

## Bauxite Beneficiation at the Grinding Stage in Kazakhstan Alumina Production

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### Abstract

This paper presents information on the pre-processing of bauxite using two different flowsheets for the removal of iron and kaolinite components at the grinding stage at the Pavlodar Aluminium Plant (PAP) of Aluminium of Kazakhstan JSC. These solutions reduce input of impurities into the Bayer circuit: Fe<sub>2</sub>O<sub>3</sub> by 35–40 %; CO<sub>2</sub> by 40–60 %; SO<sub>3</sub> by 50–70 % and SiO<sub>2</sub> by 12–15 %.

The removal of iron sand reduces the mass of Fe<sub>2</sub>O<sub>3</sub> entering the sintering stage by ~ 20 %, partially debottlenecking the sintering furnaces, increasing the throughput capacity of both the Bayer and sintering circuits.

This in-house development of PAP is the main technological solution to increase the capacity of the “Bayer-Sintering in series” plant and was achieved while maintaining alumina product quality. Implementation of this flowsheet also solved the constraint faced from declining ore reserves, allowing lower quality ore to be processed and extend the life of operation.

**Keywords:** Bauxite, Iron-rich sands, Kaolinite, Impurities.

### 1. Introduction

To suite mineral and chemical composition of local bauxite from Kazakhstan, PAP is applying a quite rare technology of Bayer-Sintering in Series for its processing [1–6]. The technology consists of Bayer digestion of high silica bauxite and then sintering of resulting red mud to extract with high efficiency, the alumina and soda losses associated with it.

Currently, PAP uses bauxite from the Krasnooktyabrsky deposit, characterized by a very low mass ratio Al<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub> (silica ratio) of only 3.5 - 4 units, and a high content of harmful components: siderite, chamosite, hematite, pyrite, organics and other impurities. As the deposit is developed, the quality of bauxite decreases, which leads to increase of impurities in green liquor, an increase in the amount of red mud and a decrease in the technical and economic production performance.

The next to come ore reserves from the Krasnooktyabrsky deposit for alumina production at PAP are associated with lower-quality raw materials with a silica ratio below 3.5 units [7–11].

Lower quality raw materials require a constant search for innovative solutions to maintain recovery and product quality specifications, as well as research and development of new technological methods to improve and modernize existing production equipment.

Various methods of bauxite conditioning are known: flotation [12–13]; roasting (to remove CO<sub>2</sub>, C and SO<sub>3</sub>) [14]; magnetic separation [15–16].

Thus, there was a need to develop technology at PAP for impurities removal at the beginning of the technological cycle of alumina production.

As a result of the introduction of new process flow schemes, including the pre-processing of bauxite at the grinding stage, removing significant part of impurities from the Bayer cycle, PAP has achieved economically viable processing of low-quality bauxite from Kazakhstan.

## 2. Description of Problem

The plant was designed and constructed in 1964 for processing bauxite supplied 100 % from the Torgai deposit with a silica ratio of ~ 4.5 units (Al<sub>2</sub>O<sub>3</sub>/SiO<sub>2</sub>).

As the deposit was developed, the reserves of Torgai bauxite deteriorated and were largely exhausted, and so bauxite from other deposits began to be involved in processing, which led to further degradation in the bauxite quality. By 2011, the share of Torgai bauxites was only 7 %, by 2020 4 %, and in 2022 this deposit, as well as the Belinskiy one, were completely consumed (Tables 1, 2, 3).

**Table 1 – Blend composition of sourced bauxite over time.**

Variant (average by year)	Source composition of bauxite by mine (%)			
	Torgai	Krasnooktyabrsky		
		Ayat	Belinskiy	Krasnogorsk
2011	7	15	36	42
2020	4	33	9	54
2022	-	32	-	68
2024	-	32	-	68

Since 2022, PAP has been processing bauxite from the Krasnogorsk mine at a level of 65–70 % and from the Ayat deposit at a level of 35–30 %, which differ in their impurity composition.

