AA09 - Effect of Pre-Desilication Time and Temperature on Desilication Behavior of Low-Silica Guinea Bauxites

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Abstract

Desilication of Bayer liquor is a very important process step in achieving acceptable levels of silica content in liquor to precipitation in order to minimize process scaling issues and to produce alumina of acceptable quality.

Pre-desilication (holding bauxite slurry at elevated temperatures prior to digestion) is a common process step being followed by many alumina refineries. One of the Hindalco's alumina refinery processes bauxites of different quality, available from the indigenous as well as imported sources. One such imported bauxite source, which has been stabilized and has been in use consistently at the refinery is Guinea.

A detailed processability study was done and the conditions were optimized before using this bauxite source. However, over the period there were visible deviations from the performance, which required understanding (in detail) the desilication behavior and then adjusting the process conditions to achieve the desired process efficiencies in the refinery.

This study identifies the optimum process conditions to be followed by the refinery, through statistically designed laboratory experiments for the Guinea bauxite samples containing low levels of silica. The desilication efficiency is evaluated considering predesilication temperature (90–95 °C) and time (16–22 h), and response being silica ratio, silica supersaturation and silica attack. To achieve the targeted silica ratio, silica supersaturation and silica attack values, pre-desilication and low-temperature digestion conditions are optimized for each of the low silica bauxites. This provides the refinery with flexibility of selecting the most appropriate process conditions based on the properties of bauxite being processed.

This paper presents the details of the studies conducted with various bauxite samples from Guinea, the results obtained, and the process conditions finalized.

Keywords: Bauxite, Desilication, Guinea, Kaolinite, Silica.

1. Introduction

All bauxites contain silica in various amounts mainly as kaolinite and some parts in the form of quartz. Depending on the digestion temperature chosen for treating particular bauxite, all of kaolinite and some part of the quartz react with caustic at elevated temperatures. Desilication is the phenomenon of silica content in bauxite reacting with caustic and its re-precipitation as sodium aluminium silicate, commonly called Bayer sodalite. Optimum desilication is desired essentially to control silica content in liquor going to hydrate precipitation stage. High level of silica content in liquor adversely affects liquor heater performance through formation of sodalite scale and increasing silica contamination in hydrate product.

One of the refineries of Hindalco was processing bauxites from the west coast mines of India. Over the years, the bauxite mines were depleted and hence the bauxite source shifted to a combination of imported and indigenous bauxite from India. Through various bauxite processability studies, the bauxite sources were optimized, and the major imported bauxite source used was from Guinea. Since the Guinea bauxite was a low silica bauxite requiring a longer predesilication (PDS) residence time and accordingly the plant desilication section was upgraded to include more tanks. Visible plant performance deviations appeared over time which were obviously due to the bauxite reactivity under the plant conditions. This required understanding (in detail) the desilication behavior and then adjusting the process conditions to achieve the desired process efficiencies in the refinery.

This paper presents the details of the studies conducted with various bauxite samples from Guinea, the results obtained, and the optimum process conditions that were identified.

2. Conceptual Approach

The desilication process starts with the kaolinite ($k.SiO_2$) dissolution and is completed by Bayer sodalite precipitation, as described in the following simplified reactions [1]:

$$Al_2O_3\ 2SiO_2\ 2H_2O + 6NaOH \rightarrow 2Na_2SiO_3 + 2NaAlO_2 + 5H_2O \quad (1)$$

$$6Na_2SiO_3 + 6NaAlO_2 + Na_2X + 12H_2O \rightarrow 3(Na_2O\ Al_2O_3\ 2SiO_2\ 2H_2O)Na_2X + 12NaOH \quad (2)$$

Incorporation of a PDS step, wherein bauxite slurry is held in atmospheric tanks at somewhat elevated temperatures (80 to 95 ºC) for long duration ranging from 8 to 24 hours has become a widespread practice in alumina refining. Process conditions in PDS step as well as those in digestion are adjusted/controlled in an optimum way so as to ensure that the silica content in liquor after digestion is within acceptable limits. In any operating refinery, the digestion conditions like temperature and residence time are almost fixed and can be varied only in a very narrow range. Hence, optimization of desilication is mainly achieved through optimization of PDS conditions. Though the aim of desilication is to achieve the lowest silica content in liquor, which would be equivalent to the theoretical solubility of silica under the given conditions, it is not practically possible to achieve the same under normal operating conditions. Hence, to find out the practical limits, that would be considered as acceptable, two terminologies are defined (as given below):

a) Silica Ratio = [Actual silica content in liquor at certain conditions / Equilibrium silica content under the same conditions] [2]

b) Silica Supersaturation, g/L SiO_2 = [Actual silica content in liquor - Equilibrium silica content]

