BR02 - Bauxite Residue Disposal: One-Step Towards Conversion from Wet to Dry Disposal

Roberto Seno[1] and Rodrigo Moreno[2]
1. Technology Manager
2. Process Consultant
Companhia Brasileira de Alumínio, Alumínio, Brazil
Corresponding author: roberto.seno@cba.com.br

Abstract

CBA has invested in projects and research to further improve its bauxite residue disposal process. One ongoing project will use filter presses to dewater bauxite residue sending the residue to the existing dam, moving from wet to dry disposal system. The project, in addition to further increasing the dam's safety, will lengthen the dam life by 20 years and will increase the caustic recovery from bauxite residue. Recovering the existing liquor inside the dam is an essential condition to dispose and stack bauxite residue processed by filter presses. This condition must be reached before the filters start-up. Several studies were conducted to find the best alternative to achieve this goal. Re-utilizing the liquor in the Alumina Refinery was the best option due to its benefits in recovering caustic and dissolved alumina present in the solution. However, the impurities in the liquor, especially sodium carbonate, must be managed before sending the liquor back to the plant. CBA has developed an improved causticization process. Based on optimum reaction conditions and the use of a 10 tph filter press to separate the calcium carbonate from the causticized liquor. The start-up of this technology allowed returning more than 1.6 million cubic meters of liquor to the refinery, representing around 70% of total liquor volume inside the dam with minimal effects to the process. The calcium carbonate produced by the 10 tph filter press presents a very low moisture content and high purity composition. A study was carried out to verify the compatibility of this material for soil amendment. CBA applies it at Miraí mining, in the environmental rehabilitation process of mined areas, representing an excellent example of circular economy. This paper presents the development, implementation and results of the causticization process. The use of calcium carbonate as soil amendment and its application at CBA bauxite mine is presented as well.

Keywords: Causticization, bauxite residue, calcium carbonate, bauxite mining, environmental rehabilitation.

1. Introduction

Significant technology improvements have taken place in bauxite residue disposal lately. The drivers for these changes are environmental and safety performance, operational efficiency and capital expenditure (Capex) optimization.

Technologies such as dry disposal with filter presses and dry stacking through high solids discharge in thin layers or mud farming are being implemented in many refineries around the world [1].

Companhia Brasileira de Alumínio (CBA) has been working to improve its bauxite residue disposal process. Currently CBA's bauxite residue is filtered in drum filters and then reslurried and pumped to a dam [2]. A project to convert its bauxite residue storage area from wet to dry disposal system, using filter presses, has showed viable and it will increase the dam's safety, will lengthen the dam's lifetime by 20 years and will increase the caustic recovery from bauxite residue [3].

An essential condition to implement the filter presses system is to remove the existing liquor inside the dam. There were more than 2.0 million m³ of liquor. This condition must be reached before the filters start-up.

Several studies were carried out to find the best alternative to achieve this goal. Alternatives like neutralization & discharge and evaporation of the liquor were studied but they are costly and Capex intensive. Re-use the liquor in the plant has proved to be the best option due to its benefits in recovering caustic and dissolved alumina present in the solution. However, the impurities in the liquor, especially sodium carbonate, must be managed before sending the liquor back to the plant.

The effects of sodium carbonate in the Bayer process are very well known. There are many studies presenting and quantifying these effects. A special attention must be given to hydrate precipitation area where the impact of the sodium carbonate can be more harmful [4]. Precipitation yield decrease and the critical sodium oxalate concentration close to the refinery operating conditions are the main effects and they must be avoided. It is important to keep the sodium carbonate concentration as low as possible.

Sodium carbonate removal processes have been studied for a long time. There are different technologies and alternatives to achieve this goal. The formation of the dessilication product (DSP) is a natural removal process. Sidestream and internal causticization, high temperature causticization (HTC), tricalcium aluminate (TCA) inhibitor and salting out evaporation are techniques that could be used to remove the sodium carbonate from the liquor [5].

CBA analyzed all of these possibilities regarding its own facilities and has found an opportunity to use and to improve the traditional causticization process.

A causticization unit with one agitated tank operated with slaked lime and washers overflow in typical sidestream configuration.

Laboratory test were carried out to find the best causticization reaction conditions using liquor from the dam and determine the necessary modifications to the existing unit. An important role is played by a 10 tph, 1.5 × 1.5 m, filter press installed to conduce the bauxite residue characterization, geotechnical studies, and to acquire operation and maintenance knowledge. This filter, showed in Figure 1, was implemented to support the future disposal method conversion based on the use of filter presses to process 100 % of the bauxite residue. With all these studies concluded, the 10 tph filter press has an opportunity to be used in a new role.

The 10 t/h filter press set up was adjusted and the equipment connected to the existing causticization unit. In this way, the calcium carbonate precipitated could be separated with a low moisture and low caustic content allowing a new utilization.

Figure 1. 10 tph Filter Press.

