Sustainable Upgrading of Bauxite and Valorization of Bauxite Tailings

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Abstract

Global bauxite production in 2022 was reported at approximately 400 million tonnes per year, with more than half originating from Australia and Guinea. A lot of other Bauxite reserves need an upgrading to meet the requirements regarding the main ingredients of Al_2O_3 and SiO_2, to make it suitable for the Alumina refinery extraction process. Therefore, upgrading by washing and classification processes could be the solution to disintegrate and to separate unwanted impurities. Due to the typical particle size distribution (PSD) of such bauxite deposits, it is essential to identify the valuable fractions and ensure their specific liberation and separation. The main objectives of the upgrading process include designing the process route, selecting and sizing appropriate equipment, and developing the overall plant layout.

A distinction should be made between bauxite tailings, which originate from washing plants, and bauxite residues, which are the residual red mud produced by alumina refineries. Additionally, the valorization of tailings from legacy washing plants could be considered to recover valuable fractions, contributing to a more sustainable use of resources. Because of limited or outdated classification techniques, older bauxite washing plants mainly targeted coarse fractions (> 4 mm). However, studies of legacy tailings dams have shown that significant amounts of material still meet today's quality standards. The challenge now is to define the optimal cut size and design a suitable process route to recover these valuable resources still present in those legacy tailings dams.

For decades, AKW Equipment + Process Design has been actively involved in bauxite washing and valorization, supplying a wide range of proprietary equipment as well as turnkey processing plants. Thanks to our state-of-the-art in-house technical laboratory, we are able to conduct test work on original material samples. Based on these test results, we define the optimal process flow, which then serves as the foundation for the plant design.

Keywords: Upgrading of bauxite, Bauxite quality demand, Bauxite tailings valorization.

1. General Information on Bauxite

1.1 Resources

Bauxite is a naturally occurring, heterogeneous material composed primarily of one or more aluminum hydroxide minerals, plus various combinations of silica, iron oxide, titania, aluminosilicate, and other impurities in minor or trace amounts.

Over the last years, due to the general decrease in the availability of good bauxite raw material quality, the need and investigations for new bauxite valorization opportunities have gained momentum. This is especially true for bauxite tailings, which, in some cases, offer a powerful alternative to newly mined bauxite.

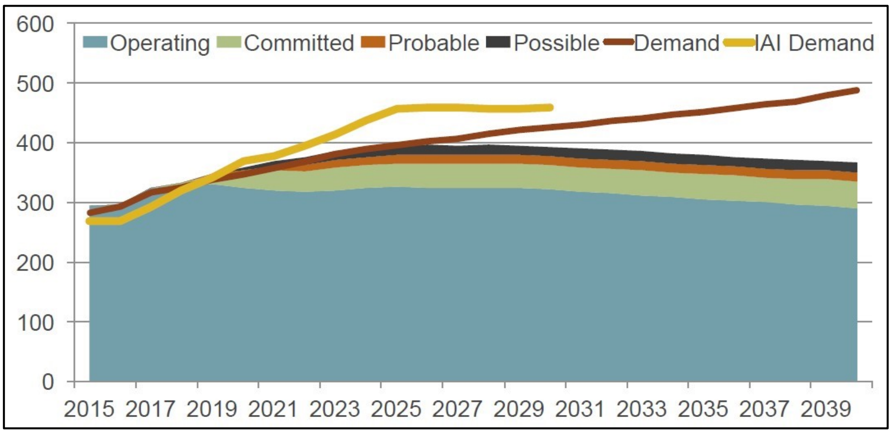


Figure 1. Current & predicated worldwide bauxite supply & demand, 2012-2039 (Mt) [1].

There are approx. 80 bauxite mines listed worldwide. The largest 8 ones, with capacities above 10 up to 25 Mt/y, are mainly located in Australia, Brazil, Guinea and Indonesia. Most of the bauxite mines have capacities below 5 Mt/y down to under 1 Mt/y.

Table 1. Bauxite world production [2]

TABLE 11

BAUXITE: WORLD PRODUCTION, BY COUNTRY OR LOCALITY[1]

(Thousand metric tons)