**Table 2. Average chemical composition of bauxite by deposit.**

Deposit	Chemical composition ((%)									A/S
	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>	CO <sub>2</sub>	C <sub>org</sub>	Cl	TiO <sub>2</sub>	FeO	
Torgai (beginning of mining)	45.7	10.2	16.0	0.20	0.20	0.1				4.48
Torgai (at the end of mining)	44.50	15.9	13.8	0.29	0.32	0.23	0.21	1.30	0.85	2.80
Belinskiy	41.40	10.3	21.2	0.60	1.79	0.16	0.84	2.15	2.88	4.02
Ayat	44.60	10.7	18.3	0.34	1.26	0.17	0.15	2.09	2.06	4.17
Krasnogorsk	42.00	10.9	19.4	0.70	3.70	0.35	0.41	2.01	5.41	3.85

**Table 3 – Mineral composition of bauxite by deposits.**

Deposit	Mineral composition (%)							
	kaolinite	chamosite	gibbsite	goethite	anatase	silica	siderite	hematite
Torgai (at the end of mining)	27.8	2.6	52.0	2.9	2.9	1.3	0.0	9.4
Belinskiy	15.0	1.95	52.3	2.7	2.7	1.0	2.4	18.4
Ayat	14.4	1.65	56.6	2.6	2.3	1.2	1.4	16.7
Krasnogorsk	22.6	2.0	50.9	2.8	2.4	1.2	4.7	11.5

From Tables 2 and 3 it follows that Torgai bauxites had a lower content of impurities: FeO, CO<sub>2</sub> (in the form of siderite), and sulfur compounds (SO<sub>3</sub>).

The bauxites of the Krasnogorsk deposit, compared to others, have much higher level of impurities. The high content of carbonates and sulfur in bauxite leads to losses of active caustic alkali by binding it into sodium carbonate, a decrease in the efficiency of the leaching stage and losses of alumina with red mud, which increases the load on material flows on the sintering stage and the mother liquor evaporation unit of the Bayer circuit [17].

Increased content of siderite and goethite in Krasnogorsk bauxite leads to a deterioration in the mud sedimentation properties, a decrease in the productivity of equipment at the stages of thickening and filtration of red mud. In addition, in the Bayer digestion circuit, small quantities of iron go into solution resulting from dissolution of FeO oxides and FeOOH hydroxides, which can lead to a deterioration of aluminum hydroxide quality during crystallization.

With switching to processing of new bauxites, studies were carried out that showed that an increase in the kaolinite content in the processed bauxite leads to an increase in the loss of aluminum and alkali in the form of sodium aluminosilicate (sodalite) during green liquor desilication. The finely dispersed sodalite formed during desilication impairs the settling of red mud, disrupting the thickening and washing operation, increasing the amount and moisture content of the red mud entering the sintering section.

With an increase in the content of iron, sulfur, silicon, carbon and clay minerals in bauxite, difficulties arise in maintaining stable production rate and competitive operating costs.

The accumulation of organic impurities in production solutions causes foaming of slurries at all stages, and in addition, results in obtaining more fine particle size distribution of aluminum hydroxide and alumina.

