

## **BX10 – Performance Changes in Alunorte Bauxite Dewatering**

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### **Abstract**

The bauxite from MPSA (Mineração Paragominas SA) is transported to Hydro Alunorte through a pipeline to the Barcarena Distribution Station (EDB), which includes three tanks and a clarifier. The bauxite slurry is pumped from the receiving tanks of the pipeline to the intermediate tank of the bauxite dewatering station. After the filtration process, the bauxite with up to 14.5 % moisture feeds the production lines. The study consists of the historical evaluation of dewatering performance parameters and bauxite quality parameters from 2019 onwards, through statistical comparisons of selected parameters that have been identified in the literature as potential influencers on filtration performance and, more systematically, in the red area process. The material profile during this period indicates changes in chemical parameters, such as a reduction in available alumina and an increase in silica content. Regarding the physical parameters, the comparison analysis of the particle size distribution shows a gradual reduction in particle size and lower pulp density. The concentration of fine materials is typically associated with poor filtration performance, as fine particles lead to smaller capillaries and low cake permeability.

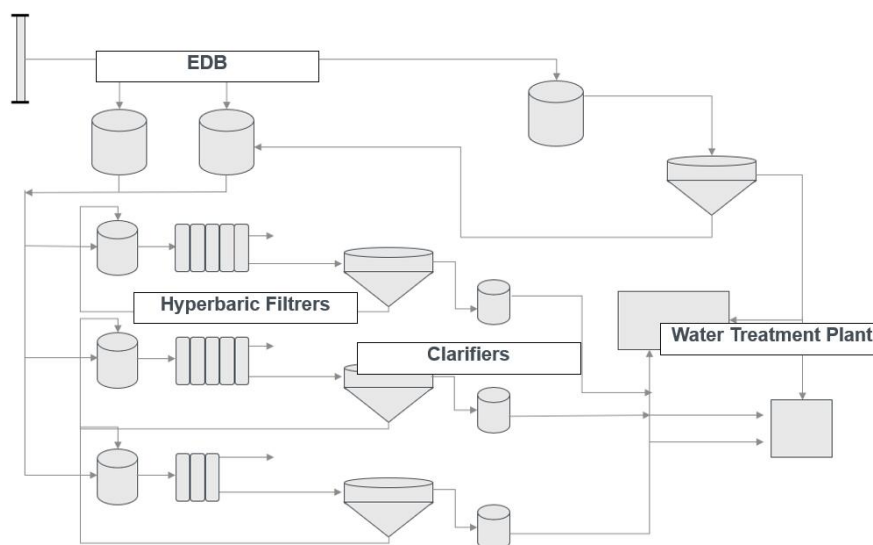
**Keywords:** Bauxite, Hyperbaric filter, Particle size distribution.

### **1. Introduction**

Bauxite is composed of an impure mixture of aluminum minerals, the most important of which are gibbsite ( $\text{Al}(\text{OH})_3$ ), diaspore ( $\text{AlO}(\text{OH})$ ), and boehmite ( $\text{AlO}(\text{OH})$ ). These minerals are known as aluminum oxyhydroxides, and their proportions in the rock vary greatly between deposits, as well as the type and amount of impurities in the ore, such as iron oxides, clay, silica, titanium dioxide, and others. Most economically usable bauxites have an alumina content ( $\text{Al}_2\text{O}_3$ ) between 50 and 55 %, with the minimum content for usability being around 30 % [1].

At Hydro Alunorte, bauxites with a high content of alumina trihydrate (Gibbsite) are used due to the configurations installed for the extraction of alumina in the refinery. They are bauxite from Mineração Rio do Norte (MRN) company that arrives at the refinery via ships, needing to go through a milling stage before digestion, and MPSA that is transported to the refinery through a pipeline and already in ideal granulometry conditions for the digestion stage.

The bauxite from Paragominas in the southeast of Pará is sourced from the MPSA company and is transported through the pipeline to the Barcarena Distribution Station (Figure 1), which comprises three tanks and a clarifier. Two of these tanks are for pulp storage, and one is for trail out storage, with a unit capacity of 6,700 m<sup>3</sup> each. The bauxite slurry is pumped from the pipeline reception tanks to the intermediate tank of the Alunorte bauxite dewatering station, which feeds the hyperbaric filters. After separating liquid solids in the filters, bauxite with up to 14.5 % moisture is conveyed to digestion lines 4 to 7 or the bauxite storage yard, as required by the process.



**Figure 1. Process Flow of Dewatering Area.**

### 1.1 Objective

The objective of this study is to evaluate the dewatering performance parameters and quality parameters of the bauxite that has been pumped since 2019, using historical data. Where applicable, statistical comparisons will be made for parameters selected based on the literature as potential factors affecting dewatering performance.