Country or locality	2018	2019	2020	2021	2022
Australia	95.948	105.544	103.627	103.056	102.290
Bosnia and Herzegovina	803	934	688	725 r	700 e
Brazil, dry basis	32.377	31.938	32.898	33.000 e	30.000 e
China	77.170	73.320 r	62.800 r, e	86.000 r, e	90.000 e
Cote d'Ivoire[e]	400	750	700	700	700
Croatia	12	14	14	14	10 e
Dominican Republic	--	--	9	89	90 e
Fiji	60 e	--	--	--	-- e
Ghana	1.011	1.116	1.162	839 r	800 e
Greece[2]	1.559	1.379 r	1.429 r	1.227 r	1.200 e
Guinea, dry basis[e, 2]	57.000	67.000	86.000	82.000 r	100.000
Guyana, dry basis	1.926	1.920	595	619	706
Hungary	5	--	--	-- e	-- e
India	23.229	22.321	19.988	22.136 r	24.000 e
Indonesia	13.243	16.593	20.800 e	21.000 e	21.000 e
Iran[2]	805	1.163	1.200 e	1.100 r, e	572
Jamaica, dry basis	10.058	9.022	7.546	5.950	4.365
Kazakhstan	5.700	4.118	4.058	4.370	4.400
Malaysia	590	901	595	624 e	600 e
Montenegro	468	775	897	542 r	442
Mozambique	10	8	6	8 r	8 e
Pakistan	121	58	105 r	97 r	45 e
Russia	5.651	5.574	5.570	5.679	5.780
Saudi Arabia	4.731	5.031	4.946	4.781	4.800 e
Sierra Leone	1.938	1.884	1.342	1.397	910
Solomon Islands	1.609	1.161	842	-- e	-- e
Tanzania	11	--	26	38 r	40 e
Turkey	1.000 e	2.255 r	2.400 r	2.765 r	2.800 e
United States	W	W	W	W	W
Venezuela	--	--	250 e	250 e	250 e
Vietnam	3.500 e	3.350 e	3.580	3.670 r, e	3.860 e
Total	341.000	358.000 r	364.000 r	383.000 r	400.000

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company propriety data. -- Zero.

[1]Table includes data available through June 21, 2023. All data are reported unless otherwise noted, totals may include estimated data. Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Dry bauxite equivalent of crude ore.

1.2 Qualities

Bauxite deposits can be divided into three major groups depending on their means of formation: sedimentary diaspore, accumulation diaspore, and lateritic gibbsite.

Lateritic bauxites are the most important bauxite deposits, accounting for approximately 92 % of total global reserves and comprising mainly gibbsitic bauxite, which is characterized by low silica, high iron, and high A/S ratios. Gibbsitic bauxite deposits are typically treated using beneficiation processes including washing which remove fine grained silica minerals as tailings, as well as coarse ore as alumina mineral [3].

The quality of the bauxite ore, in general, is highly variable between individual deposits. The bauxite deposits differ widely in:

- their geological associations,
- content and type of aluminium ore minerals and
- gangue minerals.

The following table shows the typical range in the composition of metallurgical grade bauxite.

Table 2. Typical range in the composition of metallurgical bauxite.

Components	**Wt. %** **(as metallic oxide if not indicated otherwise)**
Al_2O_3	30 – 60
Fe_2O_3	1 – 30
SiO_2	< 0.5 – 10
TiO_2	< 0.5 – 10
Organic Carbon (as C)	0.02 – 0.40
P_2O_5	0.02 – 1.0
CaO	0.1 – 2
V_2O_5	0.01 – 0.10
ZnO	0.002 – 0.10
Ga_2O_3	0.004 – 0.0.13
Cr_2O_3	0.003 – 0.30
S	0.02 – 0.10
F	0.01 – 0.10
Hg (ppb)	50 – 1000

If required, a beneficiation could improve the ore quality. By simple processing with crushing, screening, washing and dewatering the waste material can be removed. So higher graded ore will be produced by separating the tailings (clay, sand).

The percentage of Al_2O_3 of the total production of bauxite:

- 63 % was of 40–45 % Al_2O_3 grade
- 15 % was of cement grade
- 12 % was of 45–50 % Al_2O_3 grade
- 7 % was of below 40 % Al_2O_3 grade
- 2 % was of refractory grade
- 1 % of production was reported together in 50–55 % Al_2O_3 and 55–60 % Al_2O_3

1.3 Quality Demand

Bauxite ore is used as the raw material for the production of alumina in the Bayer hydrometallurgical process. Clay agglomerates on the bauxite surface create lot of complications in this process. The aim of bauxite washing is to increase the concentration of alumina i.e. alumina grade and reduce that of silica (clay) grade in the Bayer process plant feed. Therefore, the ratio of alumina grade to that of silica grade (A/S) is one of the deciding parameters for the bauxite ore processing. The efficiency of the washing process can be characterized by determination of the amount of silica (clay) agglomerates removed from bauxite surfaces. Bauxite with a minimum aluminium oxide content of 45–50 % provides a competitive advantage in alumina production via the Bayer process. Hence, a well-designed beneficiation plant can provide a competitive advantage for alumina refineries.

Furthermore, certain bauxite reserves in India have a Al_2O_3/SiO_2 ratio in the range of 4 to 6. The consumption of soda in the Bayer process is directly related to the reactive silica content of the bauxite: the higher the silica content, the greater the caustic consumption is in the refinery. Hence, a well-designed beneficiation plant capable of removing excessive amounts of SiO2 will provide a competitive advantage for alumina refineries.

