

Development of a Model for Optimization of Bauxite Sources to Achieve Operational Excellence in Alumina Refinery

Sagar Pandit¹, Vikram Usulkar², Asutosh Acharya³, Sandeep Patil⁴ and Kaushal Gupta⁵

1. General Manager – Bayer Process Development

2. Senior Engineer – Analytical Development

3. Assistant General Manager – Analytical Development

Hindalco Innovation Centre – Alumina, Hindalco Industries Limited, Belagavi, India

4. General Manager – Standard Production

5. Manager – Technology & Process

Hindalco Industries Limited, Belagavi Works, Belagavi, India

Corresponding author: pandit.sagar@gmail.com

Abstract

Availability of a consistent quality and long-term sustainable bauxite source is a major challenge for the Bayer refineries around the world. With the depletion of high-grade bauxite ores and stringent environmental regulations, it is extremely challenging for most Indian alumina refineries to access indigenous high-quality bauxite ore for smooth operation of the process. Accordingly, there is a shift in the overall bauxite sourcing strategy, with imported bauxite ores making up a percentage of the overall bauxite requirements for the refineries. With this change, there is a need to revisit the overall refinery process control strategy owing to the sharp difference in the processing characteristics of both indigenous and imported bauxites. A model for bauxite source optimization has been developed to forecast the blend ratio for better process control in a plant. Bauxite sources (received at the refinery) were analyzed for their processing characteristics and the data used to optimize the blend ratio. The model developed entails a three-point strategy for evaluation of the bauxite sources and consists of a combination of i) preliminary screening of bauxites, ii) generation of detailed processing data and iii) a summary of bauxite performance for plant scale implementation at refinery. The developed strategy was put into practice through plant scale trials, where the performance of the various bauxite sources were analyzed for suitability of operations with various bauxite combinations. This unique model for bauxite source optimization led to achieving overall operational excellence for the refinery, with significant improvement in operational efficiencies, reduction in specific consumption factors including overall cost reduction in specific bauxite and caustic consumption, along with an increase in the liquor productivity. This paper presents a detailed explanation of model development, its application, and the benefits in terms of operational excellence for the alumina refinery.

Key Words: Bauxite, Bayer, Excellence, Model, Processability, Sourcing.

1. Introduction

Availability of high-grade bauxite reserves is a major challenge for the alumina refineries across the world. Stringent environmental regulations have made it extremely challenging for sourcing high quality bauxites for steady operation of refineries. In the context of India, alumina manufacturers are forced to shift the bauxite sourcing strategy from operating with only indigenous bauxites, to having a mix of imported and indigenous bauxites. This has led to a change in operating philosophy for bauxite sourcing due to the marked difference in processing characteristics of imported and indigenous bauxites.

Conventional philosophy for bauxite sourcing involved the evaluation of bauxite samples in the laboratory, then sharing of the results to the plant team. Based on the results from the processability studies, the bauxite sample was used in the refinery, unless a drastically negative

performance of the bauxite was found to be expected. This method worked well initially, since the bauxite samples were from a single mining location, and so drastic differences in the processing characteristics of the bauxite samples did not arise. However, with the change in the bauxite sourcing plan, the overall process control strategy of the alumina refineries needed to be revisited owing to the sharp difference in processing characteristics of both indigenous and imported bauxites [1].

With a view to forecast the preferred blend ratio for the different bauxites and improving process control in a plant, a model for bauxite source optimization has been developed. Model development involved analyzing all the bauxite sources (received at the refinery) for their processing characteristics, then using this data to optimize the blend ratio in the refinery. This unique model for bauxite source optimization led to achieving overall operational excellence for the refinery, with significant improvement in operational efficiency.

This paper details the process of model development, its application, and the benefits in terms of operational excellence for the alumina refinery.