## 2. Bibliography

### 2.1 Bauxite Mineralogy

Gibbsite, boehmite, and diasporite are the most important minerals contained in bauxites, with the main impurities being kaolinite, quartz, hematite, goethite, rutile, and anatase. The primary distinction between boehmite and diasporite, in relation to gibbsite, lies in their crystalline structure. Gibbsite exists in a crystalline form, while the others are in monohydrate form. The most notable difference between these two types of bauxite is their  $\text{Fe}_2\text{O}_3$  content. As a guiding principle, refractory bauxite is expected to have higher alumina content and fewer impurities.

The temperature at which bauxite is digested depends on the alumina mineral composition of the bauxite. The most readily extractable hydrate form is gibbsite. Gibbsite can be effectively processed at temperatures as low as atmospheric temperature, i.e., 105 °C. Typically, temperatures in the range of 135 °C to 150 °C are employed to treat bauxite containing gibbsite.

The form of alumina in the bauxite is of utmost importance in the Hydro Alunorte process, which is designed to treat gibbsite bauxites under specific temperature conditions. In this process, bauxite should ideally have a lower content of boehmite. Under the extraction conditions used for gibbsite, the digestion solution becomes supersaturated in relation to the less soluble boehmite. This means that while gibbsite is dissolving as sodium aluminate, alumina is simultaneously precipitating as boehmite on the original boehmite seed within the bauxite already undergoing digestion. Under certain conditions, boehmite can also serve as a catalyst for significant precipitation of gibbsite during mud separation. Fortunately, some boehmite occurs as partially agglomerated masses, reducing its surface area and, hence, its efficacy as a seed for alumina precipitation.

For refineries designed to operate at lower digestion temperatures, such as Hydro Alunorte, receiving bauxites with lower gibbsite alumina content and higher boehmite content than typical MPSA and MRN bauxites can adversely affect the process, reducing recovery and increasing Bayer's specific bauxite consumption.

## 2.2 Impact of Bauxite Quality on the Bayer Process

Hydro Alunorte typically receives Amazonian bauxites with a reactive silica content ranging between 4 % and 5 %. Consequently, the residence time in the digesters is sufficient for desilication reactions to occur, resulting in a liquor concentration of up to 1.9 g/L of SiO<sub>2</sub> at the end of the digestion process. Desilication typically takes 1 to 2 hours, depending on the flow rate.

In contrast, when desilication is applied to Brazilian bauxites, a longer hold time of 4 to 8 hours is required, while African bauxites necessitate 8 to 12 hours of hold time. Monitoring this time control is crucial to maintain the lowest possible silica concentration in the refinery liquor. This ensures precise control of silica levels in the final alumina product, while also preventing an increase in fouling rates in the digestion heat exchangers.

Various other reactions can also influence the determination of the optimal hold time during digestion, depending on the bauxite's quality:

- Gibbsite bauxite, under specific conditions, can lead to the formation of monohydrate. This includes extended periods at design temperatures and specific load rates.
- Bauxites with a high goethite content require consideration of sufficient residence time in digestion to allow for the conversion of goethite to hematite at the desired lime load.

It's important to note that particle size, bauxite surface area, residue generation, and the presence of goethite can alter the general characteristics of sedimentation, compaction, and liquor clarification. Bauxites with a high goethite/hematite ratio, low particle density, fine particle size distribution (PSD), and high surface area are typically challenging to handle and settle in most slurry circuits. These may require a unique flocculant dosing strategy.

Another issue related to the iron content in bauxite is how this element behaves in the liquor processing. The solubility of iron in liquor from bauxites varies when other parameters are altered, such as digestion temperature and free soda concentration. According to Roach [2], starting from the general case, where bauxites with low iron content result in high iron content in the liquor, it would be reasonable to assume that simply mixing bauxites, resulting in an average total iron content, could generate liquor with a low concentration of soluble iron. This statement generally holds true, as high-grade bauxite provides the necessary iron oxide seed needed to precipitate some of the soluble iron from low-grade bauxite.

## 2.3 Filtration

According to Cremasco [3], filtration is a unit operation where mechanical separation occurs between the particulate and fluid phases in a given suspension. This separation is achieved using a porous medium which retains the particulate phase while allowing the fluid phase to pass through. The fluid leaving the filter is known as the filtrate. Depending on the suspension being processed, the particulate phase may accumulate beneath the filter, forming what is called the cake.

For the filtration process to occur, a force must be applied to the particles through the porous medium. In vacuum filtration, negative pressure is created below the filter media, whereas in pressure filtration, positive pressure is applied to the slurry. Hyperbaric filters use a combination of vacuum and pressure.

In hyperbaric filters, the pressure applied during operation can reach up to 600 kPa above atmospheric pressure. To achieve this, the filters are placed in a pressure vessel and operate in a hermetically sealed manner. A system of special valves allows for the discharge of both the filtrate and the cake without the need to open the filter.