Bárdossy and Bourke published in 1993 the ideal characteristics for metallurgical-grade bauxite:

• High extractable alumina	+ 49 %
• Low “reactive silica”	1,5 – 3 %, kaolinite
• Low boehmite	< 3 %
• Iron content	ideally 5 – 15 %
• Low quartz	ideally < 1 %
• Low titania	ideally < 0,5 %
• Low carbonates	ideally < 0,1 %
• Low impurities and trace elements	

1.4 Upgrading Request and Test Works

With the advantages of an in-house state-of-the-art technical laboratory, AKW Equipment + Process Design is able to perform comprehensive and extensive tests, as well as define and elaborate the process guarantees for the specifically designed processes and flow sheets. To identity potential recovery rates of valuable bauxite and the possibility of improving the overall yield of the process, AKW Equipment + Process Design has been engaged by different major bauxite players – worldwide – to perform the extensive test procedure to get reliable results and define the performance targets.
Bauxite from different deposits tested by AKW Equipment + Process Design:

- Suriname
- Vietnam
- India
- Sierra Leone

The various test phases of the extensive test procedure include:

- Determine the particle size distribution and the related mineral identification
- Analyze the available alumina (Al_2O_3) content and how to increase it from the “run of mine” ore
- Test how to reduce the un-wanted SiO_2, Fe_2O_3, Clay content
- Increase the recovery of the mine by beneficiation and upgrade the washing plant efficiency

The aim of the beneficiation process is to reduce the silica content of the bauxite with a minimum of Al_2O_3 losses. Attention has to be paid on the kaolinitic impurities of the bauxite ores and the content of Al_2O_3, SiO_2 (especially reactive Silica), Fe_2O_3 and TiO_2 of the product.

To improve the characteristics of the Run of Mine ore (R.O.M. ore) mineral processing techniques are common in the mining industry of ores and minerals like iron ore, non-ferrous ore, phosphate ore, China clay, coal and so on.

The classical processes for beneficiation of bauxite ores are listed as:

- Crushing and milling
- Screening
- Elutriation (scrubbing)
- Cycloning (in combination with dewatering screens)
- Dewatering of fine ground ore (for pipeline transportation)

New developments are:

- Gravity separation (spiral)
- Magnetic separation
- Flotation

To have a first idea of a suitable process, the general physical appearance of the ore, including the geometric aspects of, and the mutual relations among component particles, like size, shape and arrangement of the constituent elements (texture) must be considered. For the upgrading of bauxite, different processes have been tested with success. Some processes are even of common use in the treatment of R.O.M. bauxite.

1.5 Exemplary Resulting Wash Plant Process Route

To develop the best process route for a bauxite beneficiation project, test work with original ROM material is inevitable. Basis for the test work should be an average representative sample of the bauxite which is expected to be processed within the first few years of the beneficiation plant.

The first step is to evaluate the PSD (particle size distribution) of the raw ore, which is generally done by wet screen analysis. The screen fractions obtained will be used for chemical XRF analysis.

With this lab testing procedure, the valuable fractions will be identified.

Pilot scale test work will then follow to practically checkout the findings from the fractionated analysis by washing tests.

Such wash test could be a combination of the following treatment steps:

- Separation of coarse lumps by wet screening
- Wash drum tests to check the workable solid concentration and the required retention time
- Followed by screen classification to separate the already washed mid-size fractions
- Scrubbing of impurities in finer fractions at high solids concentrations and related retention time
- Fine classification at the fine cut sizes indicated by the fractionated analysis
- Dewatering test work
- Sedimentation test work to get the basis for the process water cleaning circuit