It is a common practice to calculate the Equilibrium silica content using the Oku-Yamada equation [3,4] as given below:

$$Equilibrium\ silica\ content,\ g/L\ SiO_2 = 1.58 \times 10^{-5} \times C \times A \quad (3)$$

where:
C Caustic concentration, g/L Na_2CO_3
A Alumina concentration, g/L Al_2O_3

Practically, in the Hindalco alumina refineries, it has been observed that if Silica Ratio is controlled below 1.27 and Silica supersaturation below 0.15, desilication can be considered as acceptable [5].

Hence in this project, the impact of the pre-desilication conditions on the desilication behavior as well as the extraction efficiency has been studied in detail for the Guinea bauxites.

3. Experimental Details & Results

3.1 Bauxite

Guinea bauxite samples received from the refinery were dried and sampled to nominal -30 mesh and then analysed for elemental and phase composition [2]. The analysis of the Guinea bauxite samples is given in Table 1.

Table 1. Analysis of Guinea bauxite samples.

Description	UoM	Bauxite* GN-0	Bauxite GN-1	Bauxite GN-2	Bauxite GN-3	Bauxite GN-4	Bauxite GN-5
LOI	%	25.7	25.3	25.7	24.9	24.9	23.2
Al_2O_3	%	49.3	50.4	46.5	45.6	45.6	51.1
Fe_2O_3	%	20.1	18.8	22.8	24.1	24.1	20.5
SiO_2	%	1.81	1.58	1.84	2.08	2.08	1.60
TiO_2	%	2.49	3.31	2.48	2.61	2.61	2.88
CaO	%	0.05	<0.001	0.006	0.004	0.007	0.005
P_2O_5	%	0.10	0.15	0.12	0.09	0.10	0.10
V_2O_5	%	0.15	0.11	0.12	0.09	0.12	0.12
THA**	%	44.7	42.8	40.0	39.9	39.9	41.5
k.SiO_2	%	0.80	0.97	1.58	1.45	1.45	0.81
Quartz	%	1.01	0.61	0.26	0.63	0.63	0.79

* GN-0 bauxite corresponds to the original EGA bauxite received at the refinery and GN-1 to GN-5 are subsequent yearly samples.
** Trihydrate alumina, $Al_2O_3 \cdot 3H_2O$ or $Al(OH)_3$.

The following observations were made:

- Over the years, the quality of the Guinea bauxite has changed considerably, there is a reduction in the total alumina content with a corresponding reduction in the THA content.
- The k.SiO_2 content has also shown an increasing trend with a corresponding increase in the quartz content.

Hence it was important to understand the impact of these changes on the desilication performance of the bauxite samples and determine the optimum operating conditions.

3.2 Optimised Conditions for Guinea Bauxite (First Consignment)

Process ability studies were conducted with the Guinea bauxite sample, received from the refinery to arrive at the optimum conditions for desilication and extraction efficiency.

3.2.1 Optimised PDS Conditions

Based on the experience in processing low silica bauxites earlier, PDS optimisation tests were conducted under two PDS temperature and residence time conditions. The optimised conditions were selected based on the maximum k.SiO_2 attack obtained [3]. The results of the test are represented in Figure 1.