The process of filtering ore slurries involves multiple variables that affect performance. In this context, the following factors can be highlighted [4,5]:

- The filtering rate increases as the filtering cycle is reduced. However, this may lead to higher cake moisture or the production of extremely thin cakes, which can affect discharge.
- Pulps with higher solids concentrations favor filtration. Most filters require a minimum solids concentration in their feed to ensure optimal performance. Therefore, it is common practice to thicken the pulp using thickeners, cyclones, or other equipment before filtration.
- A fine particle size distribution results in cakes with smaller interstices. As a result, liquid passes through the filter medium with greater difficulty, reducing filtration rate and increasing the moisture content of the cake.

Alunorte's hyperbaric filters play a crucial role in recovering water for reuse in the process, reducing moisture for transportation purposes, and enabling the consumption of discharged bauxite. This necessitates adjusting the percentage of solids in the pulp as required by subsequent unit operations.

### 3. Results

The dewatering performance and quality profile exhibited notable variations throughout the evaluation period. Additionally, concerning the quality parameters, shifts in both chemical and physical profiles were observed. These parameters can have a substantial impact on the filtration process.

#### 3.1 Dewatering Performance

##### 3.1.1 Productivity and Moisture

The productivity profile of the hyperbaric dewatering filters exhibited changes in performance levels over time, as depicted in Figure 2. Between 2021 and 2022, they operated near their nominal capacity.

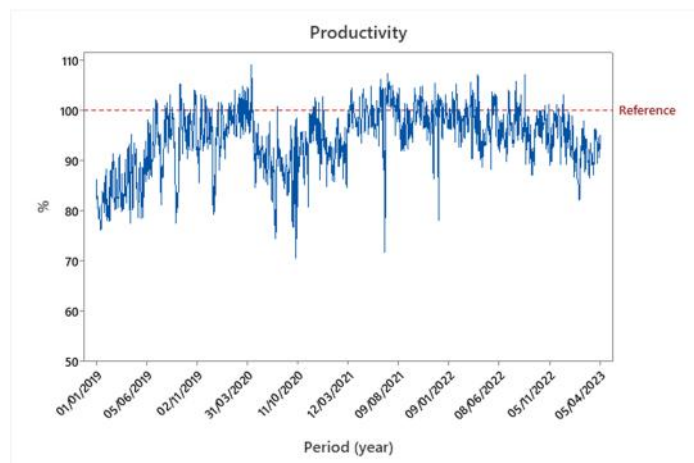


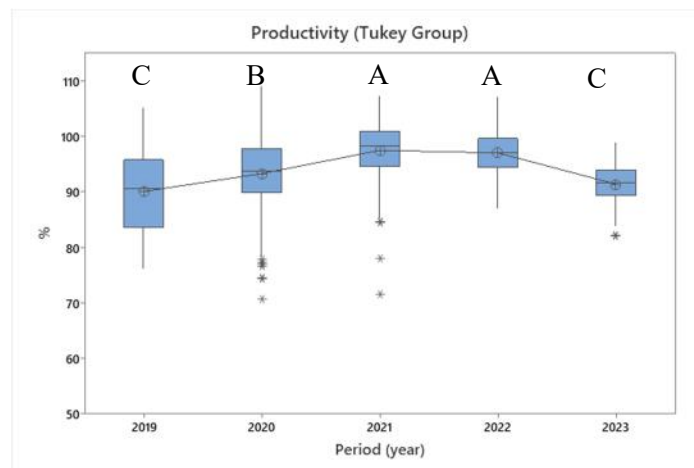
Figure 2. Dewatering productivity profile (2019-2023).

Statistical analysis of productivity data, grouped by year, indicates a significant difference with 95% confidence (Table 1), highlighting changes in productivity over time.

**Table 1. Analysis of Variance (Productivity).**

	GL	SQ (Aj.)	QM (Aj.)	F-value	P-value
Period	4	20222	5055,56	116,39	0
Error	1496	64981	43,44		
Total	1500	85204			

After conducting the ANOVA (Analysis of Variance) analysis, we performed a means comparison test (Tukey test) to compare different time periods and identify significant differences. This test allowed us to compare pairs of periods and group them according to the Tukey Groups (A, B, C). When factors fall within the same group, it suggests statistical equality with the level of confidence implemented.