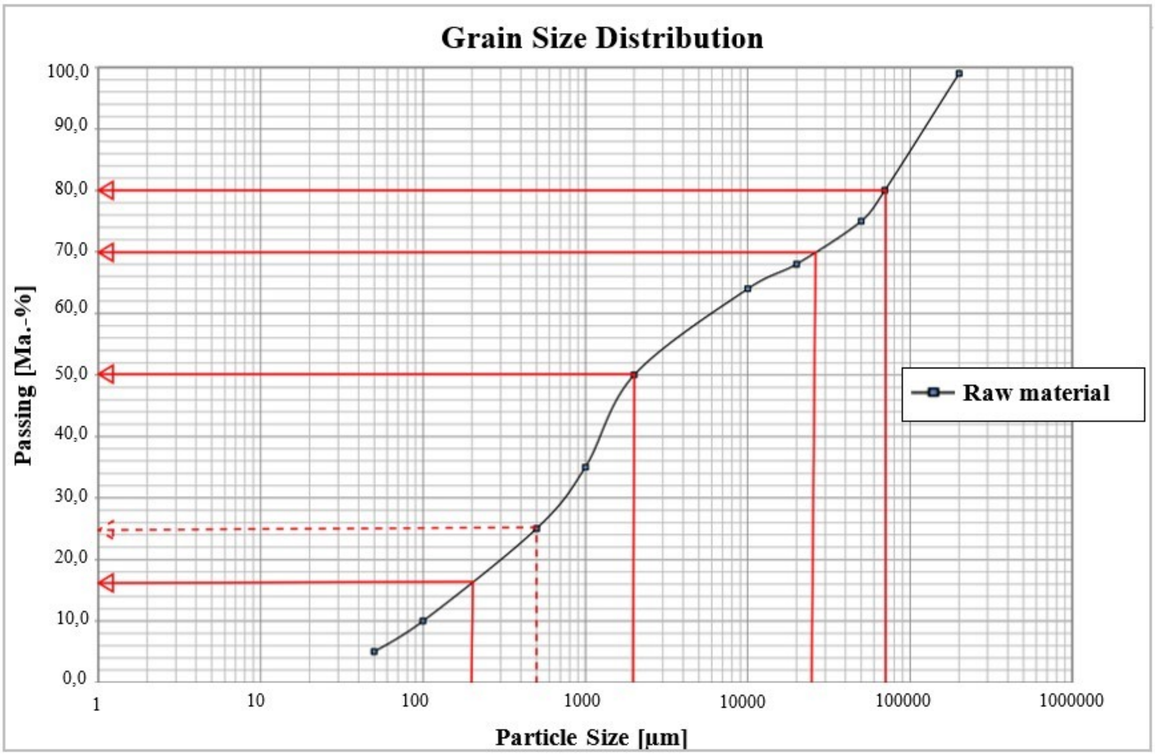


Figure 2. PSD resulting from test work, indicating the tentative classification cut sizes.

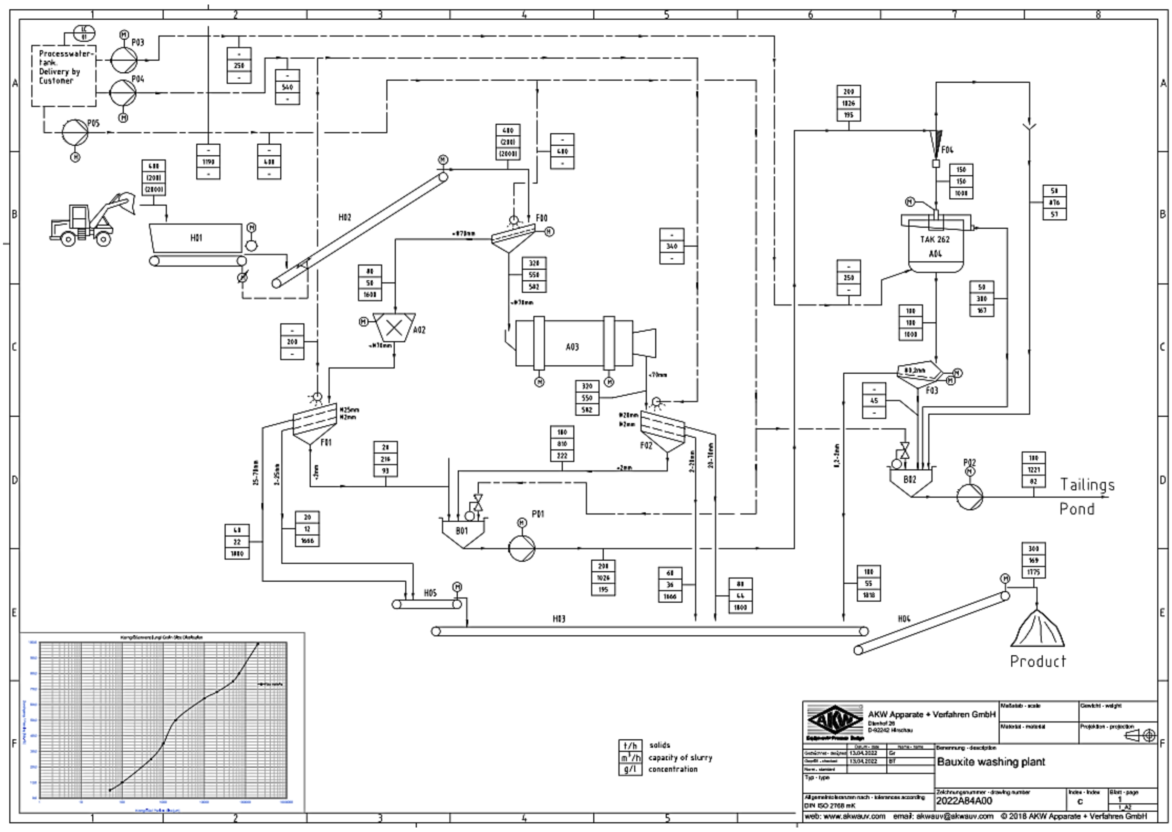


Figure 3. Illustrative process flow derived from the developed PSD (excerpt from an engineering package by AKW Equipment + Process Design).

