BX02 – Reactive Silica Reduction on Bauxite by Flotation

Geraldo Magela Pereira Duarte[1], Allan Suhett Reis[2], Otávia Martins Silva Rodrigues[3], Paulo Sérgio Rueda Criscoulo[4], Geovan Damásio[5], Eslyn Neves[6], Cácio Silva[7] and José Erik Nunes de Araújo[8]
1. Senior R&D Specialist
2. R&D Consultant
Norsk Hydro Brasil, Paragominas, Brazil
3. Professor at Federal University of Ouro Preto, Ouro Preto, Brazil
4. Senior Engineer
5. Senior Engineer
6. Process Manager
7. Senior Technical Manager
Hydro Paragominas, Paragominas, Brazil
8. Senior R&D Manager at Norsk Hydro Brasil, Belém, Brazil
Corresponding author: geraldo.duarte@hydro.com

Abstract

Bauxite is the main ore used in the production of alumina. Amazonian bauxite has gibbsite (source of available alumina) as main mineral, and is commonly associated with iron and titanium oxides, in addition to clay minerals such as kaolinite (source of reactive silica). The presence of silica is a common and significant problem in the bauxite and alumina industry, due to the kaolinite, quartz, and other silicates present in bauxite. Reactive silica (RS) reacts with sodium hydroxide (NaOH) in the Bayer process, consuming it in the precipitation of the desilication product (DSP). This increases alumina production costs and residue generation at the refinery. The purpose of this work was to evaluate the reduction of the kaolinite content in an Amazonian bauxite via reverse flotation using an amide-amine (Flotinor 16939) as a kaolinite collector. Bench flotation tests were performed at natural pH (~ 7) varying the collector dosage at 100, 200, 300 and 400 g/t. In all evaluated conditions, there was a decrease and increase, respectively, in the contents of RS and available alumina (AA) in the concentrate. It was possible to promote the selective separation between gibbsite and kaolinite by flotation at natural pH using the Flotinor 16939. The collector was considered efficient to reduce the kaolinite content in the tested Amazonian bauxite. The highest kaolinite removal was at the collector dosage of 400 g/t with metallurgical recovery of AA of approximately 73.5 %, eliminating 47 % of the kaolinite content. The Al/Si ratio in the concentrate was 11.3 (the Al/Si ratio in flotation feed was 6.8).

Keywords: Bauxite, Flotation, Reactive Silica, Available Alumina.

1. Introduction

The production of alumina is an important process in the aluminum industry, as primary metallic aluminum is obtained from alumina. There are different methods for producing alumina, the Bayer process being the most commonly used [1].

Bauxite is the main ore used in the production of alumina. Amazonian bauxite has gibbsite as main mineral and it is commonly associated with iron and titanium oxides, in addition to clay minerals such as kaolinite [2].

The presence of silica is a common and significant problem in the bauxite and alumina industry, due to the kaolinite, quartz, and other silicates present in different types of bauxite. In the Bayer process, kaolinite reacts with sodium hydroxide (NaOH) consuming it in the precipitation of the desilication product (DSP). This increases alumina production costs and waste generation at the refinery [3].

It is important to emphasize that the production of alumina generates residues. The refinery residue contains impurities and by-products of the Bayer process, such as silica, iron, and titanium oxides, which need to be properly treated and managed to minimize environmental impacts. The higher the RS content, the greater the residue generation in the refinery [1, 4]. Flotation can be a solution to concentrate bauxite and favor the Bayer process with a more adequate feed.

Flotation is a mineral concentration process that aims to selectively separate two or more mineral phases by exploiting differences in their surface properties. There are two types of flotation, direct and reverse. In direct flotation, the collector adsorbs on the surface of the main mineral and it is reported to the foam, while the gangue minerals are suppressed at the bottom of the equipment. In reverse flotation, the collector adsorbs onto gangue minerals surface, removing them through the foam, while the main mineral is suppressed to the bottom of the equipment [5, 6, 7].