**Figure 3. Dewatering Productivity Boxplot (2019-2023).**

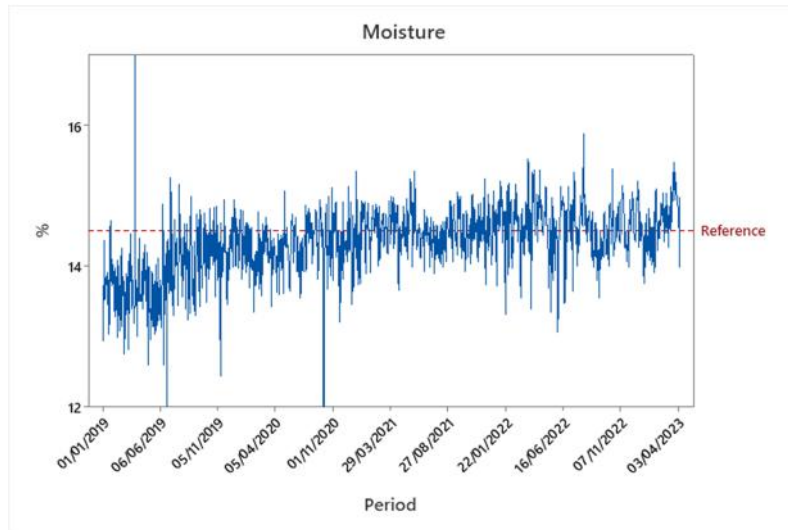
Based on the results and comparison tests, it was found that the years 2021 and 2022 exhibited statistically equal performance, achieving the highest productivity results in line with the target. However, starting in 2023, there was a noticeable drop in performance levels, returning to levels comparable to those in 2019, with an average productivity 6% below the target. A significant portion of this decline in productivity can be attributed to the reduction in dewatering feed density, which will be discussed in detail in Section 3.2.

The moisture profile of the dewatered bauxite mirrored the productivity trend, with the year 2019 falling below the upper specification limit. However, there was a gradual improvement in moisture levels, as illustrated in Figure 4.

The analysis of variance (Table 2) reveals statistically significant differences in moisture levels, with a 95% confidence level, as evident in the trend graph (Figure 5). Further confirmation comes from the Tukey pairwise comparison test.

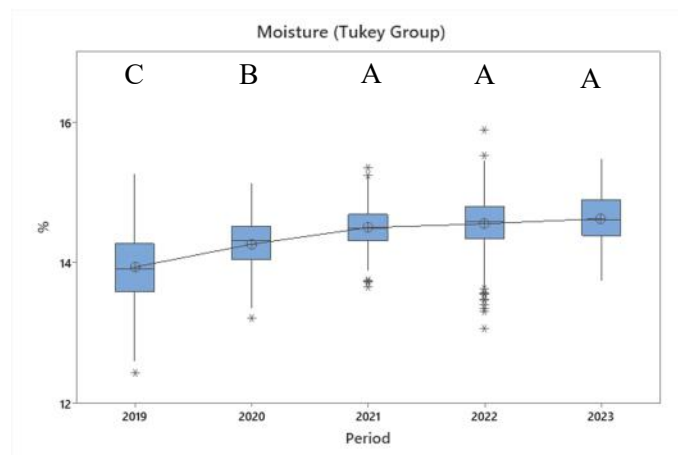
**Table 2. Analysis of Variance (Moisture)**

	GL	SQ (Aj.)	QM (Aj.)	F-value	P-value
Period	4	89,58	22,3961	121,3	0
Error	1438	265,51	0,1846		
Total	1442	355,09			



**Figure 4. Dewatered bauxite moisture profile (2019-2023).**

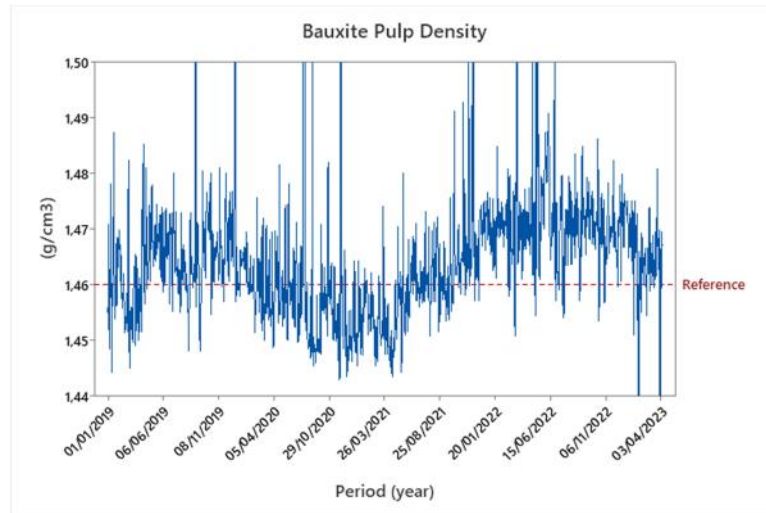
Similar to the findings for productivity, the results of the Tukey test revealed three distinct profiles: Groups A, B, and C (Figure 5). According to the results, the years 2021, 2022, and 2023 exhibited statistical similarity, setting them apart from the other years. When comparing the results of productivity and moisture, an upward trend becomes evident from 2021 onward for both indicators, reflecting the refinery's production growth curve.