2. Conceptual Approach

Bauxite processing studies involve simulating the alumina refinery unit operations of Predesilication, Digestion, Settling, Precipitation as well as organic carbon build up with the bauxite sample under evaluation. The process involves the following steps:

1. Optimisation of process conditions for predesilication & digestion
 - a. These tests are done on a small scale using parr bombs
 - b. Conditions of interest being temperature, residence time and charging A/C optimization.
2. Evaluation of settling, filtration, and organic load
 - a. Tests under optimized conditions to evaluate settling, liquor filtration and bauxite residue filtration
 - b. Cyclic organic load tests to determine the organic and oxalate conversion

Any new bauxite source was evaluated using the above procedure, in order to arrive at a set of process conditions which could be implemented by the refinery for the specific bauxite, along with gaining an understanding of the expected settling and the filtration characteristics.

In order to make this philosophy more relevant in relation to using a blend of bauxites from imported as well as indigenous sources, a 3-step evaluation strategy was developed. This strategy focused on preliminary screening of bauxites as well as development of a summary document outlining the plant scale implementation philosophy. This improved philosophy would help to speed up the process of bauxite evaluation as well as bridge the gap between laboratory generated data and plant scale implementation strategy.

3. Development of Model for Bauxite Source Optimization

Alumina refineries in India, currently face a major challenge in terms of adjusting the process conditions when using combinations of indigenous and imported sources as this can include as many as 5-10 or more sources of bauxite.

Historical data on the processing characteristics of imported bauxites show that there is a major difference in the quality, especially with respect to the lower reactive silica ($k \text{ SiO}_2$) content and higher organic carbon content. Thus, processing of these bauxites in a blend with some indigenous

sources requires technological differences in terms of the higher residence time in Predesilication and a higher sodium oxalate removal rate.

The challenge was to develop a strategy for bauxite sourcing and evaluation, aligning with the refinery technology, so as to have a seamless integration. Major bottlenecks in terms of development of the model to address this challenge were however:

1. Non availability of historical data for the individual bauxite sources:
 - a. Bauxites were received from different mining locations
 - b. There was variability, not only location-wise but also within the same location, making quality mapping a complex process
 - c. Conducting the analysis of all the parameters for each of these bauxite sources received was a challenge:
 - i. Historical data based on single location bauxite blends was insufficient for analyzing new bauxite sources
 - ii. New bauxite sources required detailed mineralogical analysis along with elemental composition to assess the initial processing characteristics
 - iii. Mix of indigenous and imported bauxite blends made process optimization a difficult task.
2. Correlating the impact of optimized conditions on process parameters:
 - a. Optimized conditions for each of the bauxite sources had to be correlated with the plant conditions in order to arrive at the optimum blend ratio
 - i. Correlations were established by conducting plant trials for the various bauxite blends and arriving at optimum conditions

All the bauxite sources (received at the refinery) were analyzed for their processing characteristics and then a model for bauxite source optimization was developed to forecast the blend ratio for the different bauxites in order to achieve better process control in a plant.

A three-point strategy for evaluation of these bauxite sources was developed and is detailed below. This was used for finalizing bauxite sources for the refinery.

1. Preliminary Analysis:

Initial analysis of bauxite for elemental composition, as well as phases were done to ascertain the qualification of bauxite for the processability study.

 - a. Elemental and phase composition of bauxite samples determined were
 - i. Correlation of the major parameters namely Al_2O_3 , Fe_2O_3 , SiO_2 , CaO , G/H (Goethite to Hematite Ratio), OC (Organic Carbon) & IC (Inorganic Carbon)
 - ii. Values of these parameters were compared with the standards established for the refinery, based on historical data
 - iii. Any bauxite having parameters lower than the standard were not taken to the next stage
2. Detailed Processability Studies:

The bauxite samples which qualified from the preliminary analysis, were further analyzed in a detailed processability study for capturing the desilication, digestion, settling & filtration performance, along with organic carbon input assessment.

 - a. Optimisation of predesilication and digestion conditions was done using small scale tests with parr bombs
 - b. Settling, filtration and organic carbon inputs were estimated under the optimized conditions

- c. Technological changes such as addition of tanks for increased residence time in Pre-desilication for low silica bauxites, causticisation flow increase based on carbonate balance etc. were implemented in refinery.