CBA has developed the use of this material for soil amendment. A greenhouse tests were conducted with different crops and different conditions. The product is being applied at CBA's Miraí mining, in the environmental rehabilitation process of mined areas, representing an excellent example of circular economy.

2. Developments

2.1 Causticization Reaction Conditions

A series of laboratory tests were carried out to evaluate the impact of lime charge and residence time in the causticization efficiency using liquor from the dam. A rotating water bath with temperature control was used to realize the tests. Lime was added as slaked lime.

The liquor from the dam composition is presented in Table 1.

Table 1. Liquor composition.

TC (g Na_2CO_3/L)	Carbonate (g Na_2CO_3/L)	TA (g Na_2CO_3/L)	TC/TA	Al_2O_3 (g Al_2O_3/L)	A/C
12,7	18,4	31,1	0,408	7,2	0,564

The conditions tested are described below:

- Lime Charge: 3 %, 17 % and 36 % above the stoichiometric ratio according to equation 1.
  Equation 1: $Ca(OH)_{2\,(s)} + Na_2CO_{3\,(aq)} \leftrightarrow 2NaOH_{(aq)} + CaCO_{3\,(s)}$
- Residence Time: 30, 60, 90 and 120 minutes.
- Temperature: 90 ºC

Slaked lime samples were prepared by hydrating limestone (plant samples) in industrial water. A beaker with a magnetic stirrer was used to mix the slurry. Industrial water was preheated up to 45 °C and then the limestone is added to the beaker keeping a constant mixing. The slurry temperature was controlled to be maximum 95 °C.

Caustic and sodium carbonate concentration were measured using an acid-base titration (Metrohm Titrator).

2.2 Separation Tests

A pilot filter press unit, Bilfinger KE 500, was used to perform the calcium carbonate separation tests. The unit is presented in Figure 2.

A filter press and a heated and agitated tank form this unit. The best causticization reaction condition obtained from the laboratory tests was used in the pilot trials. Nevertheless, this time, slaked lime from the plant was used to causticize the liquor from the dam.

Caustic and sodium carbonate concentration were measured using an acid-base titration (Metrohm Titrator).

The cake from the filter press was collected and moisture, particle size and mineral composition were performed using a muffle, laser diffraction particle size analyser and an X-Ray diffractometer, respectively.

The filtration rate and cake discharge performance were analysed as well.

Figure 2. Pilot filter press unit.

2.3 Soil Amendment

The calcium carbonate precipitated and separated in the pilot trials were used to perform the soil amendment studies.

2.3.1 Experiments Facilities

The experiments were conducted in a greenhouse (Figure 3). The total experiment time was 164 days. All the analyses and experiments followed the protocols and standards from Ministry of Agriculture, Livestock and Food Supply (MAPA) and Brazilian Agricultural Research Corporation (EMBRAPA).

Figure 3. Greenhouse.

The experiments used 80 plastic vessels, which of them is a 5 litres capacity unit. They were filled with 2 types of soil with different textures, clay soil and sandy soil, for a better evaluation of the effect of clay content.

An experimental design was applied. A factorial structure of 1 × 4 × 2 × 2 was chosen, with 1 product (CBA Product or Conventional Limestone), 4 doses, 2 soils with different textures, 2 crops (Eucalyptus and Soy) in 4 repetitions.

The tests are shown in Table 2.

Table 2. Doses applied in the Eucalyptus tests.

Type os Soil	Dose	Crop
Clay	100% CBA	Eucalyptus
Clay	50% CBA + 50% Limestone	Eucalyptus
Clay	30% CBA + 70% Limestone	Eucalyptus
Clay	100% Limestone	Eucalyptus
Clay	100% CBA	Soy
Clay	50% CBA + 50% Limestone	Soy
Clay	30% CBA + 70% Limestone	Soy
Clay	100% Limestone	Soy
Sandy	100% CBA	Eucalyptus
Sandy	50% CBA + 50% Limestone	Eucalyptus
Sandy	30% CBA + 70% Limestone	Eucalyptus
Sandy	100% Limestone	Eucalyptus
Sandy	100% CBA	Soy
Sandy	50% CBA + 50% Limestone	Soy
Sandy	30% CBA + 70% Limestone	Soy
Sandy	100% Limestone	Soy
Clay	Blank	Eucalyptus
Clay	Blank	Soy
Sandy	Blank	Eucalyptus
Sandy	Blank	Soy

CBA product and conventional limestone were added to the vessels (5 dm^3), homogenized and kept for 20 days in an incubation process, with 70 % of the typical local moisture. The doses applied in the tests are presented in Table 3 and 4.

Table 3. Doses applied in the Eucalyptus tests.

Eucalyptus				
Dose	Clay Soil		Sandy Soil	
	CBA Product	Limestone	CBA Product	Limestone
100% CBA	8,38 g	-	4,63 g	-
50% CBA + 50% Limestone	4,19 g	3,97 g	2,31 g	2,19 g
30% CBA + 70% Limestone	2,51 g	5,55 g	1,39 g	3,07 g
100% Limestone	-	7,93 g	-	4,38 g
Blank	-	-	-	-

Table 4. Doses applied in the Soy tests.