Lot et. al. (2019) evaluated the use of an amide-amine (Flotinor 5530) to reduce the RS content in a Brazilian bauxite via reverse flotation. Tests were performed at pH 10 in the presence of 800 g/t of starch (gibbsite depressant), varying the collector dosage between 100 and 200 g/t.

The purpose of this work was to evaluate the reverse flotation in Amazonian Bauxite beneficiation to improve its chemical quality (decreases reactive silica grade and increases the available alumina grade).

2. Materials and Methods

2.1 Ore

To perform the bench flotation tests, a sample of Amazonian bauxite from Hydro Paragominas, was used. The sample was collected at the processing plant.

2.2 Reagents

Flotinor 16939 (amide-amine) was used as kaolinite collector. The reagent was supplied by Clariant Brasil and prepared in a 0.5 % w/v solution. Flotinor 16939 is used in silicates reverse flotation in iron ore industry.

2.3 Methodology

Sampling generated a global sample of approximately 40 kg. This sample was filtered, dried in an oven at 105 °C, homogenized, and quartered. 20 aliquots of approximately 1 kg were generated to perform the ore characterization and flotation tests. The rest of the sample was archived. To perform the ore characterization, three aliquots were randomly selected.

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

Contents of Reactive Silica (RS) and Available Alumina (AA) were obtained by digestion, volumetry, and atomic absorption. Iron and titanium oxides were obtained by X-ray fluorescence spectrometry. The overflow and underflow of each condition tested were analyzed to perform the metallurgical balance.

2.3.3 Bench Flotation Tests

The flotation tested was the reverse type (kaolinite flotation). Flotation tests were conducted at natural pH (~7) with 50 % solids by weight in the conditioning step and 20 % solids by weight in the flotation step. The conditioning and flotation time were 3 and 2 minutes, respectively. The air flow was 8 L/min, and the rotation was 700 rpm. The tests were done in duplicate and the following collector dosages were tested: 100, 200, 300, and 400 g/t. The tests were performed in a FLOTLAB model bench cell from Brastorno using a 1L acrylic vat. Figure 1 shows the equipment used in the bench tests.

Figure 1. Equipment used in bench scale tests.

3. Results and Discussion

3.1 Sample Characterization

3.1.1 Particle-Size Distribution

Figure 2 shows the particle-size distribution of the characterized aliquots (flotation feed). As can be seen, the three curves overlapped, indicating good homogenization and quartering, thus ensuring good representativeness of the samples. The P_{80} is 212 µm. Approximately 6 % of the particles are below 10 µm. This particle-size distribution is considered compatible for flotation using cells (equipment used in the tests). The slime content (particles below 10µm) was not considered significant. The slime content is an important control factor in flotation, the higher the percentage of slime, the greater the consumption of reagents (high surface area of the particles). In addition, the chances of a phenomenon known as "slime coating" increase, when fine particles cover coarse particles, preventing the adsorption of the collector [5, 6].

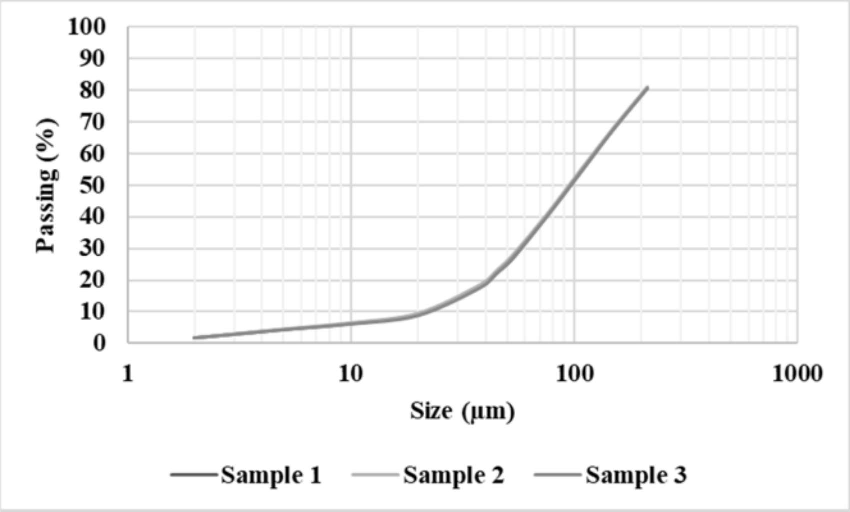


Figure 2. Particle-size distribution of the flotation feed.