3. Summary:

The data from all the processability studies were summarized in the form of a spreadsheet & this data was used for projecting the performance of different bauxite blends to be processed at the refinery.

The entire model philosophy is explained by the flow-chart, given in Figure 1.

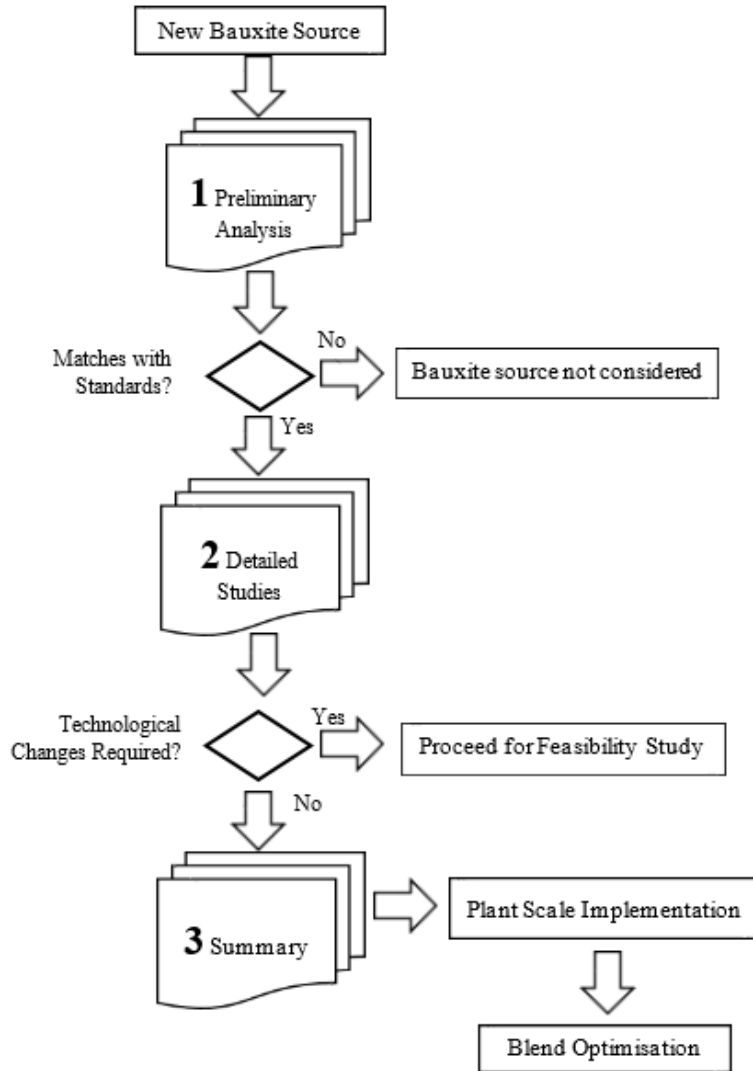


Figure 1. Model for Bauxite Source Optimization.

4. Model Application and Benefits

This strategy of analyzing the performance of the various bauxite sources to find out its suitability for Refinery operations, was put into practice through plant scale trials with various bauxite combinations [2,3,4]. The data from the processability studies was captured in a summary sheet which was used for estimating the settling & filtration performance. This was useful in optimizing the temperature profile for pre-desilication and digestion and also in arriving at an average

flocculant dosage for the bauxite blend, in order to avoid any issues during actual implementation of bauxite blend in the refinery. The summary sheet is presented in Table 1.

Table 1. Summary of Bauxite Processability Studies.