### 3. Solving the Problem

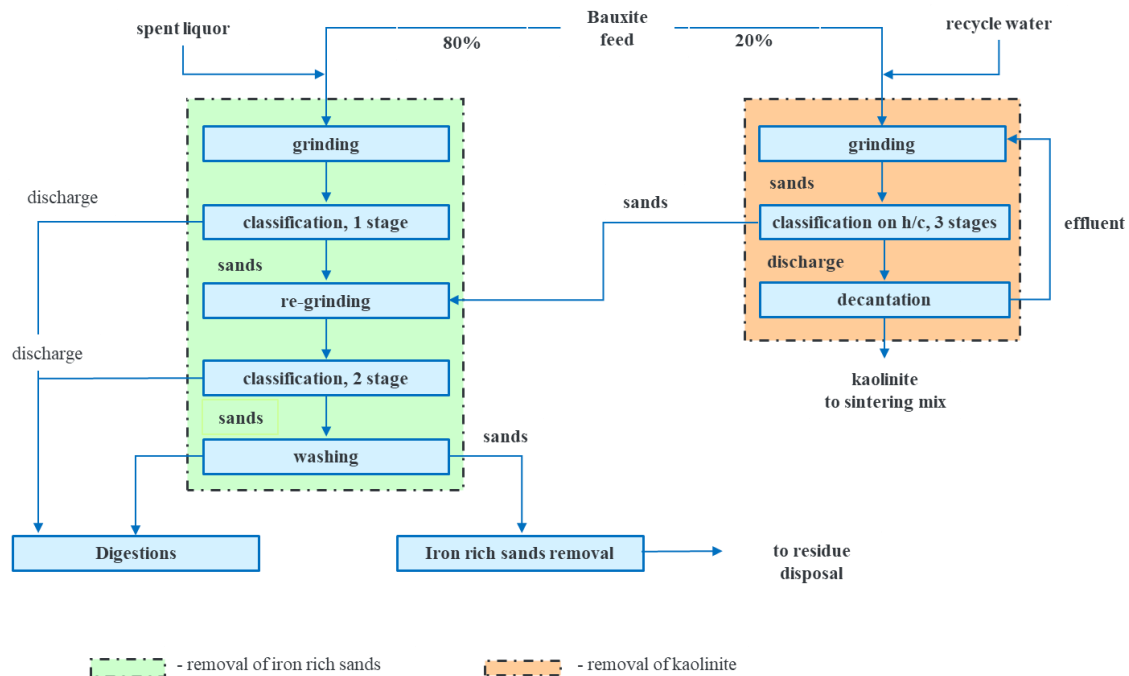
In early 2000s the task was set for technical specialists of PAP and the Research Center for developing and implementing an action plan to solve this problem as soon as possible. Various options were considered:

1. Involvement in the production of better-quality small lens reserves of bauxite of the East Ayat group, scattered and low-tonnage reserves of other deposits;
2. Transfer of the plant to the processing of imported bauxite;
3. Processing of substandard bauxite from the Krasnogorsk deposit with a reserve of 140–150 million tonnes.

Based on an economic assessment, it was decided to develop a technology for processing bauxite from the Krasnogorsk deposit at the existing facilities of the enterprise. The development and implementation of process flow sheets made it possible not only to involve the low-quality bauxite in the alumina production process, but also to increase plant production capacity by 40–50 %. Due to the removal of negatively affecting impurities of bauxite in the beginning of Bayer process, it became possible to increase the throughput capacity of all stages of the plant and improve the process performance.

Firstly, due to the heterogeneity of the composition of the processed bauxites, special attention was paid to blending bauxite raw materials before feeding it into the beneficiation process.

Secondly, to reduce the input of impurities during bauxite grinding, the flowsheets have been developed for the removal of iron-rich sands and the kaolinite components of bauxite (Figure 1), where separated stage underflows of iron-rich sands is dumped to a red mud storage facility, while the kaolinite stream component is sent to the sintering mix for processing jointly with red mud.



**Figure 1. Flowsheets for the removal of iron-rich sands and the kaolinite components of bauxite.**

### 3.1 Removal of Iron-Rich Sands

The iron-rich sands removal flowsheet was implemented and successfully operated since 2000. It allows significant removal of the underflow containing coarse dense impurities from the production cycle of the Bayer circuit before they have time to react in the alkaline solution. Process performance monitoring is used to continually optimize the circuit to mineralogical variation and achieve operational stability

The method is based on grinding bauxite to a given size, to suite liberation of mineral phases, and stage classification on hydrocyclones, followed by washing on vertical devices and dumping sand into a red mud disposal facility.

