HS model from Shimadzu, located in the process laboratory of the company. Zn, Pb, and Fe grades were analyzed, and the results were used to perform mass balance and metallurgical calculations.

Table 1. Flotation Plant Feed Specifications

Specifications	Bench flotation test
Zn content	2.0% ≤ x ≤ 3.0%
Pb content	0.6% ≤ x ≤ 1.5%
Fe content	≤ 3.0%
Particle size	~ P65% passing 44 µm

2.4 Reagents

The flotation tests were conducted using the same reagents as those employed in the mine's operational process, with concentrations specified in Table 3.

2.5 Bench flotation test

The bench flotation tests were performed in the process chemistry laboratory of the mine. The experimental procedure followed the mine's standard testing protocol, designed to replicate operational conditions as closely as possible. Figure 2 provides a detailed schematic of the procedure employed during the tests.

The flotation tests aimed to evaluate the effect of different depressants (sodium metabisulfite and quebracho) on flotation performance during the lead rougher stage. Each test followed the mine's standard flotation protocol, with variations in depressant type and dosage. Table 4 consolidates the depressant dosages and key operational parameters for both lead (Pb) and zinc (Zn) flotation circuits.

3 Results

The feed grade results from flotation tests using metabisulfite (MBS) are presented in Table 5. The Zn, Pb, and Fe contents show slight variations across the tests, which can be attributed to the differences in ore characteristics for each sample used in the flotation trials. Despite these fluctuations, Zn content remained relatively stable, with a mean of 2.238% and a low (CV) of 1.66%. In contrast, Pb

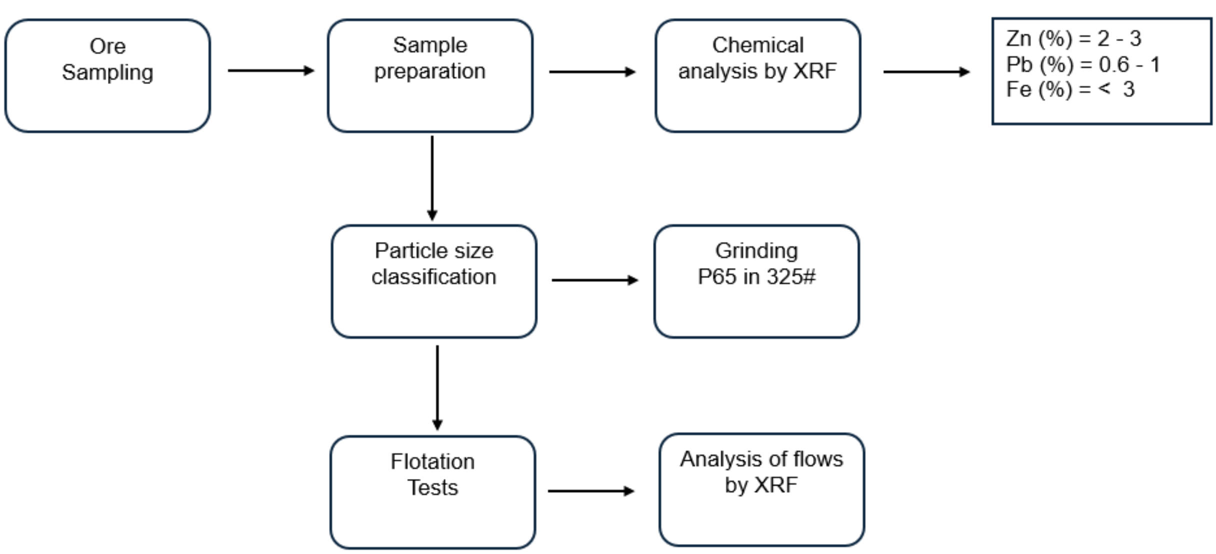

Figure 1. Flowchart of the Mineralogical and Particle Size Characterization Tests.