3.1.2 Chemical Analysis

Table 1 presents the result of the chemical analysis of the characterized aliquots. As can be seen, there was no significant deviation between the results (alpha = 0.05) demonstrating good representativeness of the samples used in the flotation tests. The bauxite sample used in the tests had approximately 42.3 % AA and 6.1 % RS.

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

Sample	AA	RS	Al_2O_3	Fe_2O_3	SiO_2	TiO_2
1	42.3	6.2	49.9	12.9	7.6	3.6
2	42.4	5.9	49.8	12.8	7.5	3.6
3	42.1	6.2	49.8	12.8	7.6	3.6
Average	**42.3**	**6.1**	**49.8**	**12.8**	**7.6**	**3.6**
Standard deviation	0.1159	0.2107	0.0472	0.020	0.0378	0.0230
Relative standard deviation (%)	0.2	2.8	0.1	0.1	0.4	0.5

3.2 Bench Flotation Tests

Figure 3 shows the recovery of AA as a function of collector dosage. It is possible to see that the metallurgical recovery decreases with increasing collector dosage. Comparing the minimum and maximum dosage, 100 and 400 g/t, the drop in metallurgical recovery was approximately 10.0 percentage points (84.0 to 74.0 %). This drop in recovery may be related to the higher concentration of the collector in the flotation pulp, increasing the chances of adsorption on the surface of the gibbsite (source of AA), promoting its flotation, and consequently reducing the concentrate metallurgical recovery. Szewczuk-Karpisz, et. al. (2018) evaluated the zeta potential of a gibbsite as a function of pH. The isoelectric point (IEP) was between 6 and 8. Zeta potential, adsorption and Fourier-transform Infrared Spectroscopy tests would be required to evaluate the collector adsorption onto gibbsite and kaolinite surfaces.

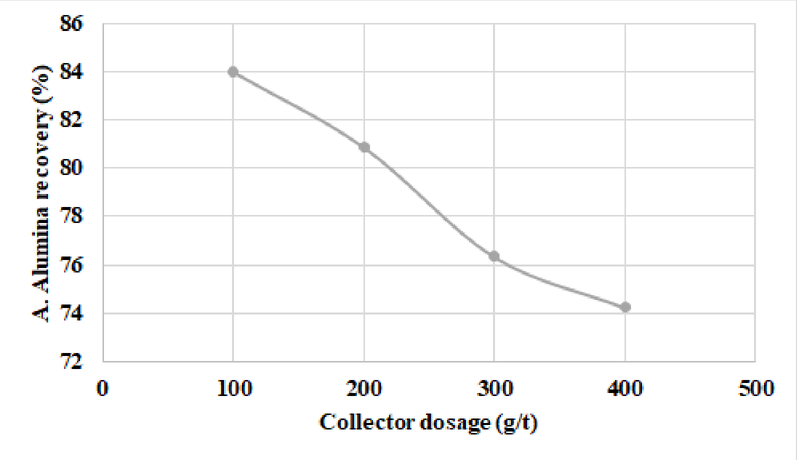


Figure 3. Metallurgical recovery of Available Alumina.

Figure 4 shows the metallurgical recovery of RS to the concentrate as a function of collector dosage. There is a drop in RS recovery with increasing collector dosage. As the flotation is of the reverse type, the lower contaminants recovery is beneficial to the result. The lower the recovery of RS and the higher the recovery of AA, the greater the selectivity during the separation between gibbsite and kaolinite. The increase in collector dosage promotes a higher concentration into flotation pulp, increasing the chances of adsorption onto kaolinite surface (source of RS). The variation in the metallurgical recovery of RS was 11.3 percentage points, 65.7 % (100 g/t) and 54.4 % (400 g/t).

