Influence of Sodium Hexametaphosphate as Dispersant on Amazonian Bauxite Flotation

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https://doi.org/10.71659/icsoba2024-bx005

Abstract

The production of alumina is a crucial process in the aluminum industry since primary metallic aluminum is obtained from alumina. Among the various methods for producing alumina, the Bayer process is the most commonly used. Bauxite, the main ore for alumina production, typically contains gibbsite as the main mineral in Amazonian bauxite in Brazil. In general, Amazonian bauxite has iron and titanium oxides, as well as clay minerals like kaolinite (source of reactive silica). The presence of silica is a common and significant problem in the bauxite and alumina industry due to kaolinite, quartz, and other silicates present in various types of bauxite. In the Bayer process, reactive silica reacts with sodium hydroxide (NaOH), forming the sodalite increasing the alumina production costs and waste generation at the refinery. The purpose of this work was to evaluate the influence of sodium hexametaphosphate as a dispersant to enhance flotation selectivity in the reverse flotation of an Amazonian bauxite, aiming to improve its chemical quality. Bench flotation tests were performed at natural pH (~ 7) with a constant collector dose of 200 g/t of Flotinor 16939 and a variable sodium hexametaphosphate dosage as pulp dispersant (0, 250, 500, 750 and 1000 g/t). The presence of 250 g/t of sodium hexametaphosphate reduced the reactive silica content in flotation concentrate approximately 6 percentage points compared to baseline (without dispersant), from 38% to 32%. The best flotation scenario tested (200 g/t of collector and 250 g/t of dispersant) had alumina recovery of 73 % eliminating 68 % of reactive silica content. It has potential to reduce approximately 60 kg of caustic soda consumption per ton of bauxite processed in the Bayer Process. Two adsorption mechanisms can explain the research results. At a dosage of 250 g/t of dispersant (best effect of silica reduction), greater dispersion of the flotation pulp may have occurred, increasing the selectivity of flotation (better adsorption of the collector on the kaolinite surface). At dosages higher than 250 g/t, there was a decrease in the potential for reducing the reactive silica content. This may be related to the depressive effect of sodium hexametaphosphate on kaolinite, reducing its flotation. Sodium hexametaphosphate can improve the selectivity of bauxite flotation.

Keywords: Bauxite, Flotation, Reactive Silica, Sodium Hexametaphosphate, Dispersant.

1. Introduction

The production of alumina is a crucial process in the aluminum industry since primary metallic aluminum is obtained from alumina. Among the various methods for producing alumina, the Bayer process is the most commonly used. Bauxite, the main ore for alumina production, typically contains gibbsite as the main mineral in Amazonian bauxite in Brazil. In general, Amazonian bauxite contains iron and titanium oxides, as well as clay minerals such as kaolinite [1,2].

A common and significant problem in the bauxite and alumina industry is the presence of silica minerals including kaolinite, quartz, and other silicates in various types of bauxite. In the Bayer process, kaolinite reacts with sodium hydroxide (NaOH), forming sodalite, increasing the alumina production costs and waste generation at the refinery [3, 4].

Flotation is a mineral beneficiation technique that exploit the differences of minerals surface properties to promote the separation between minerals phases present into the pulp. The flotation route can be direct (floating the main mineral) or reverse (floating the gangue minerals) [5, 6,].

Lot et al. (2019) evaluated a cationic collector (Flotinor 5530) to promote a Brazilian low-grade bauxite beneficiation at bench-scale. Tests were performed at pH 10 in the presence of 800 g/t of starch as gibbsite depressant varying the collector dosage between 100 and 200 g/t. In the presence of 800 g/t of starch and 200 g/t of Flotinor 5530 it was possible to reduce the reactive silica content in 20 % with 93 % of metallurgical recovery. The bauxite had high slime content around 25 %.

Duarte et al. (2023) evaluated an amide-amine (Flotinor 16939) as kaolinite collector to promote an Amazonian bauxite beneficiation at bench-scale. The highest re. silica reduction was under 400 g/t of collector dosage with av. alumina recovery of 73.5 %, eliminating 47 % of re. silica content. The time of flotation was 2 minutes.