Table 2. Specifications for the grades of concentrates, final tailings, and recovery of Zn and Pb

Flow	Zn (%)	Pb (%)	Fe (%)
Pb concentrate	-	≥ 48	-
Zn concentrate	≥ 38	-	< 3
Final tailings	< 0.200	< 0.100	-
Pb recovery		≥ 70	-
Zn recovery	≥ 87	-	-

Table 3. Flotation Test Reagents

Reagent	Supplier	Function	Concentration (%)
Potassium Amyl Xanthate	Interfusion	collector	1
Copper Sulfate	*Nexa* (JF)	activator	2
Lime	*Lhoist*	pH regulator	5
MBS	Interfusão	depressant	15
Quebracho	*Nexa* (Peru)	depressant	20
MIBC	Interfusion	frother	100

Table 4. Bench Flotation Tests: Depressants, Dosages, and Operational Parameters

Steps	Rotation (rpm)	Cond. Time (min.)	Flotation Time (min.)	pH target	$CuSO_4$ (g/t)	PAX (g/t)	MBS (g/t)	Quebracho (g/t)	MIBC (g/t)
Cond. 1 Pb	1300	2 (PAX) 3 (MBS and Quebracho)	--	--	--	40	50/100/150/200	200	--
RGH Pb	1050	--	4	--	--	--	--	--	20
SCV Pb	1050	--	4	--	--	10	--	--	10
Cond. Zn 1	1200	5	--	9.5	200	--	--	--	--
Cond. Zn 2	1200	2	--	9.5	--	50	--	--	20
RGH Zn	1300	--	5	9.5	--	--	--	--	--
Cond. Zn 3	1300	2	--	9.5	--	60	--	--	20
SCV Zn	1300	--	7	9.5	--	--	--	--	--
CL	700	--	2	9.5	--	--	--	--	--

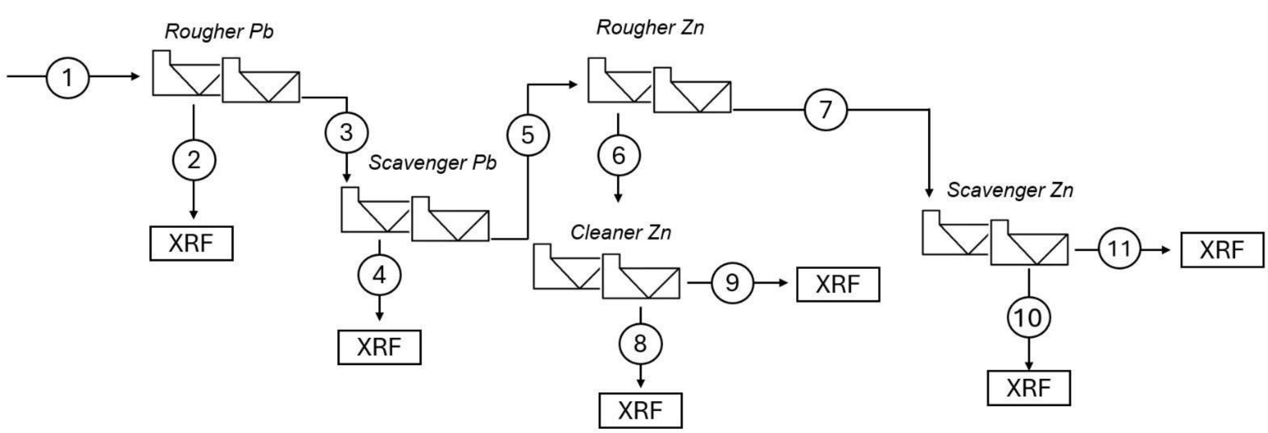

Figure 2. Flotation Test Flowchart. **Legend:** (1) Feed; (2) Pb Rougher Concentrate; (3) Pb Rougher Tailings; (4) Pb Scavenger Concentrate; (5) Pb Scavenger Tailings; (6) Zn Rougher Concentrate; (7) Zn Rougher Tailings; (8) Zn Cleaner Concentrate; (9) Zn Cleaner Tailings; (10) Zn Scavenger Concentrate; (11) Zn Scavenger Tailings. XRF – Chemical analysis via X-ray Fluorescence Spectroscopy.

content displayed greater variability, with a mean of 0.768% and a CV of 5.79%. Fe content exhibited moderate variability, with a mean of 5.718% and a CV of 3.13%. These differences highlight the inherent variability in the ore body, which can influence flotation performance.