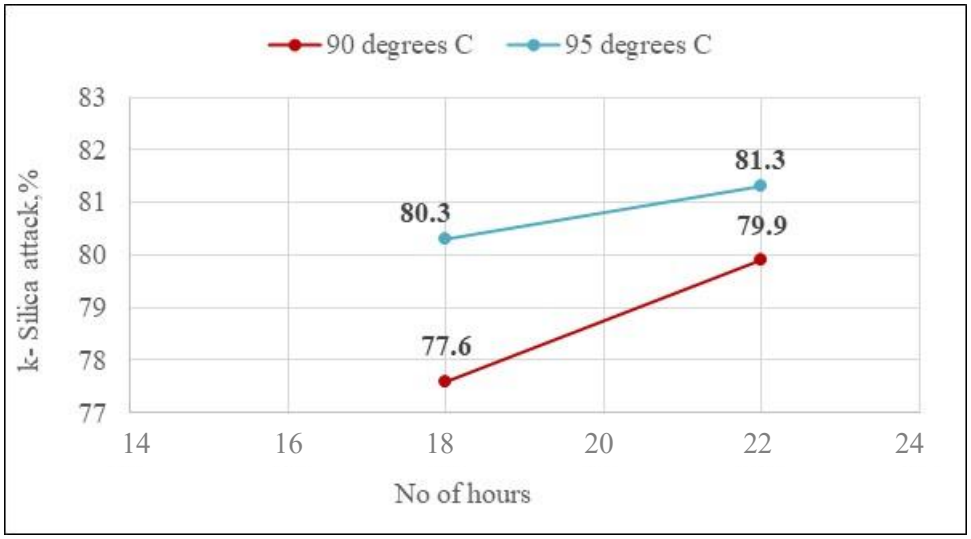

Figure 1. k.SiO_2 attack at different PDS temperature and time.

The following observations can be made about the graph shown in Figure 1:

- There is an increase in the k.SiO_2 attack with an increase in the PDS residence time from 18 to 22 h.
- The maximum k.SiO_2 attack obtained is 81.3 % at PDS, which is a fairly good number.
- Hence 95 °C and 22 h was selected as the optimum PDS condition.

3.2.2 LTD Optimised Conditions

LTD optimisation tests were conducted using the optimised PDS conditions identified above (95 °C and 22 h). Two (2) digestion temperatures and residence times of were tested. The optimum condition was selected based on the achievement of target silica ratio < 1.27 and silica supersaturation < 0.15. The optimised condition is presented in Table 2.

Table 2. LTD optimised conditions.

Digestion Temperature, °C	138		**145**	
Digestion Time, min	45	60	**45**	60
Liquor Silica, g/L SiO_2	0.79	0.76	**0.69**	0.72
Silica ratio	1.44	1.36	**1.26**	1.30
Silica supersaturation , g/L SiO_2	0.24	0.20	**0.14**	0.16
THA Extraction, %	99.8	99.7	**99.7**	99.8

The following observations can be made about the data shown in Table 2:

- To achieve 100% k.SiO_2 attack, the higher digestion temperature of 145 °C was selected.
- For the same digestion temperature, there is a reduction in the liquor silica levels with an increase in the digestion residence time. However, the reduction in liquor silica is more evident with a higher digestion temperature of 145 °C.
- The silica ratio and silica supersaturation values show a reduction with an increase in residence time from 45 to 60 minutes at 138 °C digestion temperature. However, the effect is opposite at digestion temperature of 145 °C.
- Target silica ratio and silica supersaturation values are obtained with 145 °C and 45 minutes digestion time.
- Digestion temperature and time do not seem to have any impact on the THA extraction efficiency.

3.3 Optimised Conditions for Guinea Bauxite (Subsequent Consignments)

The optimised PDS-LTD conditions were implemented in the refinery and the subsequent bauxite samples were tested in the refinery under the selected conditions. However, a drop in the THA extraction efficiency was observed in the refinery, as shown in Figure 2, after the first Guinea bauxite consignment (green bar in the graph below).

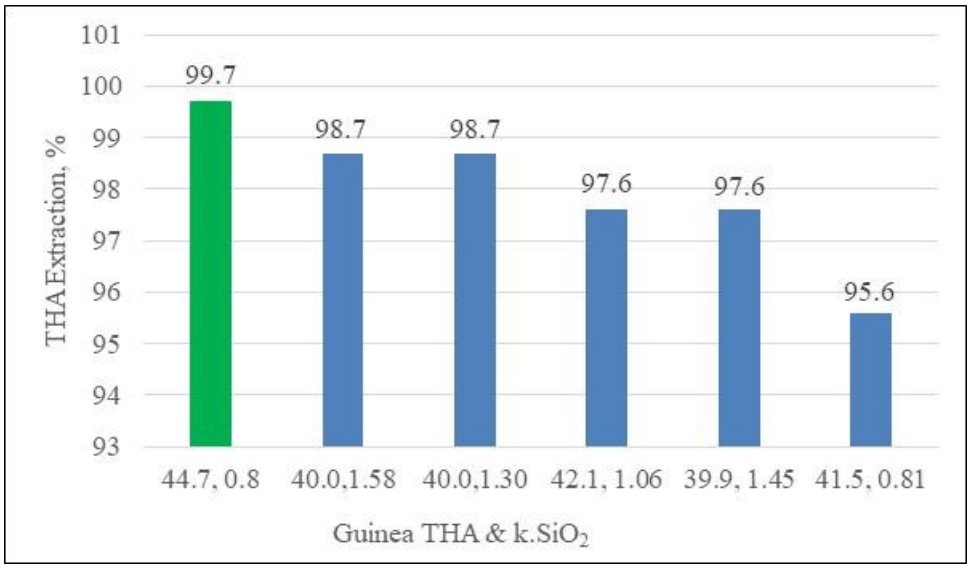

Figure 2. THA extraction efficiency for 6 Guinea bauxite samples.