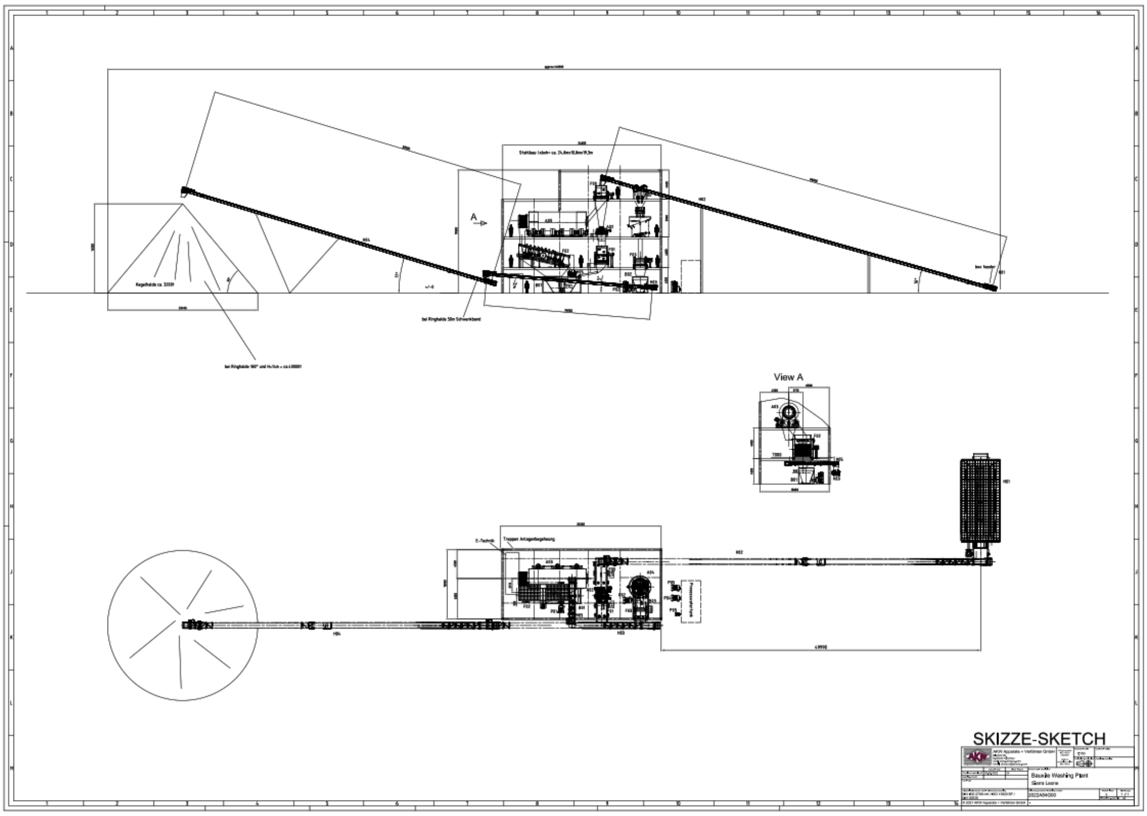


Figure 4. Illustrative process plant lay out – GA drawing example (excerpt from an engineering package by AKW Equipment + Process Design).

1.6 Tailings Handling

The resulting tailings from bauxite wash plants consist of water, fine bauxite, sands and clay, which will usually be settled in ponds. Since bauxite washing does not require the use of chemicals, the resulting tailings are not hazardous. These should not be confused with bauxite residues generated by alumina refineries. Additionally, not all bauxite deposits require beneficiation, and therefore, not all bauxite mining operations produce tailings.

2. Example of a Tailings Beneficiation of a West Africa Bauxite Mine

The setup example described in Figure 4 illustrates the existing bauxite washing plant, which can also be used as a reference model for other sites. As shown in Figure 5, the run-of-mine (ROM) feed entering the plant is sized at up to -1000 mm, with a processing capacity of up to 400 tonnes per hour (t/h).

The standard process includes a crusher that reduces the material to -70 mm, followed by a washing drum that treats the -70 mm fraction. This is succeeded by multiple wet screening stages, with the final classification set at 2.4 mm.

The process yields a final product of > 2.4 mm at approximately 200 t/h, while the tailings (< 2.4 mm) also amount to around 200 t/h, discharged as slurry at a rate of approximately 1000 m^3/h (see Figure 6).

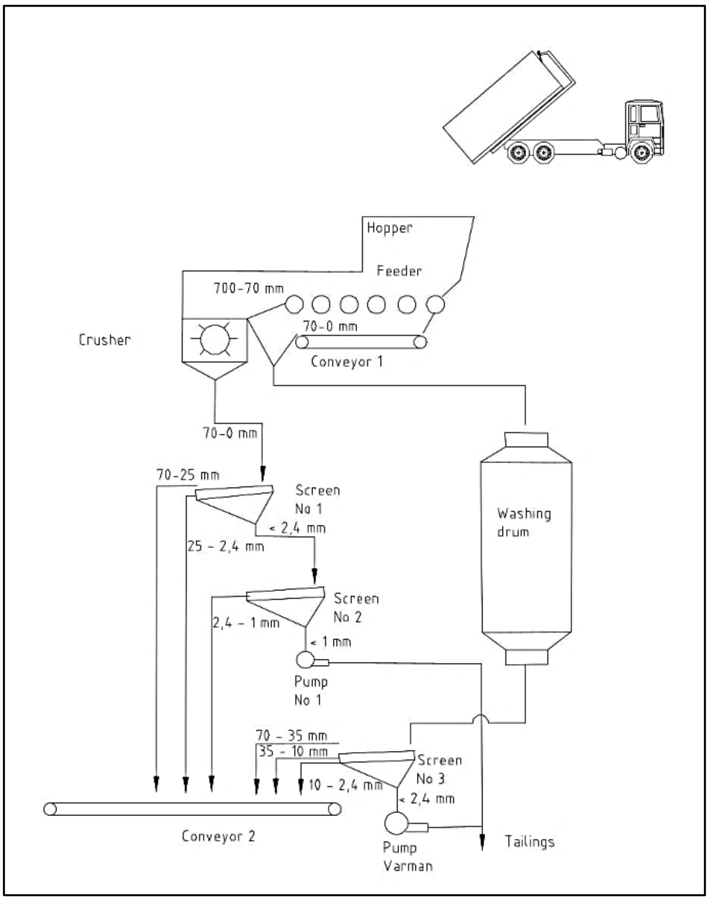


Figure 5. Illustrative flow diagram of the existing bauxite washing plant.