3.1 Galena flotation

In the galena flotation, the highest Pb recovery was achieved with a dosage of 200 g/t of sodium metabisulfite (MBS) in the Pb rougher stage, as illustrated in Figure 3. While the Pb

Table 5. Feed grade results from flotation tests with sodium metabisulfite MBS

Tests	Zn (%)	Pb (%)	Fe (%)
Test 1	2.19	0.74	5.69
Test 2	2.27	0.73	5.45
Test 3	2.29	0.78	5.64
Test 4	2.21	0.85	5.98
Test 5	2.23	0.74	5.83

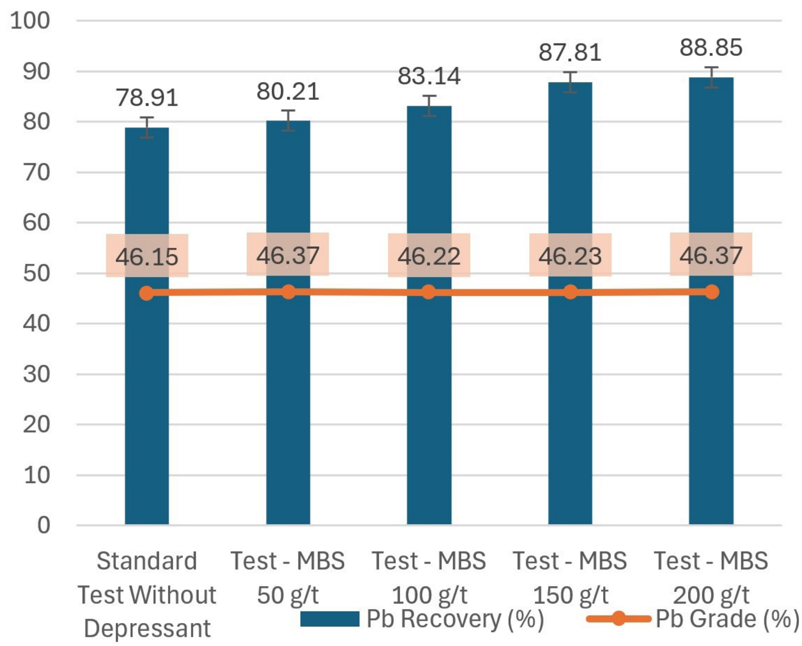

Figure 3. Pb Recovery and grade in the Pb concentrate as a function of MBS dosage in the Pb rougher stage.

grade in the concentrate remained relatively constant across the tests, significant variations were observed in Pb recovery.

By improving Pb recovery in the galena flotation stage, the use of MBS reduced the carryover of galena particles into the sphalerite flotation circuit. This is evident in Figure 4, which shows a reduction in Pb recovery within the sphalerite stage. This outcome is critical, as it minimizes the contamination of sphalerite concentrates by galena, thereby enhancing the selectivity and efficiency of the subsequent flotation steps.

The use of MBS proved advantageous for the overall flotation process by simultaneously increasing Pb and Zn recovery while inhibiting pyrite particle collection. This aligns with findings from previous research [12], which reported improved lead recovery using sodium hexametaphosphate as a dispersant. However, unlike sodium hexametaphosphate, MBS does not compromise the lead concentrate grade or cause significant zinc losses in the lead concentrate

3.2 Sphalerite flotation

The application of sodium metabisulfite (MBS) demonstrated a significant impact on the sphalerite flotation process. As shown in Figure 5, the use of MBS resulted in increased Zn recovery and an improved Zn grade in the final concentrate.

In the highest dosage test (200 g/t), the Zn concentrate exhibited a Fe grade of 2.89%, which is lower than the Fe grade observed in test 1 (3.45%). This reduction in Fe contamination indicates that MBS effectively depresses pyrite, improving the selectivity of the flotation process and contributing to a higher-quality Zn concentrate.