The purpose of this work was to evaluate the influence of sodium hexametaphosphate as a dispersant to enhance flotation selectivity in the reverse flotation of an Amazonian bauxite, aiming to improve its chemical quality.

2. Materials and Methods

2.1 Ore

To perform the bench flotation tests, a sample of bauxite from Hydro Paragominas was used. The sample was similar to the sample used by Duarte et. al. (2023).

2.2 Reagents

Flotinor 16939 (amide-amine) was used as kaolinite collector and sodium hexametaphosphate as dispersant.

2.3 Methodology

The sampling process yielded a global sample of approximately 15 liters, containing around 61 % solids by weight. This global sample underwent filtration, followed by drying in an oven at 105 °C, homogenization, dry disaggregation, and quartering. Twenty aliquots each weighing approximately 1 kg were then generated from this processed sample for ore characterization and flotation tests.

2.3.1 Particle-size distribution

The Particle-size distribution was made by wet sieving (> 400#) and laser diffraction (< 400#).

2.3.2 Chemical analysis

The samples were subjected to analysis for reactive silica and available alumina grades. Both the overflow and underflow from each condition tested were analyzed to conduct the metallurgical balance.

2.3.3 Bench flotation tests

The flotation tests conducted were of the reverse type, specifically targeting kaolinite flotation. These tests were carried out at the natural pH level of around 7, with a solid concentration of 35 % by weight during the conditioning phase and 20 % by weight during the flotation phase. Conditioning involved a 5-minute period for dispersant addition and a subsequent 3-minute period for collector addition. The flotation process itself lasted for 4 minutes. Airflow was maintained at 8 liters per minute, and the rotation speed was set at 700 revolutions per minute (rpm).

All tests were performed in duplicate to ensure consistency. The collector dosage remained constant at 200 grams per ton (g/t) across all tests, while the dispersant dosage levels varied at 0, 250, 500, 750, and 1000 g/t. The experiments were conducted using a FLOTLAB model bench cell from Brastorno, utilizing a 1.5-liter acrylic vessel (the same equipment used by Duarte et. al. (2023).

3. Results and discussion

3.1 Sample characterization

3.1.1 Particle-size distribution

Figure 1 shows the particle-size distribution of the flotation feed, with a P_{88} of 212 µm. About 9 % of the particles measure below 10 µm. This particle-size distribution is deemed suitable for flotation employing cells, the equipment utilized in the tests. The slime content, referring to particles below 10 µm, was not regarded as significant. However, it's essential to note that controlling slime content is crucial in the flotation process due to its impact on reagent consumption and the occurrence of "slime-coating" phenomena. The amount of slime in the sample may influence the dispersant dosage required for the system [5, 6].

Comparing with the sample used by Duarte et al. (2023), which had a P_{85} value at 212 µm and 6 % passing below 10 µm, the samples appeared to be quite similar.

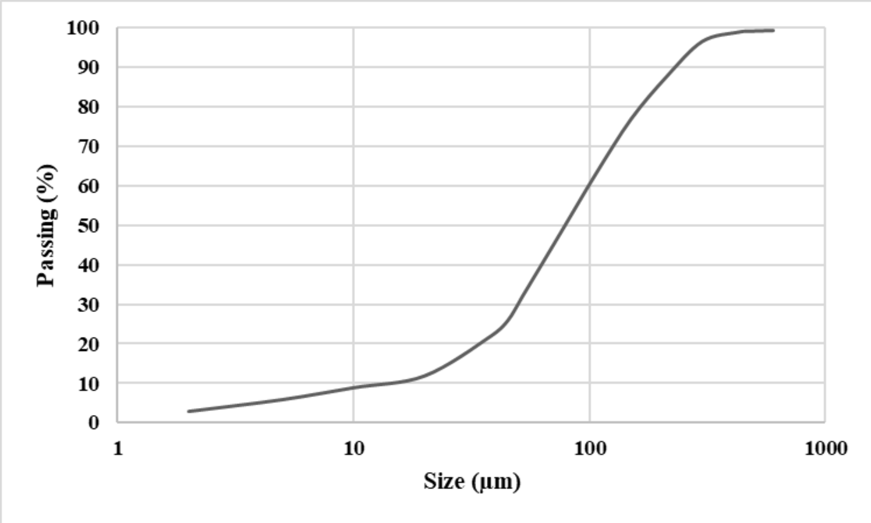

Figure 1. Particle-size distribution of the flotation feed.