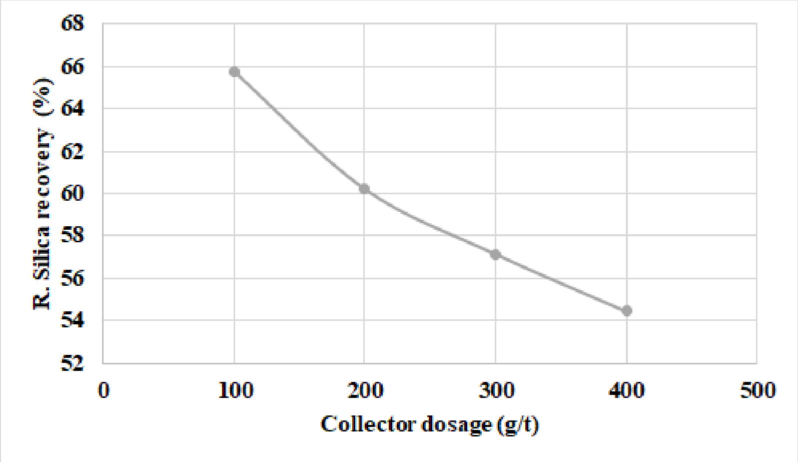


Figure 4. Metallurgical recovery of Reactive Silica.

Figure 5 shows the recoveries of AA and RS for concentrate and tailings, respectively. In the search for a balance between recovering gibbsite and removing kaolinite, it is believed that the optimal collector dosage is between 200 and 300 g/t. Using 200 g/t of collector it was possible to reduce approximately 40 % of kaolinite content, recovering 81 % of gibbsite content. At a dosage of 300 g/t it was possible to eliminate approximately 43 % of kaolinite content, recovering 76 % of gibbsite content. To improve the levels of gibbsite recovery and the chemical quality of the concentrate, other flotation steps (scavenger and cleaner) must be evaluated.