Additionally, the results align with previous findings, where zinc recovery in 2022 was reported at 71.7% [13]. The use of MBS in the current tests surpassed this benchmark, further demonstrating its effectiveness. By inhibiting pyrite collection, MBS not only improved Zn recovery but also optimized the flotation circuit by minimizing contamination from gangue minerals.

3.3 Flotation test with quebracho

The use of quebracho as a depressant in flotation tests resulted in improved recovery for both Pb and Zn, with distinct effects on each metal. In case of Pb recovery, quebracho increased recovery in the flotation stage compared to the test without a depressant (Figure 6). However, the Pb grade in the final concentrate was higher in the test without the depressant.

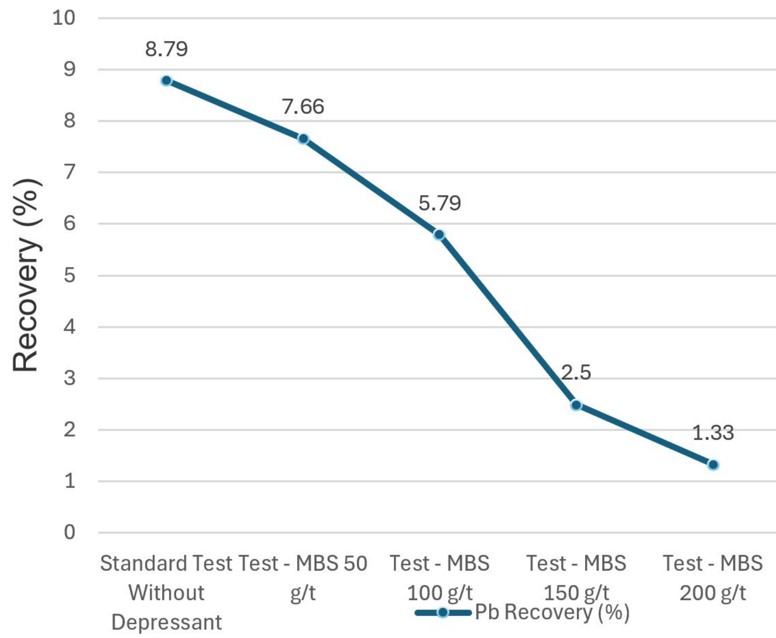

Figure 4. Pb recovery in sphalerite flotation stage as a function of MBS dosage.

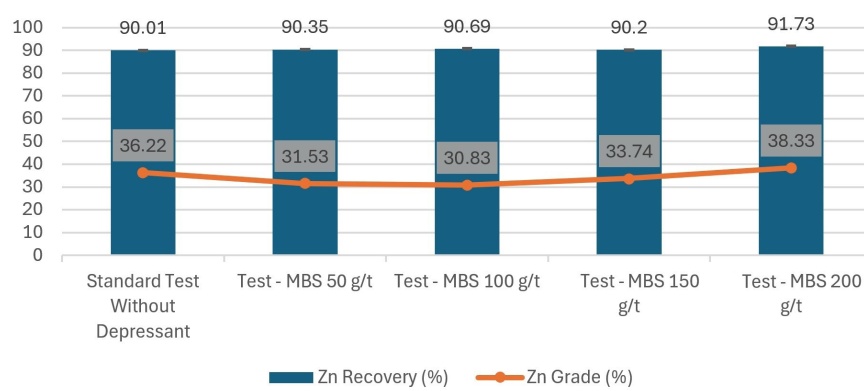

Figure 5. Zn content and recovery in the Zn concentrate as a function of MBS dosage in the sphalerite flotation stage.