**Table 4 - Qualitative characteristics of Bayer bauxite and iron rich sands (2024) with the removal of 10% of iron rich sands.**

Deposit	Chemical composition (%)					A/S	Mud factor t/t bauxite	Mineral composition (%)			
	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>	CO <sub>2</sub>			Gibbsite	Kaolinite	Siderite	Hematite
Bayer bauxite before beneficiation	42.2	10.8	19.9	0.35	2.60	3.91	0.52	51.8	17.4	3.6	18.2
Bayer bauxite after beneficiation	45.3	11.4	15.7	0.21	1.67	3.97	0.50	-	-	-	-
Iron-rich sands	14.4	4.9	57.8	1.60	11.0	-	-	8.0	8.0	12.9	36

As shown in Table 4, removal of the iron component of bauxite in an amount of ~ 10 % of the bauxite mass of the Bayer circuit makes it possible to increase A/S ratio by ~ 0.06 units, reduce formation of red mud by ~ 0.02 t/t bauxite (~ 8–10 t/h) and remove from the process up to 30 % Fe<sub>2</sub>O<sub>3</sub>, 40–50 % CO<sub>2</sub> (depending on the initial content), 4.5–7 % SiO<sub>2</sub> and up to 45 % SO<sub>3</sub>. At the same time, losses of Al<sub>2</sub>O<sub>3</sub> with sands are ~ 3.5 %.

The introduction of a unit for removing iron-rich sands into the technological process of alumina production made it possible to expand ore reserves, by involving lower quality bauxites into operation.

### 3.2 Removal of the Kaolinite Component of Bauxite

The need to develop a flowsheet for removing the kaolinite fraction from bauxite entering the Bayer circuit was based on reducing processing costs associated with kaolinite and goethite content in Krasnogorsk bauxites.

A flowsheet for separating the kaolinite fraction of bauxite was introduced at PAP in 2001; the results of bauxite beneficiation for removal of kaolinite are in Table 5.

**Table 5 - Qualitative characteristics of Bayer bauxite and kaolinite fraction (2012, last operation) with ~5 % removal of total bauxite.**

Deposit	Chemical composition (%)			A/S	Kaolinite removal from bauxite (%)	Mud factor t/t bauxite	Mineral composition (%)				
	Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>				Gibbsite	Kaolinite	Siderite	hematite	goethite
Bauxite before beneficiation	41.8	11.0	19.3	3.80	n/a	0.64	52.4	19.6	2.8	13.8	2.9
Bauxite after beneficiation (20 %)	41.5	7.39	21.5	5.62	35	-	-	-	-	-	-
Kaolinite fraction	42.3	17.7	15.3	2.39	n/a	-	43	36	0	6	5.5
Bauxite after beneficiation (100 %)	41.7	10.6	19.5	3.93	~5	0.61	-	-	-	-	-

The method is based on water washing of 20 % of the bauxite input feed in a grinding mill then classifying on a battery of hydro cyclones before the start of contact of bauxite with recycled alkaline liquors. This process serves for partial removal of kaolinite from the Bayer bauxite flow (~ 5–7 %) with transfer of the washed kaolinite phase to red mud disposal area or used in a mix for sintering.

From the data given in Table 5 it follows that due to the discharge of the kaolinite fraction in an amount of ~ 5 %, the alumina to silica ratio of the processed bauxite increases by ~ 0.13 units, while the amount of red mud decreases by 0.03 t/t bauxite. Mineralogical analysis also showed that the kaolinite fraction contains almost 2 times more finely dispersed kaolinite and has an increased content of goethite, compared to the original bauxite.

The kaolinite removal flowsheet made it possible to involve bauxite with lower quality in the process flow of alumina production at PAP. After 2012, the kaolinite removal circuit has not operated due to insufficient filtration, which caused high water content in cake and, subsequently, in the sintering mix.

Currently, options are being explored to improve the kaolinite removal scheme at the stage of bauxite grinding with dewatering in a decanter centrifuge/press filter to minimize the input of water into the sintering mix.

#### 4. Conclusions

The bauxite beneficiation flowsheets at the Bayer circuit of Pavlodar Aluminium Plant allowed reduction of material flows and increased the productivity of the plant's processing areas, including increase in extraction of alumina, intensifying thickening processes and reduction of red mud volume, which allowed transferring part of the sintering kilns to stand-by. The technology also made it possible to optimize the plant's alkaline balance by reducing the formation of sodium carbonate in the process liquors and losses of alkali with red mud, while increasing ore reserves by operating on lower quality bauxites.

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