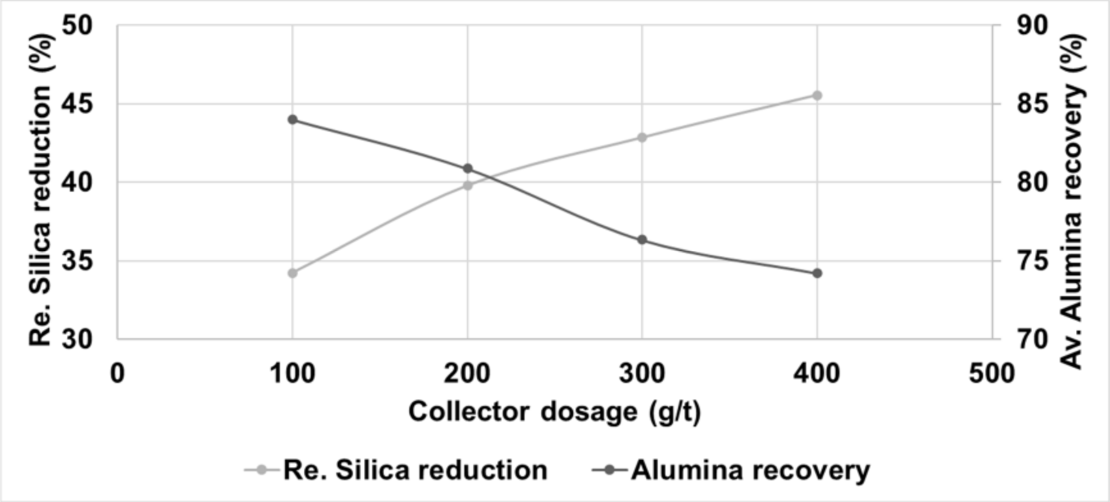
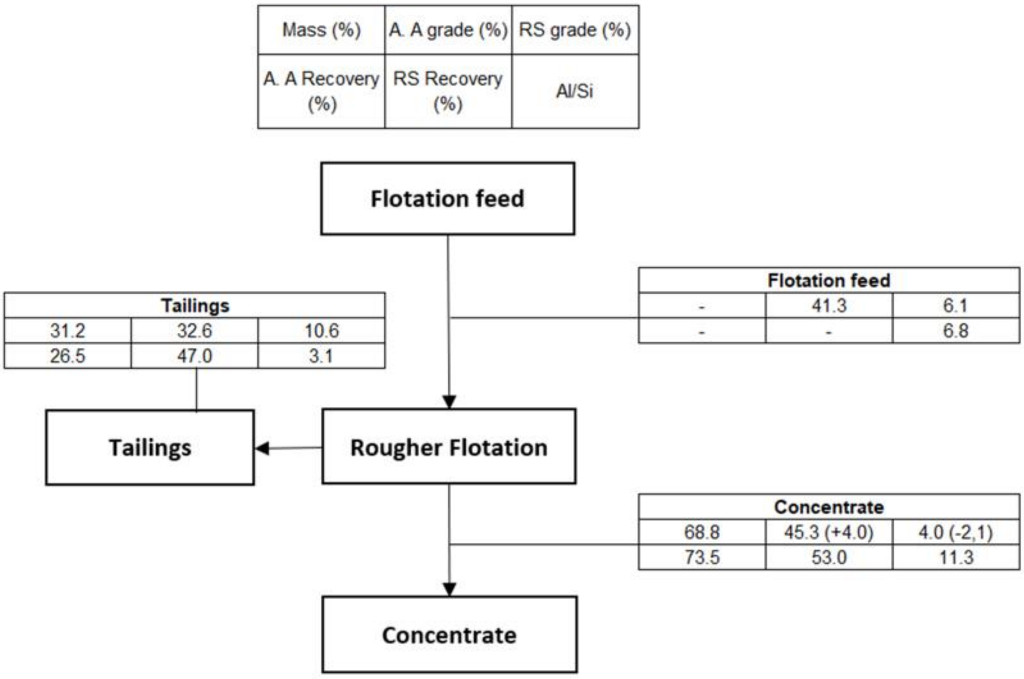


Figure 5. Recovery of AA and RS reduction for concentrate and tailings, respectively.

Figure 6 presents the mass and metallurgical balance of one of the tests performed using 400 g/t of collector. As it can be seen, after a single flotation step (rougher) it was possible to increase the AA content by 4 percentage points and decrease the RS content by 2.1 percentage points (6.0 to 4.0 %). It was possible to recover approximately 73.5 % of the gibbsite, eliminating 47 % of the kaolinite. The Al/Si ratio of the feed, which was 6.8, rose to 11.3 in the flotation concentrate. According to Yuehua et. at. (2004) and Smith (2009), bauxite must have an Al/Si ratio greater than 10 to be processed via Bayer in an economically viable way.



Mass (%)	A. A grade (%)	RS grade (%)
A. A Recovery (%)	RS Recovery (%)	Al/Si

Flotation feed		
-	41.3	6.1
-	-	6.8

Tailings		
31.2	32.6	10.6
26.5	47.0	3.1

Concentrate		
68.8	45.3 (+4.0)	4.0 (-2,1)
73.5	53.0	11.3

Figure 6. Metallurgical balance of the test with lower RS content obtained in the concentrate (400 g/t of collector).

4. Conclusion

In all tested conditions, there was a decrease and increase in reactive silica content and available alumina content, respectively.

The Flotinor 16939 collector was considered efficient in reducing the reactive silica content in the tested Amazonian bauxite.

In all tested conditions the alumina/silica relation in flotation concentrate was greater than 10.

The highest reactive silica reduction was under 400 g/t of collector dosage with available alumina recovery of 73.5 %, eliminating 47 % of re. silica content.

The elimination of 47% of reactive silica content on bauxite is a huge benefit to reduce the alumina production costs on the refinery.

5. References

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