Soy				
Dose	Clay Soil		Sandy Soil	
	CBA Product	Limestone	CBA Product	Limestone
100% CBA	10,13 g	-	5,72 g	-
50% CBA + 50% Limestone	5,06 g	4,79 g	2,86 g	2,70 g
30% CBA + 70% Limestone	3,04 g	6,71 g	1,71 g	3,79 g
100% Limestone	-	9,59 g	-	5,41 g
Blank	-	-	-	-

Once harvested, the leaves were sent for analysis in the plant tissue laboratory, where they were washed, dried and crushed and, subsequently, digested in an acid solution to determine the levels of N, P, K, Ca, Mg, S, Zn, Cu, Fe, Mn, Na and Al.

The soil from each vessel was sieved, identified, registered, air dried and prepared for the analysis of the following parameters: pH H_2O, pH $CaCl_2$, P, K, S, Ca, Mg, Al, H + Al, $CTC_{pH7.0}$, Base saturation (V %) and Na.

2.3.2 Eucalyptus Experiment

An eucalyptus clone AEC-144 (hybrid Eucalyptus urophylla), very used in Brazil, was used in the experiment. The main parameters measured in this experiment were: stem diameter at the height of the plant stem (DC) and total plant height (HT). The evaluations were performed on the day of the transplanting, 60, 90 and 120 days after the transplanting. Figures 4 and 5 show some images from eucalyptus experiment: a Greenhouse view and data collection, respectively.

Figure 4. Greenhouse view with eucalyptus experiment.

Figure 5. Eucalyptus experiment data collection.

2.3.3 Soy Experiment

The soy variety M7110 IPRO was used to perform the experiment. Figures 6 and 7 show some images from soy experiment: a Greenhouse view and plant grinding and sample for dry mass evaluation, respectively.

The main parameter measured in this experiment was the plant productivity expressed in dry mass after 103 days.

Figure 6. Greenhouse view with Soy experiment.

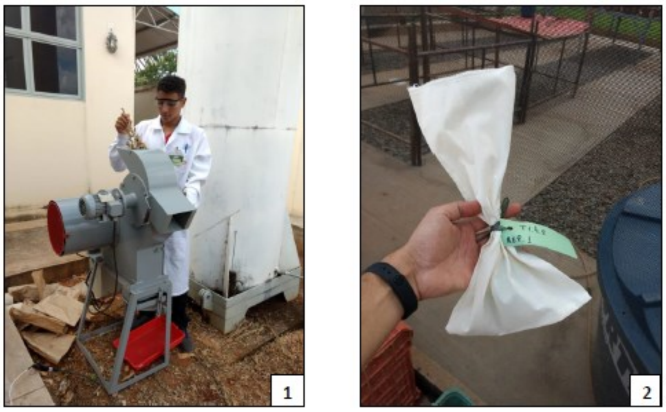

Figure 7. Samples preparation for dry mass measurement.

3. Results

3.1 Laboratory Results

The causticization lab tests showed a high efficiency especially in trials realized with lime charge of 36 % excess of stoichiometric ratio.

The effect of residence time showed to be the same regardless the lime charge. The reactions reached the maximum value after 40 minutes and present a stable profile up to 120 minutes.

The results are consistent to those found in the literature [6], where higher causticization efficiencies were obtained in higher lime charges and low caustic concentrations. Reaction reversion were found after 2 hours in this study.

The results are presented in Figures 8 and 9. The results are expressing the TC/TA evolution and the causticization efficiency, respectively.

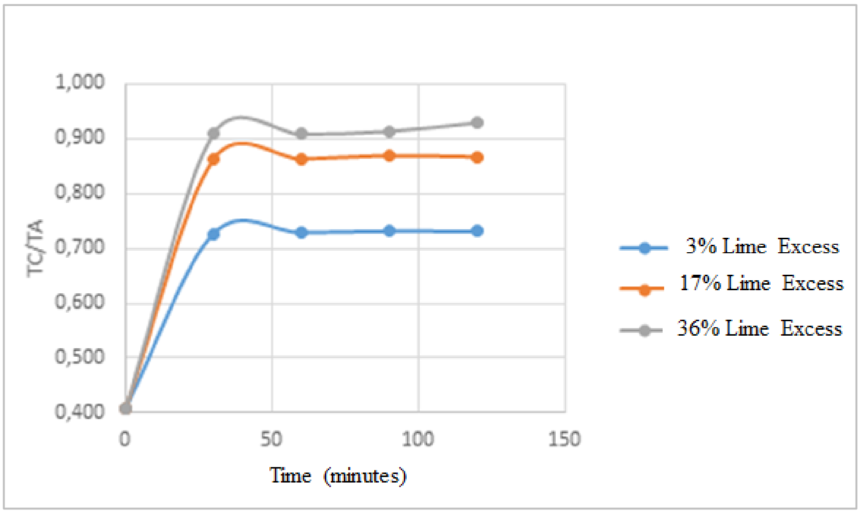

Figure 8. TC/TA liquor from the dam causticization test.