Figure 6. Left: Fresh tailings from washing plant, Right: existing old tailings dam.

To identify the most effective upgrading process and significantly improve recovery rates, a comprehensive testing program was launched at the state-of-the-art technical laboratory of AKW Equipment + Process Design. For this purpose, an average tailings sample were provided by the operating washing plant of the bauxite mine.

2.1 Fresh Tailings Tests

The standard PSD of the received sample was determined and is shown in Table 3.

Table 3. Standard particle size distribution (PSD) – fresh tailings.

Screen [µm]	Raw material mass - %	Raw material cum. %
4000	6.0	6.0
2000	13.7	19.7
1000	20.9	40.6
500	13.3	53.9
250	9.2	63.1
125	8.4	71.5
90	4.1	75.6
63	3.0	78.6
45	3.1	81.7
25	2.9	84.6
undersize	15.4	100

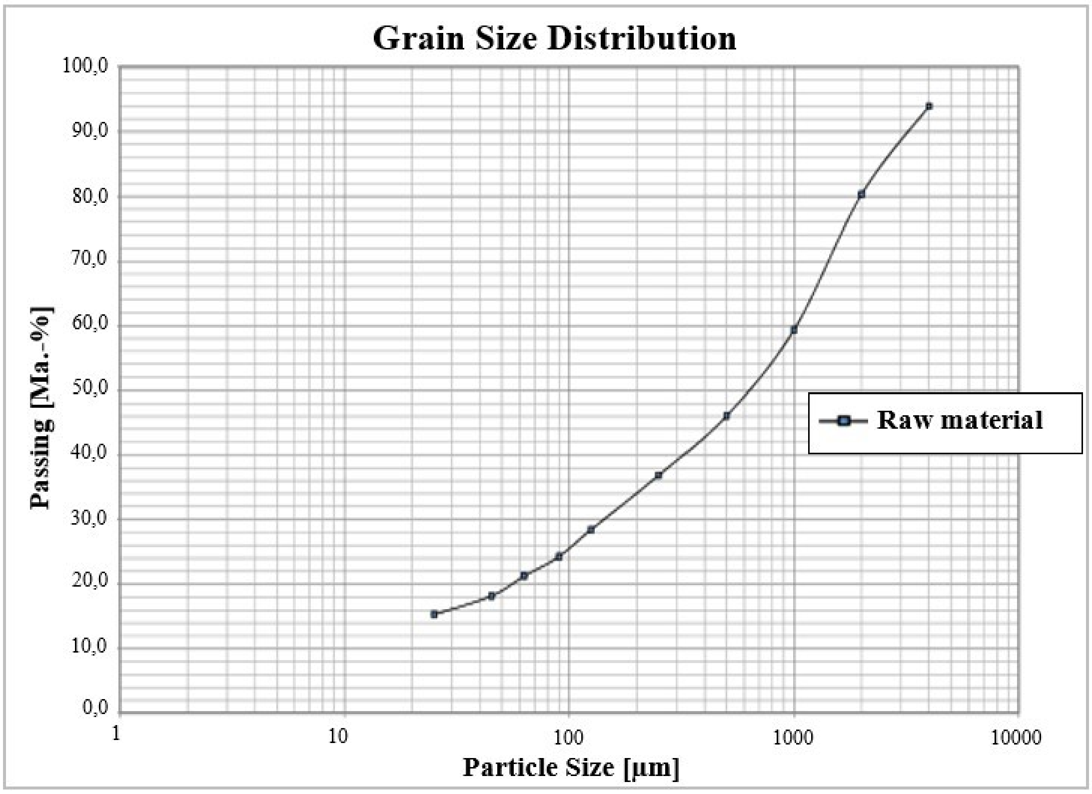


Figure 7. Grain size distribution – fresh tailings.

A fractionated analysis shows the different level of the valuable or not wanted ingredients.

Table 4. Fractionated analysis – chemical and mineralogical analysis.