Sl. No	Bauxite used	Bauxite Analysis		THA Extraction	Settling test results (Target settling rate : 5-10 m/h)		BR Filtration Rate (Kg/m ² -h)
1	INDG-1	Fe ₂ O ₃	27.9	98.8	Dosage, (PA+Hx-PAM) g/t	17+215	300
		SiO ₂	6.66		overflow solids, mg/L	144	40.1
		THA	30.4		Filtration rate, L/h	7.2	
		k-SiO ₂	5.63		underflow solids, g/L	30.9	
2	INDG-2	Fe ₂ O ₃	18.8	87.8	Dosage, (PA+Hx-PAM) g/t	34+339	373
		SiO ₂	13.7		overflow solids, mg/L	270	
		THA	26.9		Filtration rate, L/h	1.6	
		k-SiO ₂	10.2		underflow solids, g/L	30.5	
3	INDG-3	Fe ₂ O ₃	27.3	100.2	Dosage, (PA+Hx-PAM) g/t	16+151	340
		SiO ₂	4.01		overflow solids, mg/L	180	
		THA	35.4		Filtration rate, L/h	6.7	
		k-SiO ₂	3.44		underflow solids, g/L	33.7	
4	INDG-4	Fe ₂ O ₃	16.8	98.5	Dosage, (PA+Hx-PAM) g/t	27+292	293
		SiO ₂	4.35		overflow solids, mg/L	98	
		THA	40.9		Filtration rate, L/h	3.3	
		k-SiO ₂	3.37		underflow solids, g/L	25.7	
5	INDG-5	Fe ₂ O ₃	19.4	96.1	Dosage, (PA+Hx-PAM) g/t	18.9+272	331
		SiO ₂	3.92		overflow solids, mg/L	146	
		THA	39.9		Filtration rate, L/h	3.2	
		k-SiO ₂	3.03		underflow solids, g/L	29.1	
6	IMP-1	Fe ₂ O ₃	16.3	98.7	Dosage, (PA+Hx-PAM) g/t	21+249	213
		SiO ₂	4.13		overflow solids, mg/L	218	
		THA	44.4		Filtration rate, L/h	2.4	
		k-SiO ₂	3.10		underflow solids, g/L	25.3	
7	IMP-2	Fe ₂ O ₃	14.0	99.5	Dosage, (PA+Hx-PAM) g/t	300+0	203
		SiO ₂	0.14		overflow solids, mg/L	130	
		THA	45.4		Filtration rate, L/h	1.5	
		k-SiO ₂	0.13		underflow solids, g/L	22	
8	IMP-3	Fe ₂ O ₃	17.4	98.7	Dosage, (PA+Hx-PAM) g/t	22+162	285
		SiO ₂	1.52		overflow solids, mg/L	112	
		THA	46.3		Filtration rate, L/h	6.9	
		k-SiO ₂	1.29		underflow solids, g/L	28.9	

Sl. No	Bauxite used	Bauxite Analysis		THA Extraction	Settling test results (Target settling rate : 5-10 m/h)		BR Filtration Rate (Kg/m ² -h)
9	IMP-4	Fe ₂ O ₃	18.6	97.5	Dosage, (PA+Hx-PAM) g/t	16+189	293
		SiO ₂	1.95		overflow solids, mg/L	154	
		THA	42.7		Filtration rate, L/h	6.7	
		k-SiO ₂	1.00		underflow solids, g/L	29.6	
10	IMP-5	Fe ₂ O ₃	17.5	95.9	Dosage, (PA+Hx-PAM) g/t	24 + 146	258
		SiO ₂	1.51		overflow solids, mg/L	152	
		THA	47.1		Filtration rate, L/h	6.00	
		k-SiO ₂	0.79		underflow solids, g/L	28.8	
11	IMP-6	Fe ₂ O ₃	18.7	99.0	Dosage, (PA+Hx-PAM) g/t	25+382	308
		SiO ₂	4.09		overflow solids, mg/L	252	
		THA	43.4		Filtration rate, L/h	2.0	
		k-SiO ₂	2.71		underflow solids, g/L	24.0	

INDG : Indigenous , IMP – Imported , PA : Polyacrylate , Hx-PAM : Hexamethylene Polyacrylamide

The summary sheet captures all the major information pertaining to the bauxite sample namely:

1. Major elemental & phase composition of the bauxite, which gives an idea of the impact on the process
2. THA extraction efficiency (calculated), which is important in terms of understanding the efficiency of digestion
3. Settling performance (estimated from the flocculant dosage), overflow solids and filtration rate for a target settling rate
4. Bauxite residue filtration rate was also determined

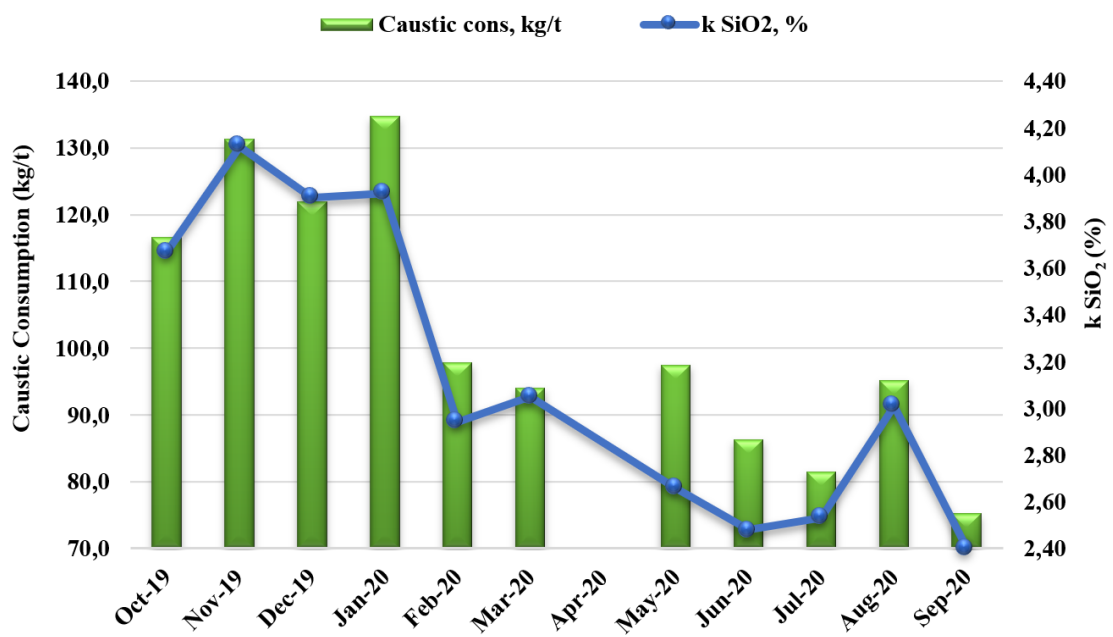
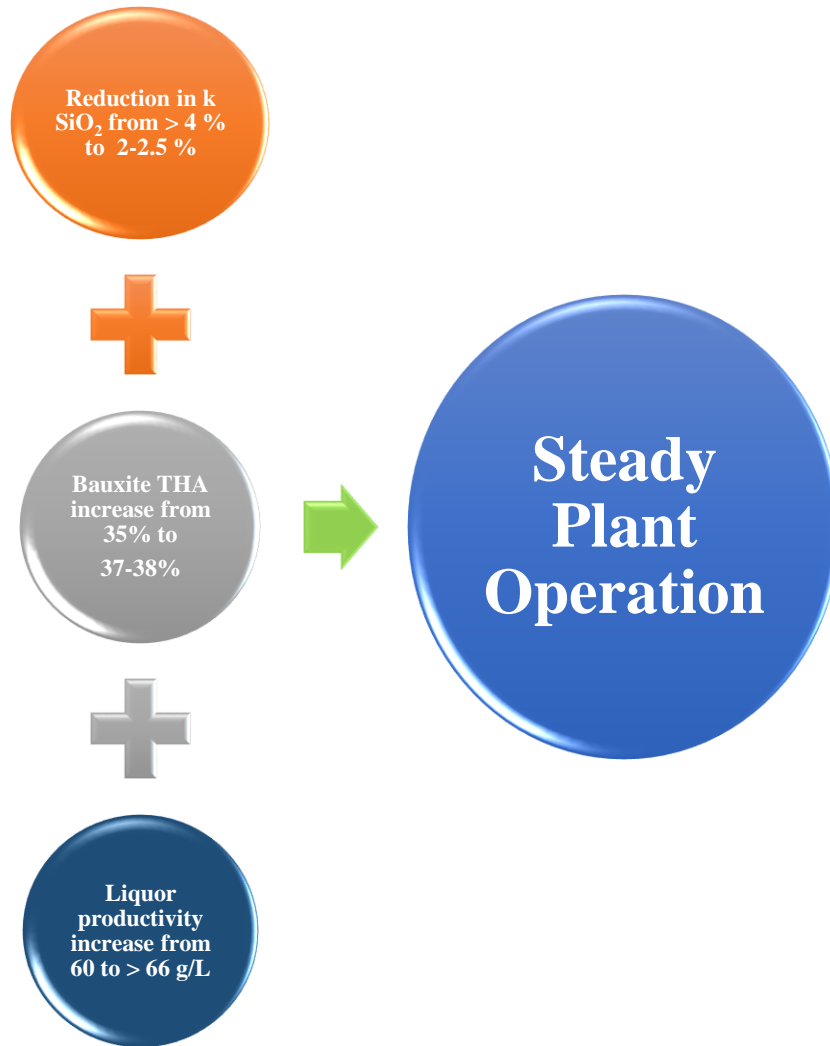
All these parameters give an overall idea of the processing characteristics of the bauxite sample and allows the flexibility of testing different bauxite blends for the average performance before actually testing in the refinery.