**Figure 5. Bauxite moisture boxplot (2019-2023).**

### 3.2 Physical Parameters: Density and Granulometry

The analysis of the bauxite slurry density profile reveals varying levels throughout the analyzed period. When considering other performance parameters inherent to the filter, it becomes evident that slurry density is one of the primary factors influencing production and quality, as it directly affects the thickness of the cake formed. Figure 6 presents a time series graph, showcasing a notable similarity with the productivity profile.



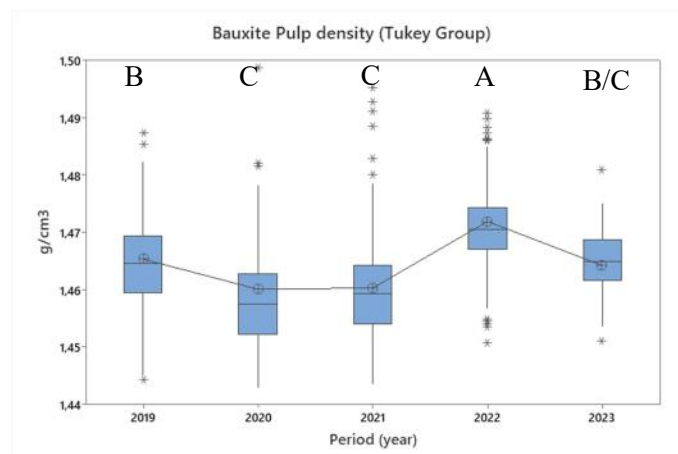
**Figure 6. Bauxite density profile (2019-2023).**

Based on the analysis of variance (Table 4), we can confidently assert, with a 95 % confidence level, that the slurry density has undergone significant changes over the years. Consequently, it possesses the potential to impact the performance of the filters [6].

**Table 4. Analysis of Variance (Density).**

	GL	SQ (Aj.)	QM (Aj.)	F-value	P-value
Period	4	0,03216	0,008039	35,49	0
Error	1437	0,32554	0,000227		
Total	1441	0,3577			

According to the Tukey groups, the density in the year 2022 reached its peak for the period, with an average of 1.47 g/cm<sup>3</sup>. This finding partially explains the improved productivity observed during that year. Notably, the presence of outliers in the boxplot for this year suggests occasional instances of lower density, which were particularly concentrated in December 2022, signaling the beginning of a transition to lower density in 2023, as depicted in Figure 7.

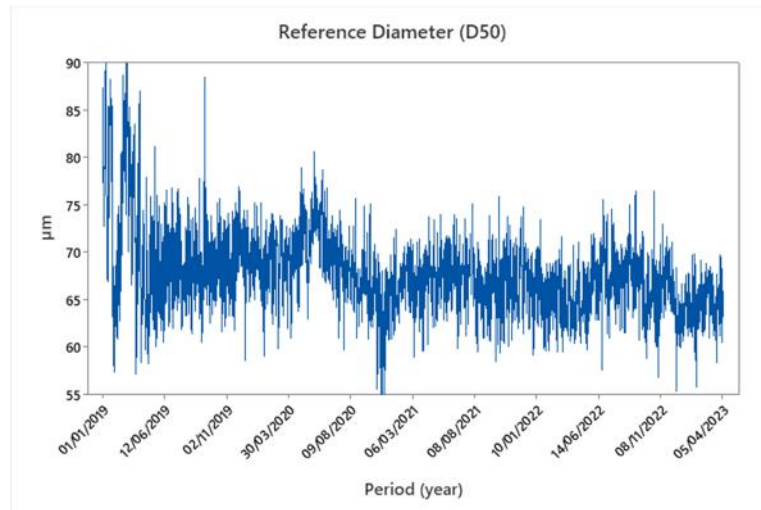


**Figure 7. Density boxplot (2019-2023).**

It is essential to emphasize that while the density was lower, it remained above the lower specification limit. However, the increase in the operational level in 2022 was a response to

studies and recommendations aimed at partially mitigating the effects of changes in the characteristics of the pulp, which will be discussed below, encompassing both physical and chemical aspects.

Another significant factor with the potential to impact filtration, particularly by influencing cake characteristics and bed permeability, is granulometry. In some scenarios, the development of new fabrics becomes necessary to address this aspect. The impact mechanisms of granulometry are linked to the risk of premature tissue clogging and, if the cleaning system proves inefficient, the early decline of filtration rates, as well as an increase in solids within the filtrate phase. Figure 8 illustrates the median reference diameter (D50) and its profile over the years.



**Figure 8. Reference diameter profile (2019-2023).**

The D50 was calculated using logarithmic interpolation, utilizing Particle Size Distribution (PSD) data, and subjected to analysis of variance, as depicted in Table 5. The results clearly indicate a statistically significant change in D50 over time, with a probability of significance less than 0.05.