All weight-%	Norm Sample name	Raw-tailings sample	Fraction > 1000 µm	Fraction 500-1000 µm	Fraction 250-500 µm	Fraction 90-250 µm	Fraction 25-90 µm	Fraction < 25 µm
Mass % of fraction		100.0	40.6	13.3	9.2	12.5	9.0	15.4
SiO_2	DIN EN ISO 12677	12.1	4.11	9.85	16.8	20.8	21.2	25.0
Al_2O_3	DIN EN ISO 12677	41.2	47.6	45.4	38.6	35.2	35.2	34.3
Fe_2O_3	DIN EN ISO 12677	21.1	19.6	17.4	20.7	21.3	22.1	20.5
TiO_2	DIN EN ISO 12677	2.01	1.10	1.71	2.71	3.08	2.50	1.64
LOI 1025°C	DIN EN ISO 12677	23.1	27.1	25.1	20.6	18.9	18.4	18.0
Moisture 105°C	DIN EN ISO 12677	3.2	0.2	0.4	0.6	0.4	0.6	1.0
RDA-Gibbsite	DIN 13925	50	68	59.5	42.5	37.5	30.5	27
RDA-Goethite	DIN 13925	20	19	17	20	20	23	20.5
RDA-Hämatit	DIN 13925	2.5	2.5	2	2.5	3	1	2
RDA-Kaolinit	DIN 13925	20	7.5	16	27	27	38	42
RDA-Quarz	DIN 13925	2.5	0.5	2	4	8	3.5	5
RDA-Rest Ingredients	DIN 13925	5	2.5	3.5	4	4.5	4	3.5

For the further treatment it was decided due to remarkable lower content of valuable material to combine the fractions 250–500 µm, 90–250 µm a 25–90 µm to one complete fraction 25–500 µm with a weight amount of 30,7 %. The fraction < 25 µm is considered as waste due to the very low content of valuable material and was not further treated.

Table 5. Adapted fractionated analysis – chemical and mineralogical analysis

All weight-%	Fraction > 1000 µm	Fraction 1000-4000 µm attritioned + deslimed	Fraction 500-1000 µm	Fraction 500-1000 µm attritioned + deslimed	Fraction 25-500 µm	Fraction 25-500 µm attritioned + deslimed
Mass % of fraction	40.6	31.1	13.3	12.2	30.7	26.5
SiO_2	4.11	3.38	9.85	7.07	19.72	16.9
Al_2O_3	47.6	49.1	45.4	47	36.22	35.4
Fe_2O_3	19.6	18	17.4	17.30	21.35	23.3
TiO_2	1.10	1.04	1.71	1.95	2.8	4.41
LOI 1025°C	27.1	28.1	25.1	26.2	19.26	19.4
Moisture 105°C	0.2	0.5	0.4	0.6	0.52	0.7
RDA-Gibbsit	68	73.5	59.5	69	36.9	41
RDA-Goethite	19	15	17	16.5	20.9	22
RDA-Hämatit	2.5	4.5	2	2	2.3	3
RDA-Kaolinit	7.5	2.5	16	5	30.2	21
RDA-Quarz	0.5	2	2	4.5	5.5	7
RDA-Rest Ingredients	2.5	2.5	3.5	3	4.2	6

A treatment of the fraction > 500 µm – X (incl. the 6 % > 4 mm) showed a recovery of approx. 50 % by weight and resulted in the following improved compositions of the bauxite tailings:

- Gibbsite mineral content: improved from 50,0 % up to 72,3 %
- Al_2O_3 content: improved from 41,2 % up to 48,5 %
- SiO_2 content: reduced from 12,1 % down to 4,4 %
- A/S ratio: improved from 3,4 up to 11

2.2 Stock Tailings Tests

Same test works were executed with samples received from the existing old tailings dams.

A similar PSD was found with the old tailings material, as shown in Figure 6.

Table 6. Standard particle size distribution (PSD) – stock tailings.

Samples	No. 1		No. 2		No. 3		No. 4	
Particle-ø/ Size [µm]	Residue [Ma %]	Sum [Ma %]	Residue [Ma %]	Sum [Ma %]	Residue [Ma %]	Sum [Ma %]	Residue [Ma %]	Sum [Ma %]
4000			7.5	7.5			19.5	19.5
2000	19.9	19.9	15.4	22.9	11.1	11.1	21.5	41.0
1000	19.1	39.0	19.8	42.7	23.6	34.7	10.9	51.9
500	10.1	49.1	13.3	56.0	16.5	51.2	7.2	59.1
250	6.1	55.2	8.6	64.6	11.9	63.2	8.5	67.6
125	5.4	60.6	7.2	71.8	10.0	73.2	8.4	76.0
90	3.1	63.7	3.6	75.4	4.0	77.1	4.4	80.4
63	2.8	66.5	3.2	78.6	3.5	80.6	3.3	83.7
45	2.4	68.9	2.7	81.3	2.9	83.6	2.8	86.5
25	3.5	72.4	3.3	84.6	2.7	86.2	2.8	89.3
pass	27.6	100.0	15.4	100.0	13.8	100.0	10.7	100.0