4.1 Benefits of the Model

The implementation of the model for bauxite sourcing, led to the following benefits

1. Based on the data generated from the model and plant implementation experience, refinery could arrive at possible long term bauxite sources and the targeted blend composition
2. Summary data was extensively used for blend ratio optimization
3. Process control philosophy shifted from reactive to proactive, thereby leading to steady refinery operation
4. Model serves as a unique process of standardization of bauxite processability studies and application to plant scale.

Implementation of this unique model for bauxite source optimization commenced in May2020 after plant shut-down in April 2020, and led to achieving overall operational excellence for the refinery, with significant improvement in the operational efficiencies as given in Figure 2.



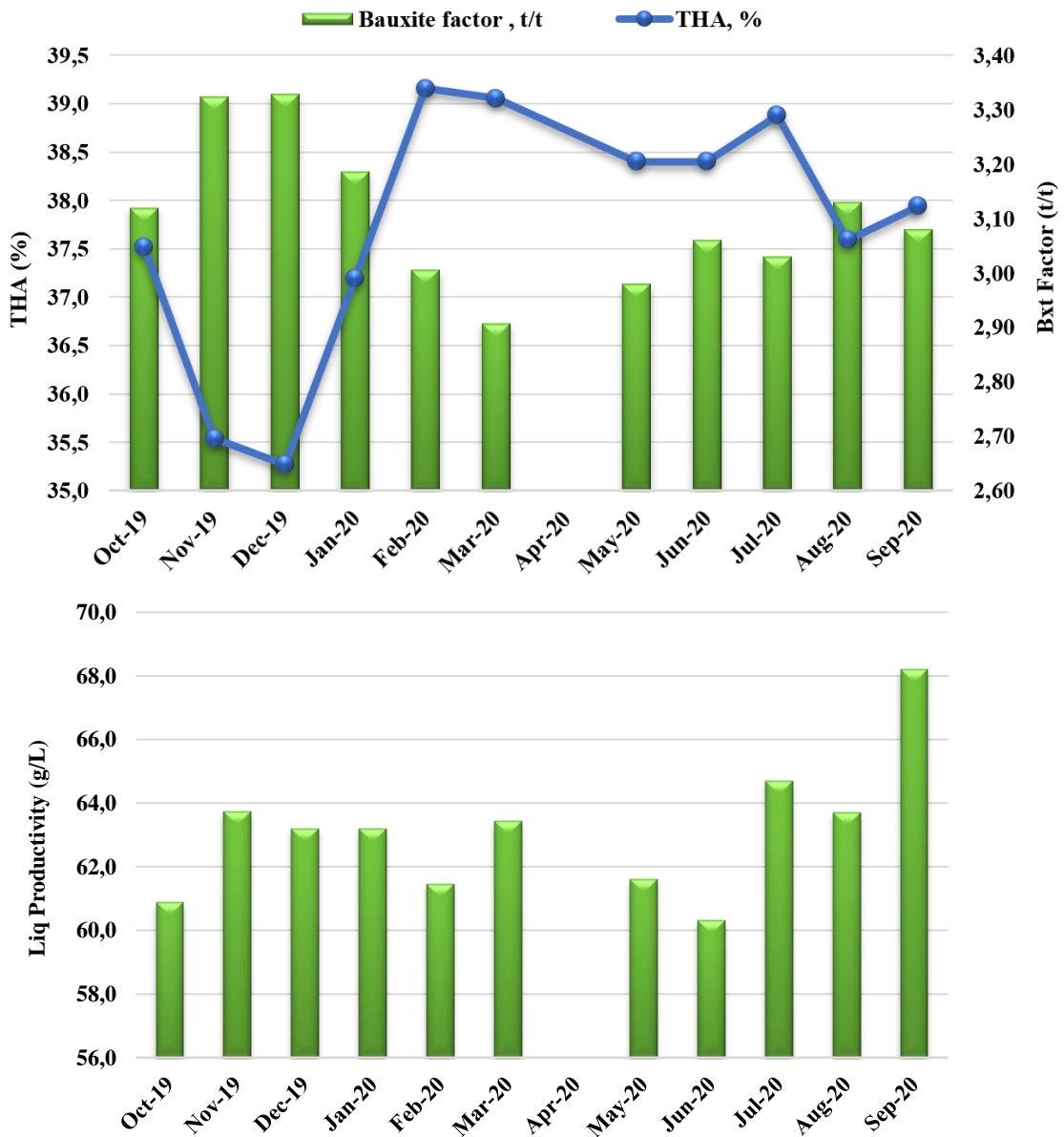


Figure 2. Benefits from Model Application.

The bauxite sourcing process was streamlined through the application of this model. There was an improvement in the feed bauxite quality to the refinery with an increase in THA content. The consistency in feed bauxite quality was reflected in the steady operation of the refinery thereby achieving higher liquor productivity.

Overall, this project has helped the refinery to devise a strategy for successfully processing bauxites from various sources and thereby stabilizing plant operations.

5. Conclusion

Bauxite sourcing is a major challenge for the alumina refineries around the world considering the non-availability of high-quality bauxites coupled with the stringent environmental regulations. In India, the conventional way of operating with bauxites from a single mine location is no longer valid. Consequently, there is a major change in the bauxite sourcing, with imported sources

replacing some of the indigenous bauxites. This change in the bauxite sourcing plan has led to a need to revisit the overall process control strategy of the alumina refineries, driven by the sharp difference in the processing characteristics of both indigenous and imported bauxites.

The bauxite sourcing model developed assisted the refinery to rule out unacceptable sources and arrive at an optimum blend ratio when the refinery is required to process multiple bauxites, potentially sourced from 5-10 or more locations, and consisting of a combination of indigenous and imported bauxites.

The 3-step model process consisting of: 1) Preliminary analysis 2) Detailed Processability studies and 3) Summary was useful in arriving at the targeted long term bauxite sourcing for the refinery and has also helped in changing the process control philosophy from reactive to proactive. Summary data from the model has been extensively used for bauxite blend optimization thereby leading to significant improvement in the operational efficiency and allowing overall operational excellence for the refinery to be achieved.

6. References

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