Figure 2 shows the extraction efficiency for the first consignment (represented by green bar) and the subsequent consignments:

- There is a consistent drop in THA extraction for the Guinea bauxite samples received year-over-year.
- THA extraction is the lowest for the last sample (41.5, 0.81).

Based on the drop in the observed extraction efficiency, it was decided to review the optimised PDS-LTD conditions for the most recent Guinea bauxite samples.

3.4 Effect of Predesilication Time on THA Extraction Efficiency

Detailed PDS-LTD tests were conducted at two PDS residence times of 16 and 20 h while keeping the other conditions similar, in order to study the impact of lower residence time on the desilication efficiency as well as THA extraction efficiency. The results of these tests are shown in Figure 3, where a consistent drop in the THA extraction efficiency is observed with the increase in the PDS residence time from 16 h to 20 h.

Based on the laboratory studies, the refinery process data was also analysed to understand the significant factors affecting THA extraction. A predictive model was developed using one (1) year of process data and the stepwise regression method. The objective of the model was to verify the observations made during the PDS-LTD laboratory studies (Figure 3). The results of the predictive model are presented in Figure 4.

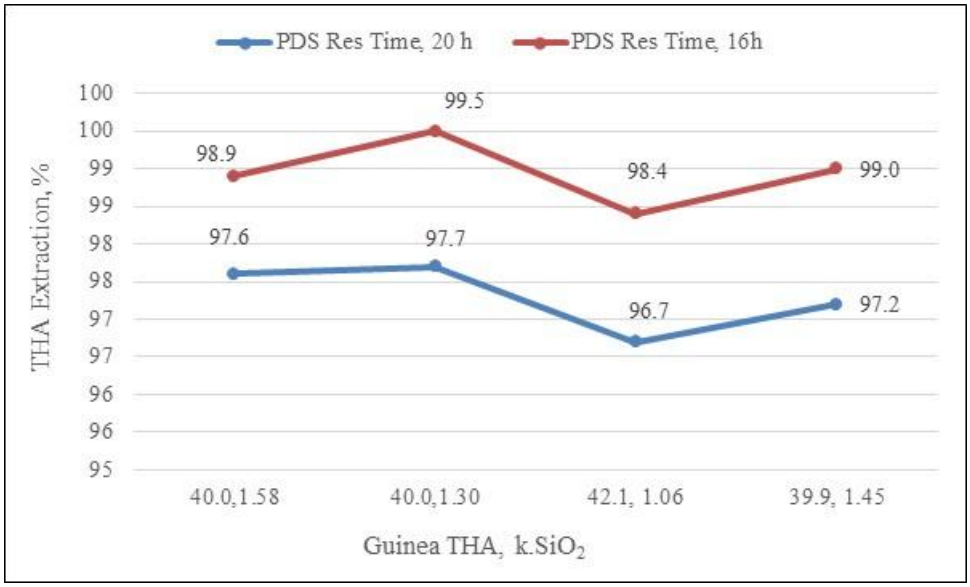

Figure 3. Effect of PDS residence time on THA extraction.