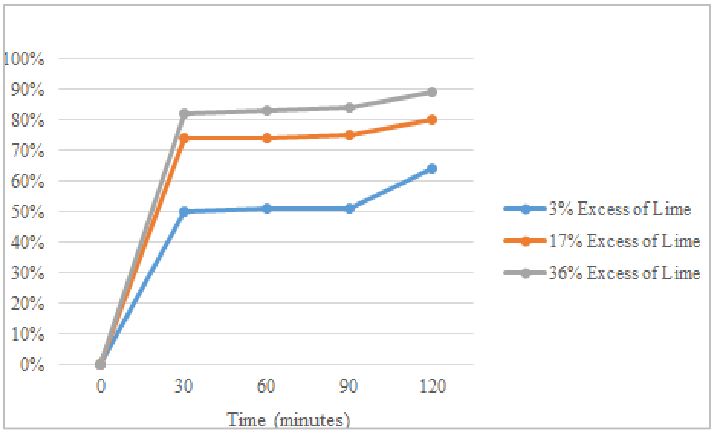

Figure 9. Causticization efficiency.

The TC/TA obtained in the lab tests were much higher than the plant TC/TA.

3.2 Pilot Filter Press Tests

The causticization reaction parameters obtained in the lab could be reproduced successfully in the pilot unit.

The filter press presented a good filtration rate with no difficulties to discharge the cake formed. A low solid content in the filtrate liquor was observed too.

Calcium carbonate produced in the pilot tests presented a low moisture and caustic content. The composition is shown in Table 5. Table 6 shows the mineralogical composition and Table 7 the particle size distribution.

Table 5. Chemical composition and moisture (%).

Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	CaO	MnO	Fe_2O_3	SO_3	Moisture
1,70	1,60	2,40	0,35	0,18	93,10	0,04	0,23	0,07	30

Table 6. Mineralogical Composition.

Chemical Formula	Percentage (%)	Mineral
CaCO3:	94	Calcite
Ca(OH)2:	4	Portlandite
Na2O.CaO.Al2O3.SiO2.H2O	2	Sodium Calcium Aluminum Oxide Silicate Hydrate

Table 7. Particle size distribution.

Diameter	Size
d(0,1):	11,82 µm
d(0,5):	36,34 µm
d(0,9):	157,96 µm
Size (µm)	**Vol. Under (%)**
25	30,43
44	56,20
75	75,17
101	82,18
150	89,22
208	93,73

3.3 Soil Amendment Results

The results for the soil amendment tests are presented in Figures 10 to 19.

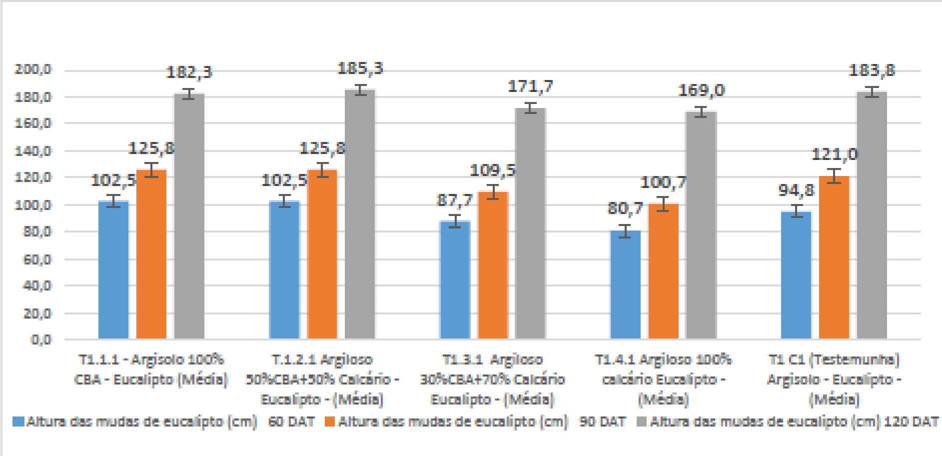

Figure 10. Eucalyptus plant height (ht) results for clay soil.

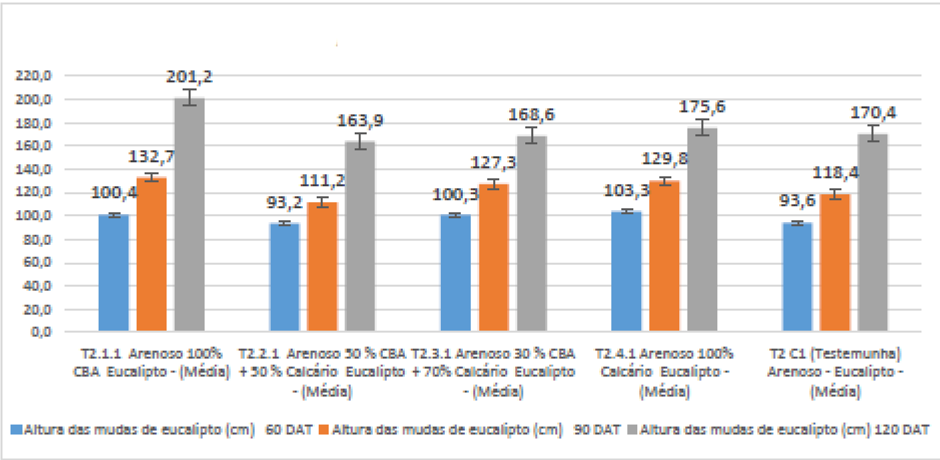

Figure 11. Eucalyptus plant height (ht) results for sandy soil.