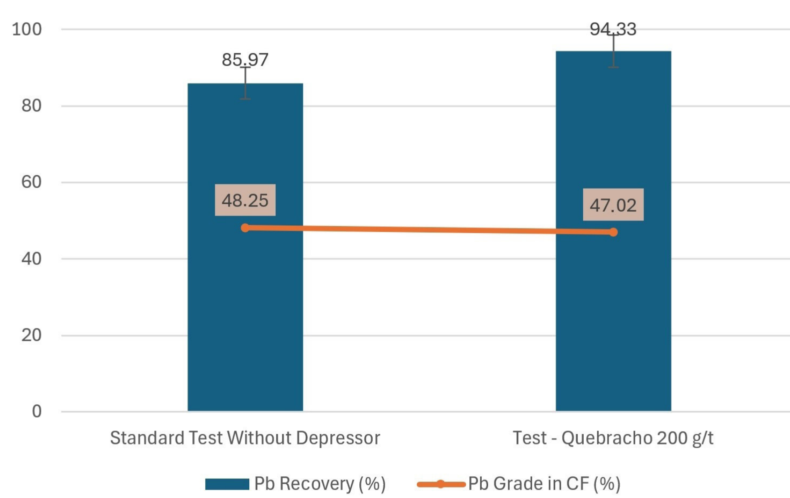

Figure 6. Pb recovery and grade in Pb concentrate with and without the use of quebracho as a depressant.

In contrast, the Zn flotation (Figure 7), the use of quebracho significantly increased Zn recovery and improved the Zn grade in the final concentrate, with a decrease in the Fe content (1.17%) compared to the test without the depressant. This highlights quebracho's effectiveness in improving the purity of the Zn concentrate by reducing pyrite contamination.

When comparing the performance of quebracho and MBS, quebracho showed a higher Pb recovery (94.33%) compared to MBS (88.85%). For Zn, both depressants improved recovery, with MBS achieving a slightly higher recovery (91.73% versus 90.21%). However, quebracho demonstrated higher purity in the Zn concentrate, reducing the Fe content to 1.17%, while MBS reached 2.89%.

3.4 Analysis of final tailings from the tests

The analysis of the final tailings revealed significant improvements in the control of zinc (Zn) and lead (Pb) losses when using depressants such as sodium metabisulfite (MBS) and quebracho.

Among the tests conducted with MBS, higher dosages consistently resulted in reduced Zn and Pb grades in the tailings. The lowest grades were observed in the test with 200 g/t of MBS, yielding 0.185% Zn and 0.078% Pb, both below the upper specification limits (<0.200% Zn and <0.100% Pb). Similarly, the use of quebracho as a depressant led to a noticeable decrease in Zn and Pb grades in the final tailings, achieving 0.184% Zn and 0.031% Pb at the same dosage. These results highlight the effectiveness of both depressants in improving the flotation circuit's selectivity and minimizing valuable metal losses. While MBS demonstrated consistent performance across varying dosages, quebracho achieved the lowest Pb grade in the tailings. The following figures (Figures 8 and 9) show the lead and zinc contents in the final tailings.

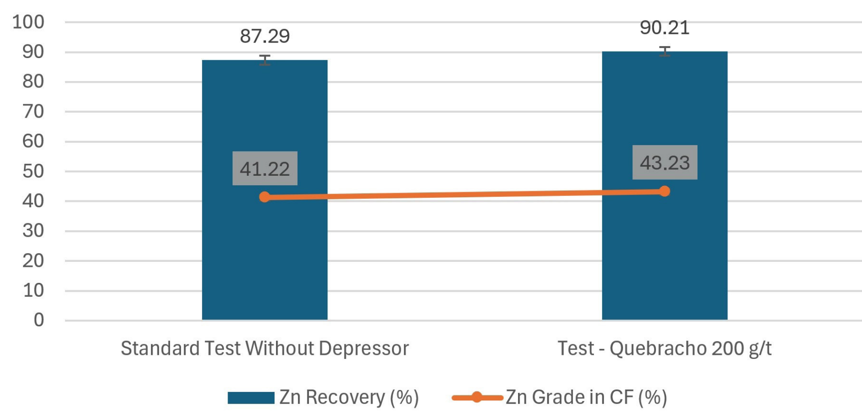

Figure 7. Zn recovery and grade in Zn concentrate with and without the use of quebracho as a depressant.