3.1.2 Chemical analysis

Table 1 presents the results of the chemical analysis of the flotation feed. In terms of chemical composition, the sample used in the test closely resembled the sample used by Duarte et al. (2023). The authors' sample had an available alumina grade of 42.3 % and a reactive silica grade of 6.1 %.

Table 1. Chemical composition of the flotation feed, %.

Sample	Available alumina (%)	Reactive. Silica (%)
Flotation Feed	41.8	6.3

3.2 Bench flotation tests

A statistical analysis was conducted on the results of mass recovery and metallurgical recovery for each tested condition. The coefficient of variation was less than 1.5 %. Figure 2 presents the mass recovery obtained in the absence and presence of sodium hexametaphosphate as a dispersant. As can be seen, the presence of sodium hexametaphosphate reduced mass recovery by approximately 4 percentage points. The reduction in mass recovery may be related to the higher level of pulp dispersion, reducing the effect of slime coating when ultrafine particles coat coarse particles, hindering their flotation. Since the flotation is of the reverse type, increasing the flotation causes a reduction in mass recovery. Variation in dispersant dosage did not cause a significant effect in terms of mass recovery.

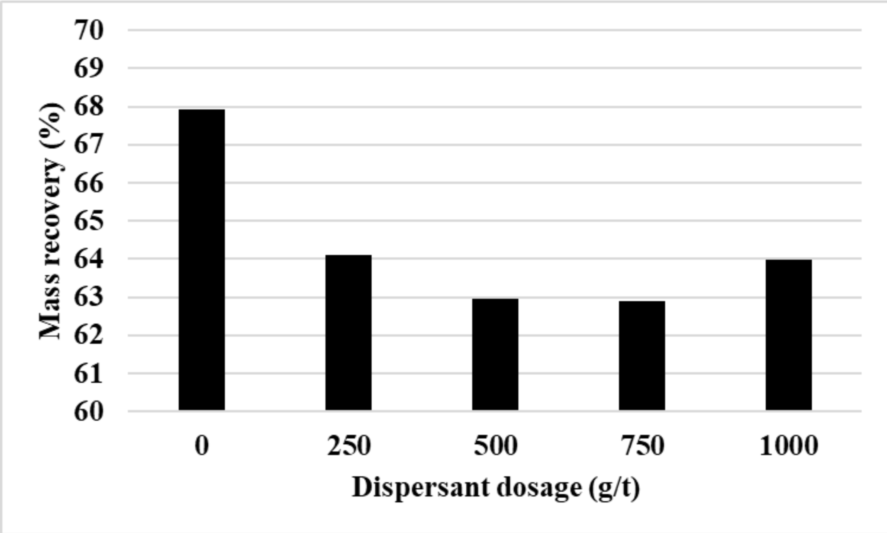

Figure 2. Mass recovery as function of the dispersant dosage.

Figure 3 shows the metallurgical recovery of available alumina in the absence and presence of the dispersant. As can be seen, the presence of the dispersant reduced metallurgical recovery by approximately 3.5 percentage points. Variation in dispersant dosage did not have a significant effect on the metallurgical recovery of usable alumina. This may be related to a higher level of dispersion of gibbsite (source of available alumina), favoring its entrainment to the froth, reducing its recovery to the concentrate.