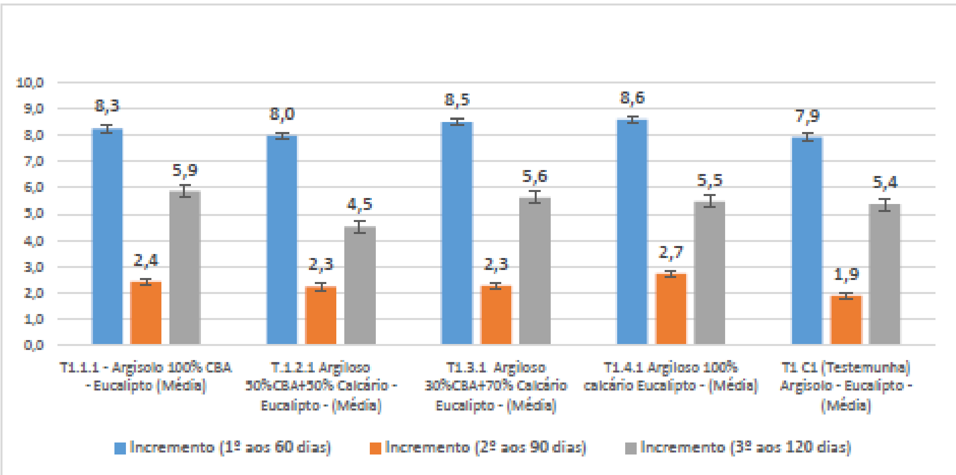

Figure 12. Eucalyptus plant stem diameter (dc) results for clay soil.

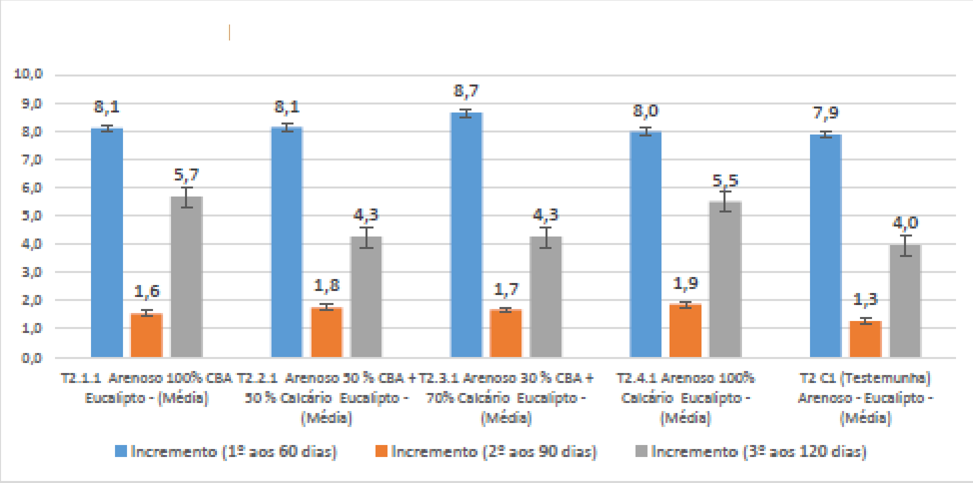

Figure 13. Eucalyptus plant stem diameter (dc) results for sandy soil.

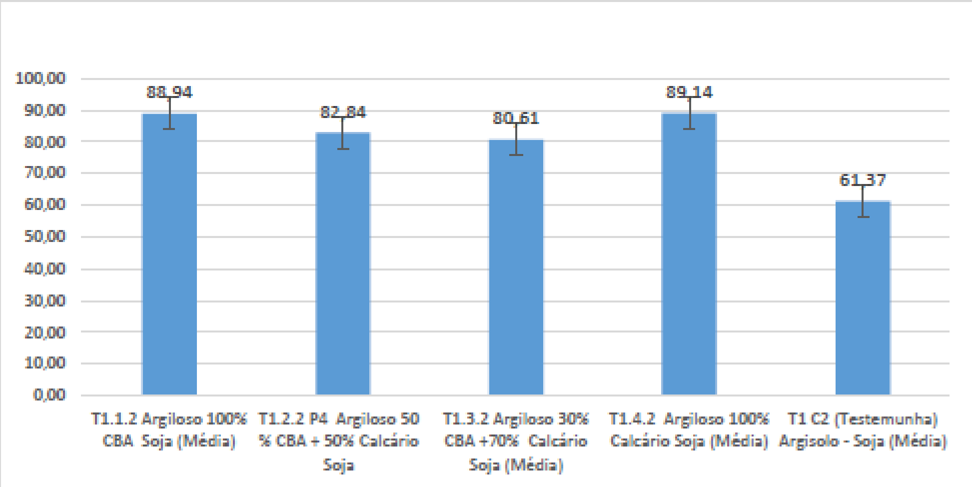

Figure 14. Soy productivity results for clay soil.