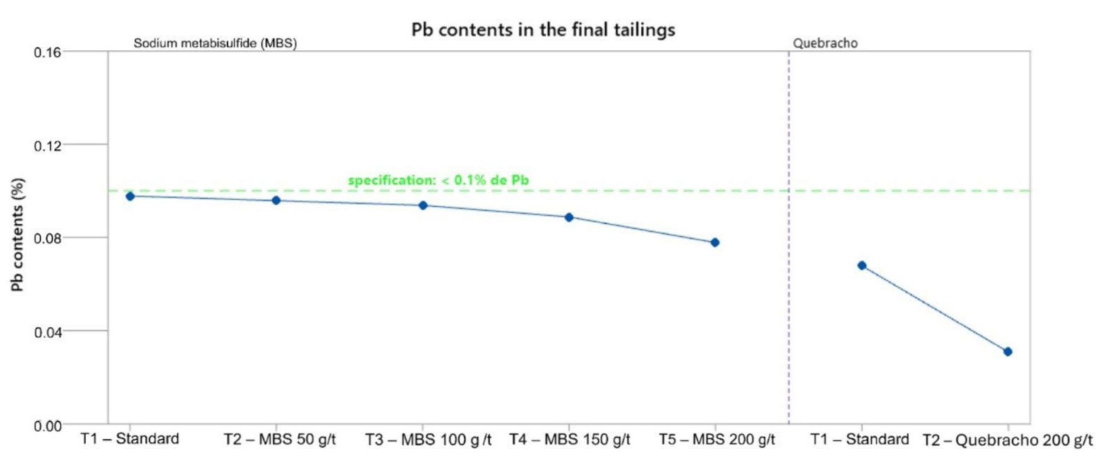

Figure 8. Pb grades in the final tailings as a function of MBS and quebracho dosages.

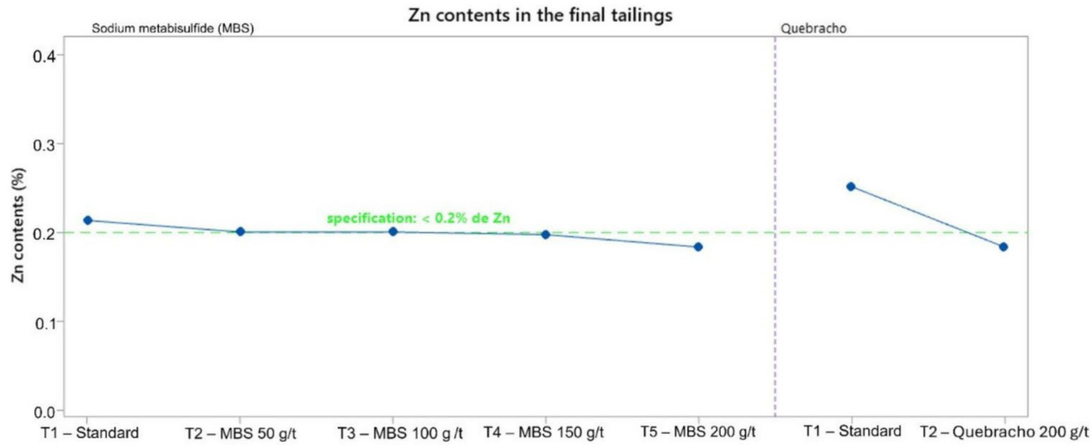

Figure 9. Zn grades in the final tailings as a function of MBS and quebracho dosages.

4 Conclusions

This study evaluated the effects of two depressants, sodium metabisulfite (MBS) and quebracho, on the flotation performance of an ore containing lead (Pb), zinc (Zn), and pyrite (FeS_2). Both depressants effectively enhanced metal recovery and improved process selectivity, significantly reducing Zn and Pb grades in the final tailings.

At a dosage of 200 g/t, MBS achieved a Pb recovery of 88.85% and a Zn recovery of 91.73%, with Zn (0.185%) and Pb (0.078%) grades in the tailings meeting specification limits (<0.200% Zn and <0.100% Pb). However, MBS did not significantly improve Pb grade in the concentrate, highlighting limitations in selectivity. In contrast, quebracho increased Pb recovery to 94.33% and Zn recovery to 90.21%, but reduced the Pb grade in the concentrate by 1.23%. The final tailings for quebracho had Zn and Pb grades of 0.184% and 0.031%, respectively, further emphasizing its effectiveness in reducing metal losses.

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