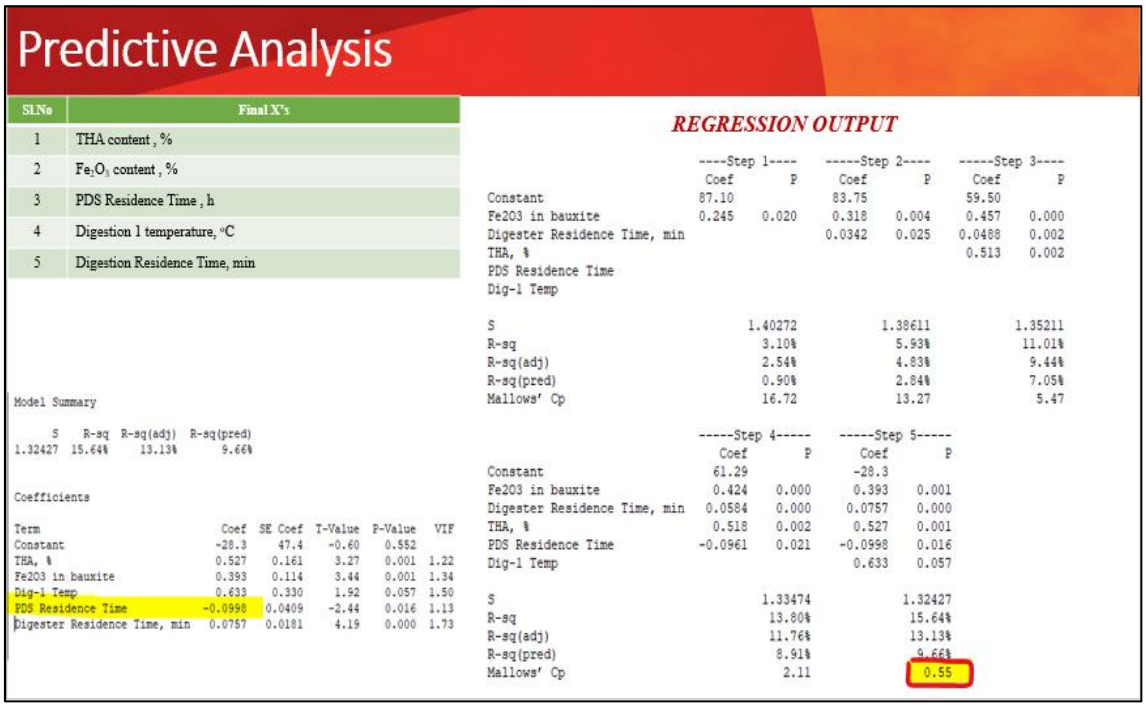

Figure 4. Predictive model for THA extraction.

Observations from the predictive model shown in Figure 4 are as follows:

- Of all the models tested, this model has the lowest Mallows' Cp of 0.55.
- THA extraction shows a strong and positive relationship with THA, Fe_2O_3 content and digestion conditions.
- Only PDS residence time has a negative correlation co-efficient, indicating an increase in THA extraction with a decrease in PDS Residence time, matching with the testwork results given in Figure 3.
- Even though the R^2 of the predictive model is lower, there are no large residuals and unusual X's.

Thus, the impact of PDS residence time on the achieved THA extraction from the PDS-LTD laboratory studies with the Guinea bauxites was confirmed by the predictive model using plant data. Hence based on the results, the PDS residence time was adjusted to 16–17 h from the original level of 22 h to achieve the desired desilication as well as extraction efficiency.

4. Discussion:

This study focusses on determining the optimum desilication conditions for low silica Guinea bauxite. PDS-LTD studies conducted under varying conditions of temperature and time showed that a PDS at 95 °C for 22 h, and an LTD at 145 °C for 45 minutes, the target silica ratio (< 1.27) and silica supersaturation (< 0.15 g/L) were achieved, as well as a higher THA extraction. However, over the years, a drop in THA extraction efficiency was observed when Guinea bauxite shipments were processed in the refinery under these optimised conditions. Hence the desilication conditions were studied again in detail by varying the PDS residence time, while keeping other parameters constant. This was made possible because of the flexibility of operation in the refinery at varying PDS residence times.

THA extraction efficiency was dropping by ~1.2–1.3 % with an increase in the PDS residence time from 16 h to 20 h. For further investigation, a predictive model was developed for estimating the THA extraction. The model results showed that, of all the process parameters analysed, only bauxite quality parameter such as k.SiO_2 long with PDS residence time are found to be significant. This further confirmed the findings from the PDS-LTD optimisation tests. Hence based on the studies and the predictive model, the PDS residence time in the refinery was reduced to 16–17 h to optimise desilication efficiency and maximise THA extraction. This resulted in steady operation of the refinery.

Hence, we can conclude that bauxite k.SiO_2 content and PDS residence time both have a significant impact on the desilication efficiency, even though the bauxite is from the same source. This study is a convincing demonstration that it is imperative to study the desilication and digestion performance of the bauxite samples on a regular basis to verify the performance and accordingly optimise the desilication and digestion conditions, in order to ensure both a steady refinery operation and an optimum bauxite utilisation.

5. References

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