**Table 5. Analysis of Variance (Granulometry - D50).**

	GL	SQ (Aj.)	QM (Aj.)	F-value	P-value
Period	4	10905	2726,32	214,36	0
Error	3121	39694	12,72		
Total	3125	50599			

Tukey's comparison analysis (Figure 9) reveals a gradual decrease in the median of the bauxite pulp, resulting in five Tukey groups (A, B, C, D, and E), highlighting statistically significant differences between all periods. This reduction in median material, particularly the D50, has the potential to significantly impact dewatering performance.

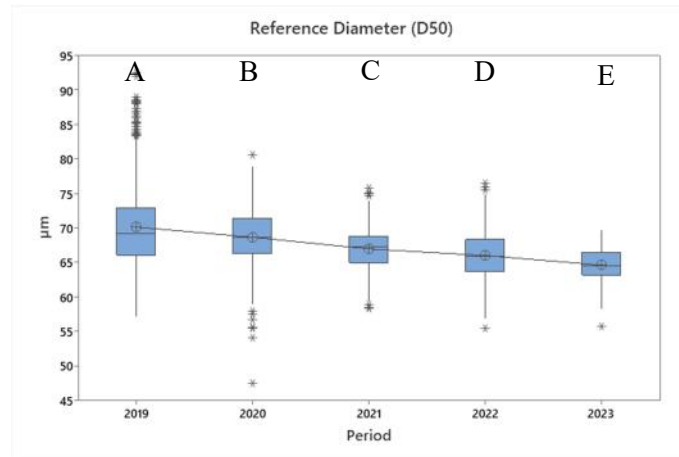


Figure 9. D50 reference diameter boxplot (2019-2023).

Expanding our evaluation to the finer fraction, specifically D30, we observe a similar trend, indicating a reduction in granulometry from approximately 16  $\mu\text{m}$  to 14  $\mu\text{m}$ , as depicted in Figure 10-A. Notably, the presence of fines in bauxite can often be correlated with silica content, particularly kaolinite. To explore this correlation, we conducted an analysis comparing D30 with Reactive Silica, revealing a tendency toward correlation. During moments of higher D30, we observed a lower Reactive Silica content. Conversely, in more recent scenarios characterized by lower D30 values, there has been an increase in bauxite reactive silica, as demonstrated in Figure 10-B.

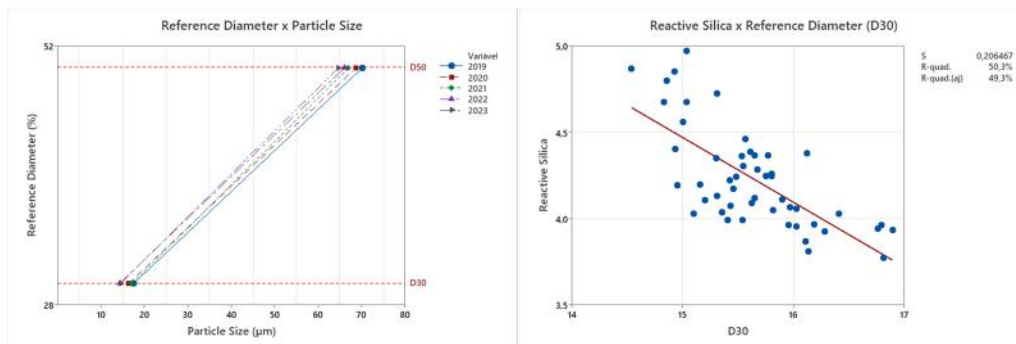


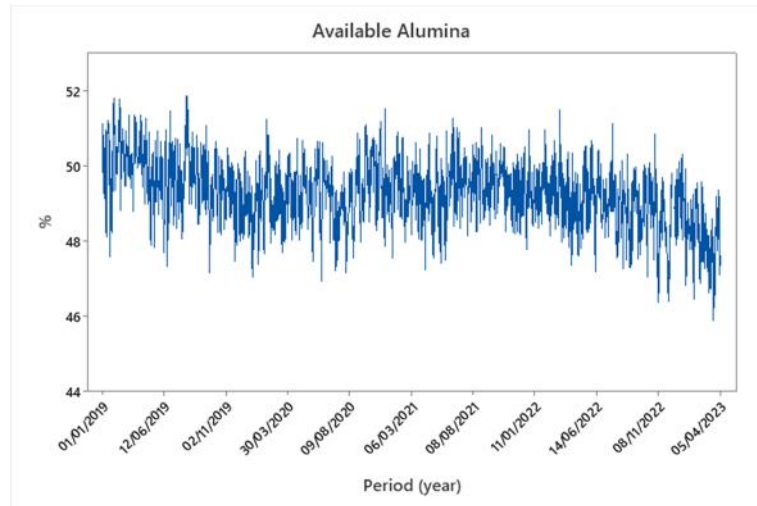
Figure 10. A) D30 and D50 reference diameter. B) D30 correlation with reactive silica.