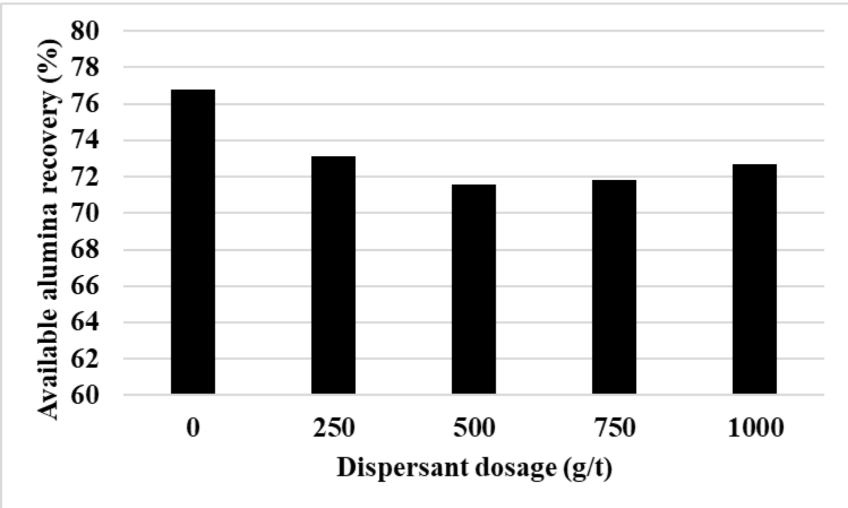

Figure 3. Available alumina recovery as function of the dispersant dosage.

Figure 4 shows the reduction of reactive silica content as a function of dispersant dosage. In the absence of the dispersant, it was possible to reduce the reactive silica content by approximately 62 %. A dosage of 250 g/t exhibited the best silica reduction effect, increasing the reduction to approximately 68 % (it may be related due to the higher dispersion on the pulp increasing the flotation selectivity enhancing the collector adsorption onto kaolinite surface). At dosages higher than 250 g/t, there was a decrease in the potential to reduce the reactive silica content. This may be related to a depressing effect of sodium hexametaphosphate onto kaolinite, reducing its flotation. Chen et al. (2005) and Rodrigues (2012) evaluated the depressing effect of sodium hexametaphosphate on the floatability of kaolinite. Both authors found that sodium hexametaphosphate reduced the floatability of kaolinite. Chen et al. (2005) conducted adsorption tests and Fourier transform infrared spectroscopy to evaluate the adsorption of sodium hexametaphosphate on the surface of kaolinite. The authors found that sodium hexametaphosphate preferentially adsorbs at Al – O sites on the surface of kaolinite. Additionally, the authors observed that the floatability of kaolinite decreased from approximately 80 % to 45 % in the presence of sodium hexametaphosphate at pH 7. There might be an optimal dispersant dosage to be explored between 0 and 500 g/t focus on benefits vs dispersant consumption. Additional testing will be necessary to evaluate the optimal dosage of sodium hexametaphosphate.