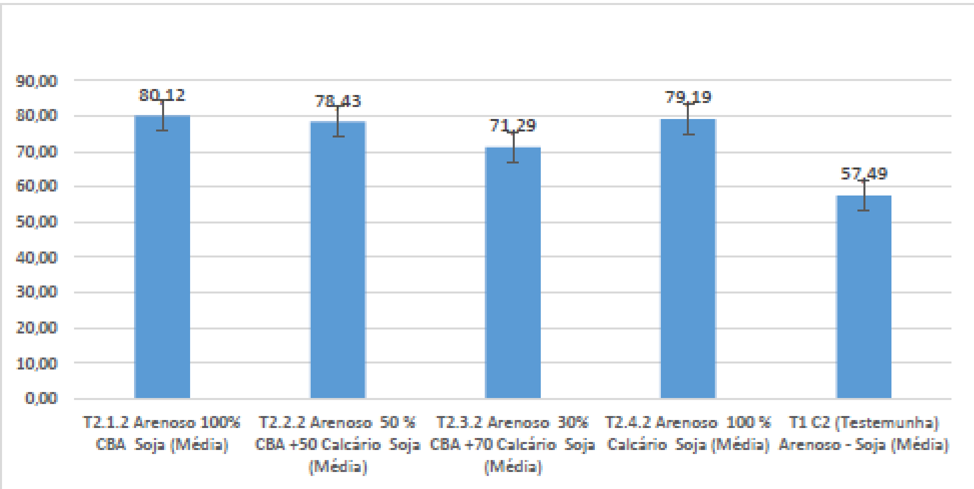

Figure 15. Soy productivity results for sandy soil.

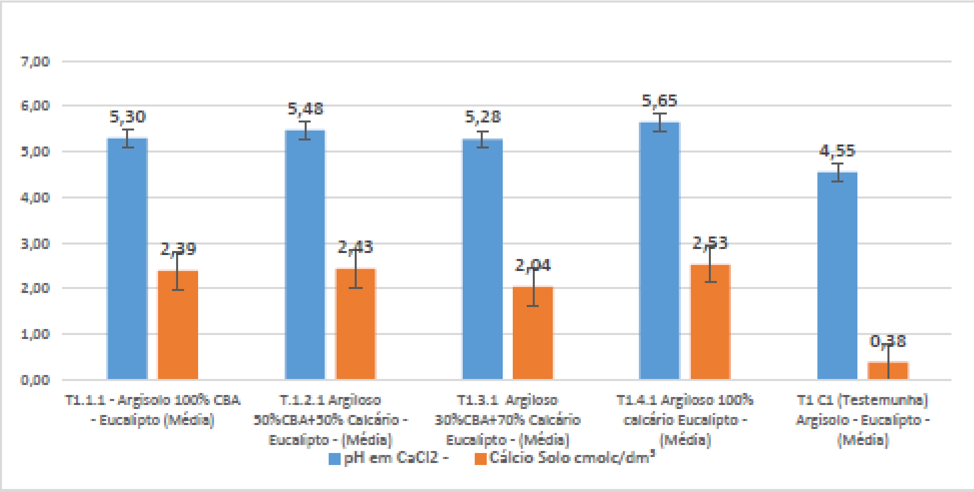

Figure 16. Eucalyptus pH $CaCl_2$ results for clay soil.

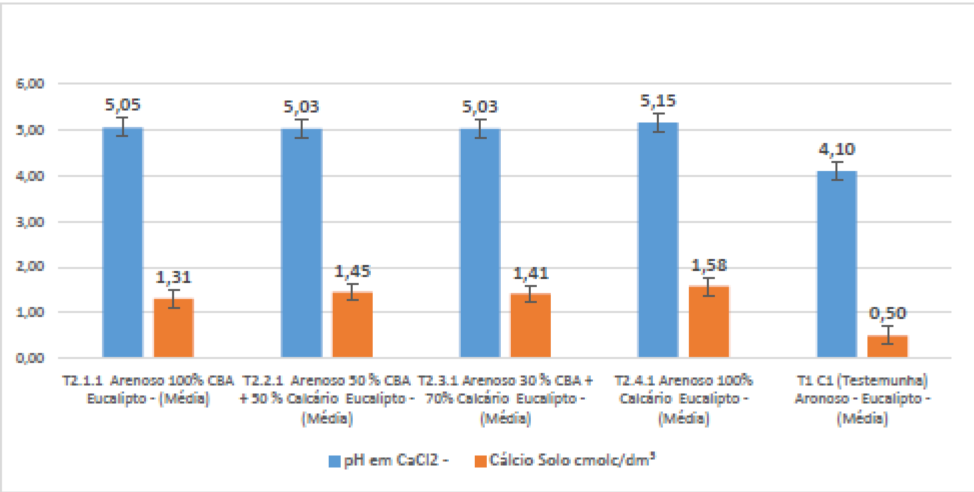

Figure 17. Eucalyptus pH $CaCl_2$ results for sandy soil.