The alterations in both granulometry and chemical composition profiles (as will be discussed in section 3.3) may suggest a shift in the mineralogical composition of the pumped material. Such changes could potentially necessitate modifications in the bauxite dewatering plant, particularly in terms of fabric technology.

### 3.3 Chemical Parameters

#### 3.3.1 Available Alumina

As previously discussed regarding the physical parameters, the evaluated period also witnessed significant changes in the chemical profile. Figure 11 illustrates the percentage of available alumina in bauxite.



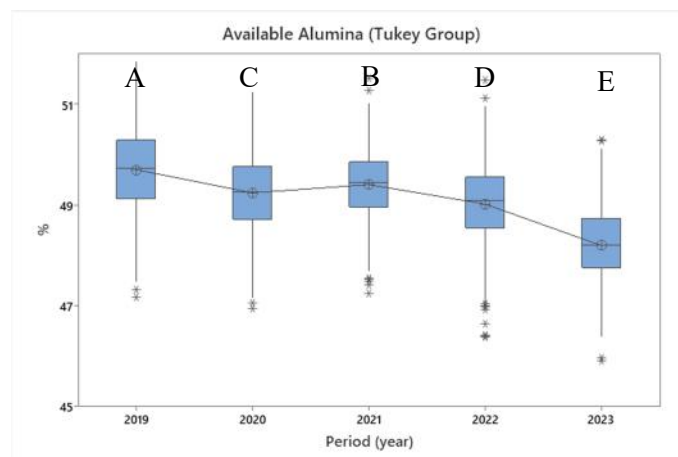
**Figure 11. Available alumina profile (2019-2023).**

Statistical analysis of alumina contents reveals significant differences, with a noticeable downward trend over the evaluated period. The decline in alumina content holds great significance, as it directly affects both the production levels and the quantity and quality of waste generated. In terms of filtration, this change can be attributed to the characteristics of the pulp, particularly the varying concentration of other components, necessitating an increased bauxite factor to sustain production.

**Table 6. Analysis of Variance (Available Alumina)**

	GL	SQ (Aj.)	QM (Aj.)	F-value	P-value
Period	4	429	107,239	181,46	0
Error	3111	1838,5	0,591		
Total	3115	2267,4			

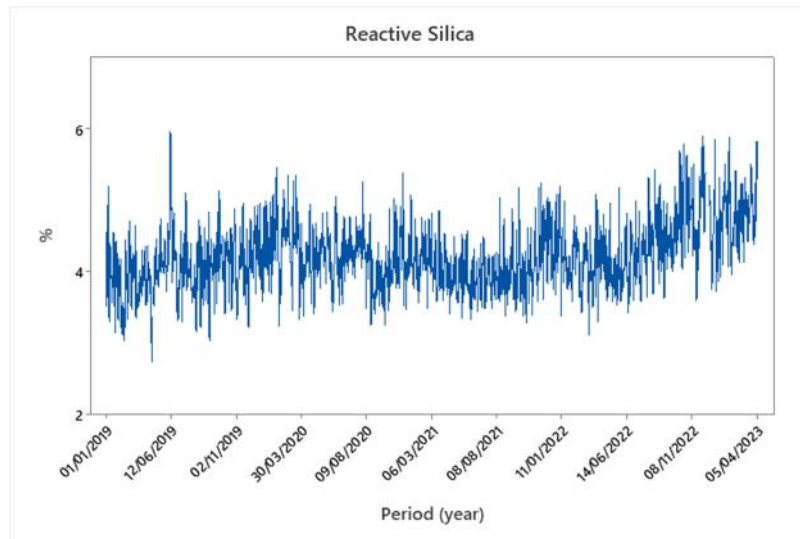
Pairwise comparisons reveal that all periods exhibit statistically significant differences, with the year 2023 showing the lowest available alumina content. The average result for 2023 is 1.5 % lower than that of 2019.



**Figure 12. Available Alumina Bloxplot (2019-2023).**

### 3.3.2. Reactive and Total Silica

Much like the assessment of Available Alumina, the profile of reactive silica has undergone changes over the years. Notably, the year 2023 exhibits the highest content when compared to other years, as illustrated in Figure 13.