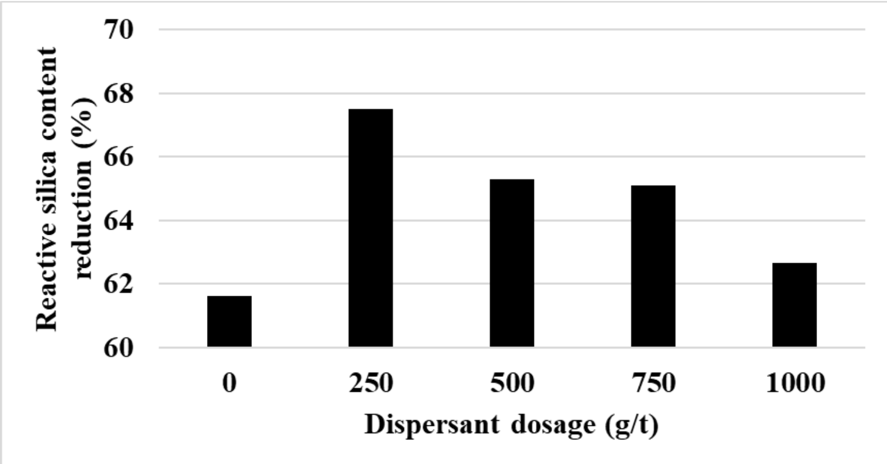

Figure 4. Reactive silica content reduction as function of the dispersant dosage

Figure 5 shows the metallurgical balance of the best scenario for reducing reactive silica content (200 g/t of collector and 250 g/t of dispersant). As can be seen, it was possible to increase the available alumina grade by approximately 6 percentage points (from 41.8 to 47.7) and reduce the reactive silica grade by approximately 3 percentage points (from 6.3 to 3.2). The metallurgical recovery of available alumina was 73 %. The Al/Si ratio increased from 6.6 to 14.9. Smith (2009) states that the Al/Si ratio in bauxite needs to be at least 10 for the bauxite to be processed via the Bayer process in an economically viable manner. During digestion, every tonne of silica dissolved from bauxite consumes approximately 1.2 tonnes of soda in the sodalite formation. Bauxites with reactive silica content exceeding about 5 % are generally deemed uneconomical to process using the conventional Bayer process due to excessive soda losses [11]. It is estimated that a 1 percentage point reduction in the reactive silica grade has the potential to reduce 20 kg of caustic soda per tonne of alumina produced. Considering the flotation scenario presented has potential to reduce approximately 60 kg in the consumption of caustic soda per tonne of alumina to be produced in the refinery.

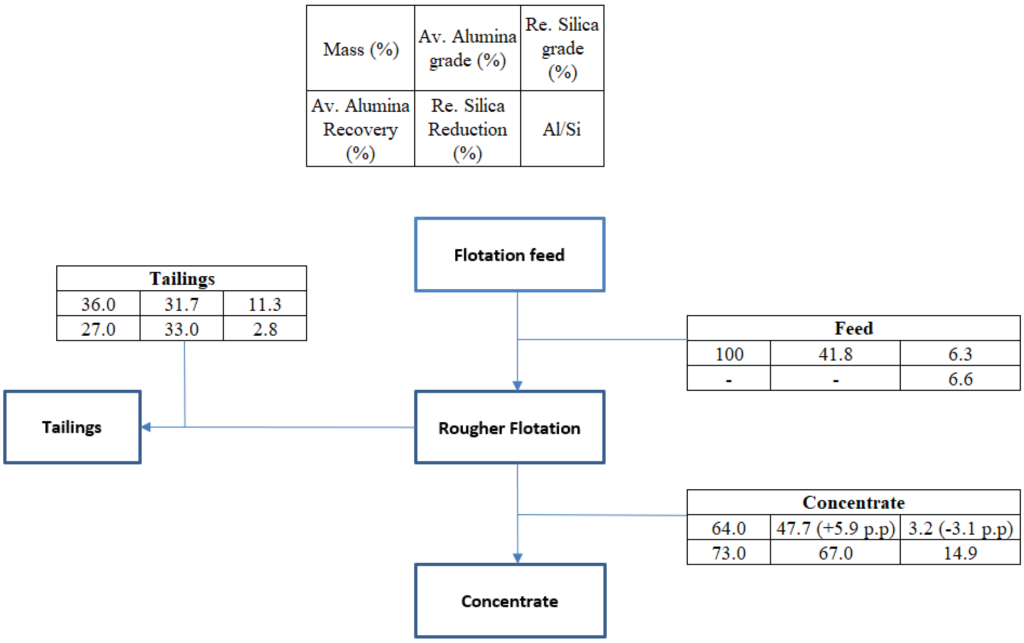

Figure 5. Metallurgical balance of the test with higher re. silica content reduction under 200 g/t of Flotinor 16939 and 250 g/t of sodium hexametaphosphate.

4. Conclusion

The presence of sodium hexametaphosphate reduced the mass recovery compared to the baseline by approximately 4 percentage points, from 68 % to 64 %.

The presence of sodium hexametaphosphate reduced the metallurgical recovery of usable alumina by 3.5 percentage points, from 76.5 % to 73 %.

The presence of 250 g/t of sodium hexametaphosphate increased the reactive silica reduction approximately 6 percentage points, from 61 % to 67 %.

The highest reactive silica reduction was with 200 g/t of Flotinor 16939 and 250 g/t of sodium hexametaphosphate with alumina recovery of 73 %, eliminating 67 % of reactive silica content. This resulted in an enhancement of the available alumina grade from 41.8 % to 47.7 % and a reduction in the reactive silica grade from 6.3 % to 3.2 %.

In all tested conditions the alumina/silica relation in flotation concentrate was greater than 10. The best flotation scenario under 200 g/t of collector and 250 g/t of dispersant has potential to reduce 60 kg on caustic consumption per alumina tonne produced in the refinery.

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