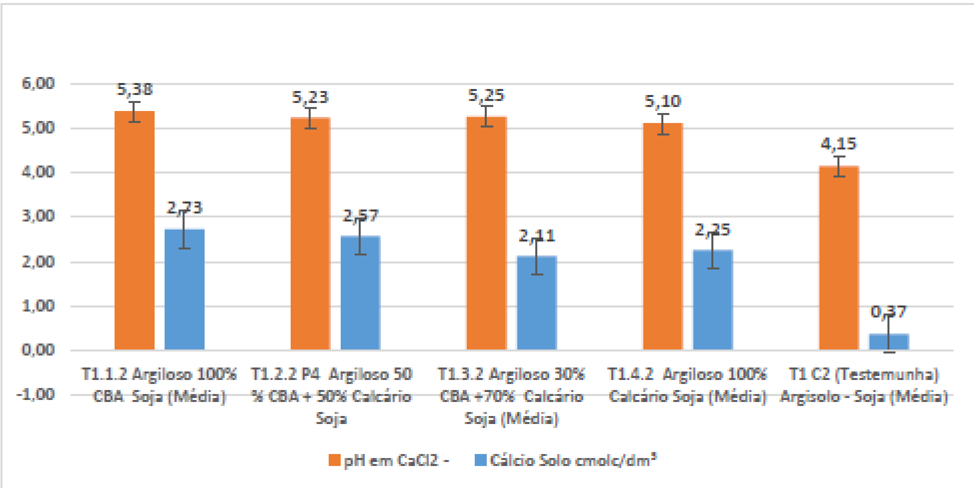

Figure 18. Soy pH $CaCl_2$ results for clay soil.

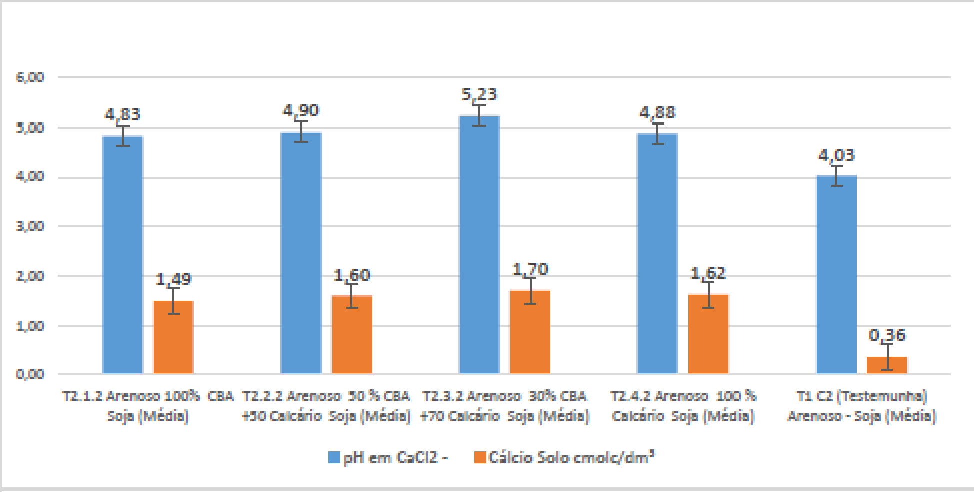

Figure 19. Soy pH $CaCl_2$ results for sandy soil.

In both soils and for both crops, the use of the CBA product resulted in morphological parameters (HT and DC in Eucaliptus), productivity (Soy), statistically equal to or higher than those observed for conventional limestone. Figures 10 to 14.

CBA product has demonstrated the ability to neutralize the active and the potential acidity of the soil and the ability to provide adequate amounts of calcium to the evaluated soils, similarly to the conventional limestone used, acting as a substitute in the treatments witch were carried out. Figures 15 to 19.

CBA product has the specific characteristics for its safe use as an agricultural corrective for soil acidity, adequately replacing conventional limestone in the treatments witch were carried out.

3.4 10 t/h Filter Press and Causticization Unit Modification

With the positive results from the lab, pilot and soil amendment tests a study was conducted to evaluate the necessary modification in the causticization unit and 10 tph filter press to start up the new process in the plant.

The agitated tank used to the conventional sidestream causticization did not require any modification and same applied to the lime slaking plant. However, the liquor from the dam temperature is much lower compare to the washer overflow. So, a plate heater exchanger was installed to increase the temperature and guarantee 90 ºC in the causticization tank.