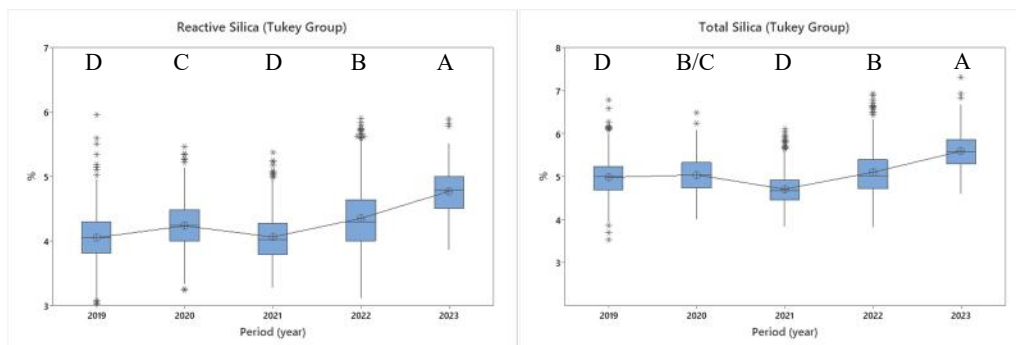
**Figure 13. Reactive Silica Profile (2019-2023).**

As previously discussed, the increase in silica content has several implications for the Bayer process. These impacts include the potential alteration of silica content in both the product and residue, the possibility of granulometric reduction in the material, potential effects on decantation processes, which may promote the presence of suspended fines, and limitations in filtration. Table 7 provides the results of the analysis of variance, clearly indicating a statistically significant difference in silica content across the evaluated periods.

**Table 7. Analysis of Variance (Reactive Silica).**

	GL	SQ (Aj.)	QM (Aj.)	F-value	P-value
Period	4	111,8	27,9614	164,77	0
Error	3107	527,3	0,1697		
Total	3111	639,1			

Figure 14 displays the boxplot with Tukey groups for both Reactive Silica and Total Silica, revealing a similar upward trend. Notably, the year 2023 stands out as having the highest silica content in the analyzed period.



**Figure 14. Bloxplot of Reactive Silica (A) and Total Silica (B) (2019-2023).**

### 3.4 Improvements in the dewatering process

After identifying the impact variables and changing the control strategy, adjustments were made to the refinery's feed density, raising the profile to values similar to those presented in 2022, as can be seen in Figure 15. The figure illustrates the comparison between two scenarios: I represents the period before the changes, while II represents the period after the adjustments, with an increase in density from 1.459 to 1.464 g/cm<sup>3</sup>.

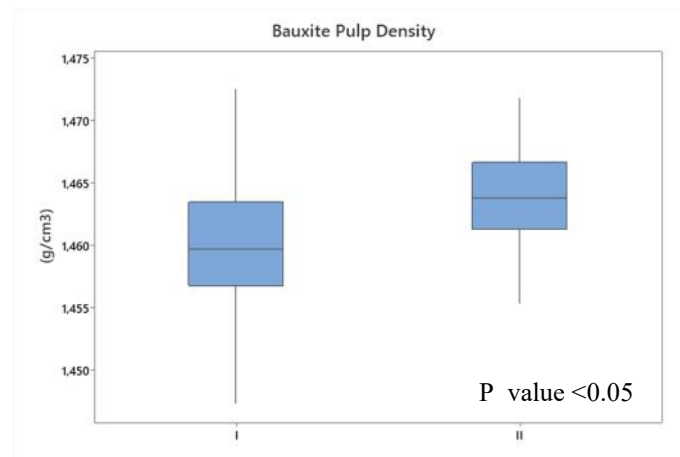


Figure 15. Bloxplot of bauxite pulp density before (I) and after the changes.

Following the adjustments in performance strategy and interface between the plants, a positive impact on the dewatering production profile is observed, with a productivity gain of almost 4%. This change, combined with the reduction in control variability through online monitoring of mass balances and the return of the clarifier system, allowed for a sustainable increase in production levels. Figure 16-A presents the density and filter performance monitoring system, with a focus on the density impact. Figure 16-B compares the two production scenarios, before (I) and after (II) the density strategy change.



Figure 16. Density Monitoring System(A) Productivity before (I) and after (II) changes(B)

## 4. Conclusion and Recommendations

The concentration of fine materials is typically linked to suboptimal filtration performance, as these fine particles result in smaller capillaries and lower cake permeability. A fine particle size distribution results in cakes with smaller interstices. Consequently, liquid has a harder time passing through the filter medium, leading to reduced filtration rates and an increase in the moisture content of the cake.

The pulp density, as indicated by the literature and presented in the case study, generally has a positive impact on the filtration process. Based on this scenario, several changes in monitoring and strategy were implemented, including:

- Operate with the high density of the MPSA bauxite pulp;
- Optimization in the monitoring and control of pulp density and recirculation;

The implemented changes yielded a positive impact, with a 6% increase in performance. As a complementary measure, it is recommended:

- Review the fabric specification of hyperbaric filters;
- Perform DOE to measure the impact in t/h of productivity on hyperbaric filters.

## 5. References

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