The causticized liquor could be used in different areas such as flocculants preparation, gaskets and washing water. A new pipeline was installed to supply this liquor to the consuming areas.

The 10 t/h filter press set up was adjusted. A lower operating pressure and longer cycle time were implemented to achieve a good cake and filtrate quality.

After these modifications, the new process was started up. The 10 tph filter press performed very well in line with the expected results shown in Figure 20. In 3 years more than 1.6 million m³ of liquor from the dam was causticized and re-used in the plant. The dam achieved the essential condition to proceed with the filter press project, processing 100 % of generated bauxite residue.

Figure 20. 10 t/h filter press discharge and calcium carbonate cake.

The TC/TA of the plant did not suffer any loss. Even using a very high amount of causticized liquor from the dam. Figure 21 shows the plant TC/TA profile before and after the use of the causticized liquor.

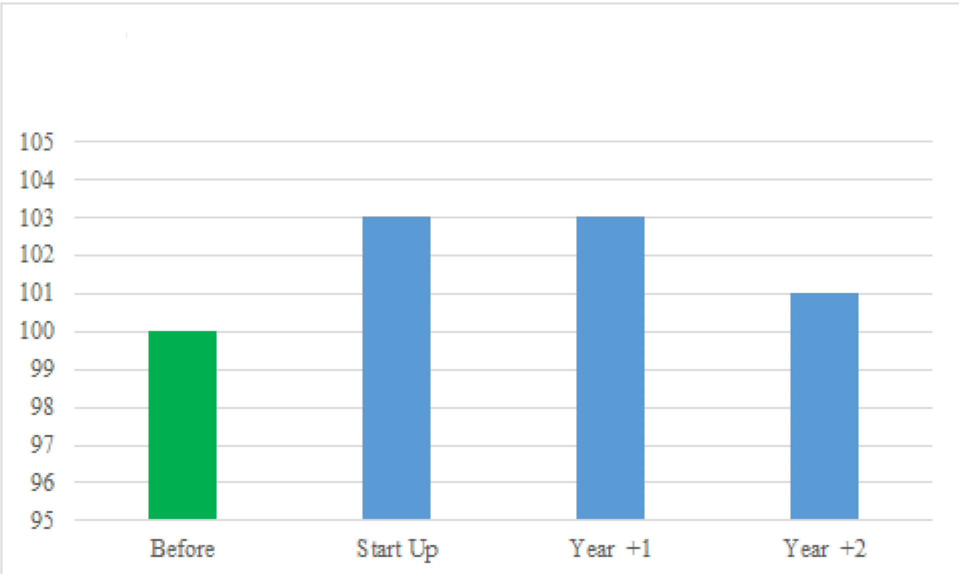

Figure 21. Plant TC/TA evolution compared to period before the new causticization unit start up.

3.5. The use of CBA Calcium Carbonate at Miraí Mine.

Currently, CBA applies this material at Miraí mining, located in Minas Gerais's sate, in the environmental rehabilitation process of mined areas, representing an excellent example of circular economy. Figure 22 presents this application.

Figure 22. Calcium Carbonate applied at Miraí Mine.

4. Conclusions

An optimum causticization reaction condition was determined in laboratory. It could be replicated in the pilot tests. The results were consistent to those found in the literature.

Filter press could be used to separate the precipitated calcium carbonate with a low moisture and caustic content.

Minor modifications were necessary in the plant and in the filter press set up to causticize the liquor from the dam.

The precipitated calcium carbonate was studied as soil amendment. This study shows that CBA product has the specific characteristics for a safe use as an agricultural corrective for soil acidity, adequately replacing conventional limestone.

These results allowed:

- The re-utilization of the causticized liquor in plant, significantly reducing the volume of liquor inside the dam, reaching the necessary condition to proceed with the disposal method change;
- The use of the calcium carbonate as soil amendment in Miraí mine in the environmental rehabilitation process of mined areas.

5. References

1. P. Sucharita, Current Status of an Industrial Waste: Red Mud an Overview, *IJLTEMAS*, August 2015, Volume IV, Issue VIII.
2. R. Seno, Use of Two Filtration Stages for Bauxite Residue, Proceedings of Technical Sessions at the 148th AIME Annual Meeting; San Antonio, TX, USA, 2019.
3. R. Seno, Votorantim Metais/CBA Bauxite Residue: Challenges and solutions, *Alumina Quality Workshop*, Perth, Australia, 19-23 April 2015, 117 -124.
4. D. Thomas, Impact of Liquor Causticity on Plant Operation, *Alumina Quality Workshop*, Bunbury, Australia, 1999, 21-26 March.
5. S. Rosenberg, Impurity Removal in the Bayer Process, *Proceedings of 35rd International ICSOBA Conference*, Hamburg, Germany, 2 – 5 October, 2017, Paper AL08.

6. Young Chemistry of Bayer Liquor Causticization, *Proceedings of Technical Sessions at the 111th AIME Annual Meeting*; Dallas, TX, USA, 1982, 97-117.