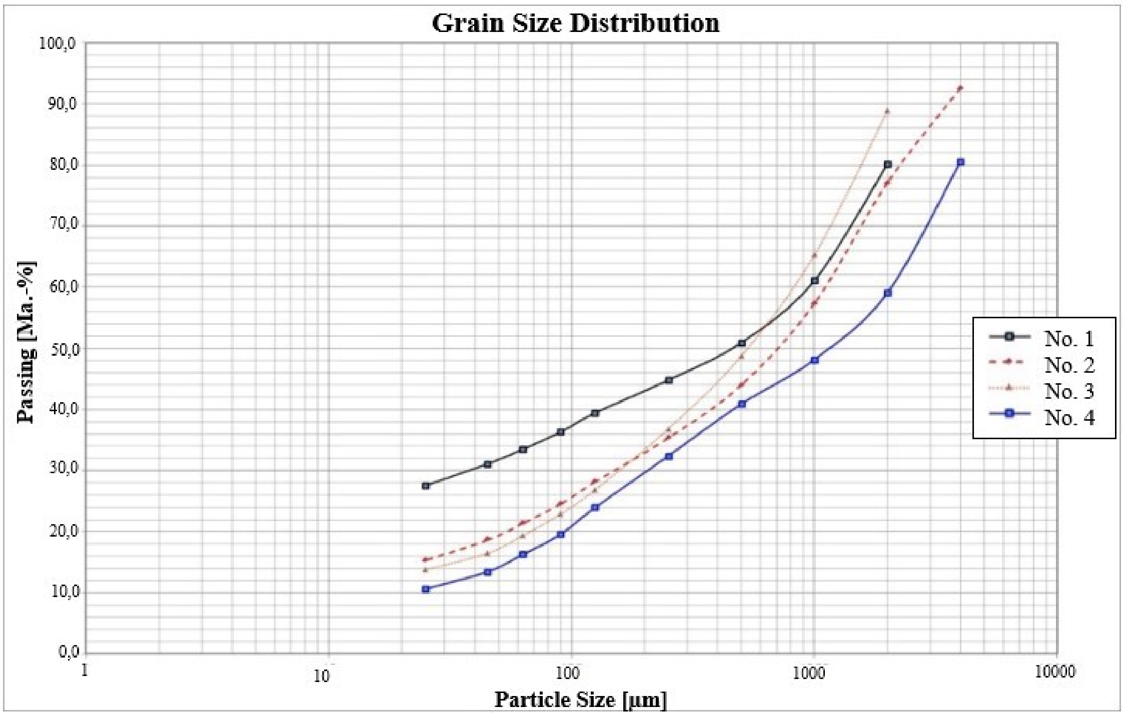


Figure 8. Grain size distribution – stock tailings.

The fractionated analysis shows the different level of the valuable or unwanted ingredients.

Table 7. Fractionated analysis – chemical and mineralogical analysis.

	N 1			N 2			N 3			N 4		
	Raw Mate-rial	**> 500 µm**	**< 500 µm**	**Raw Mate-rial**	**> 500 µm**	**< 500 µm**	**Raw Mat e-rial**	**> 500 µm**	**< 500 µm**	**Raw Mate-rial**	**> 500 µm**	**< 500 µm**
SiO_2	10.9	3.87	16.6	8.76	3.35	12.9	7.54	3.14	11.1	6.63	1.86	13.7
Al_2O_3	42.2	50.6	35.9	42.6	48.6	36.7	39.7	46.3	35.1	39.3	42.9	33.5
Fe_2O_3	21.1	16.1	24.8	21.4	18.8	25.0	25.5	22.0	27.8	28.1	27.5	29.6
TiO_2	2.13	1.13	2.87	3.18	1.37	4.77	4.29	1.50	6.26	2.98	2.41	3.75
L.O.I. 1025°C	23.2	28.0	19.3	23.7	27.5	20.1	22.6	26.7	19.2	22.5	24.9	18.7
A/S	3.87	13.07	2.16	4.86	14.51	2.84	5.27	14.75	3.16	5.93	23.06	2.45
% (w/w)		49.1			56.0			51.2			59.1	

A classification at 500 µm allows:

- a significant reduction of the SiO_2 content and
- results in a significant improvement of the A/S ratio.

The fractioning at 500 µm shows a recovery of 49 % to 59 % of the old tailings samples.

The A/S ratio in the old tailings shows values in the range from 3.87 up to 5.93.
The resulting A/S ratio in > 500 µm shows improved values from 13.07 up to 23.06.

The raw Al_2O_3 content ranges from: 39.3 % to 42.2 %
The Al_2O_3 in the > 500 µm fraction rises to: 42.9 % to 50.6 %

3. Upgrading Process

Based on the performed tests and the corresponding test results, the required processing was evaluated. Considering the existing bauxite process plant, it was checked where the additional processing steps could be realized:

- is an improvement of the existing plant possible?
- could additional steps be added to the existing plant?
- is an additional unit for the tailings treatment required?

After intensive investigations, two treatment units were designed and discussed accordingly:
Processing of the fresh tailings coming from the existing washing plant:

- Solids feed capacity: approx. 200 t/h
- Slurry feed capacity: approx. 1000 m³/h

Processing of the stock tailings from existing old dam:

- Solids feed capacity: approx. 100 t/h
- Moisture of feed: approx. 10–12 % (14–16 %)

The stock tailing treatment unit will be operated independently from the existing washing plant.

3.1 Developing of the Process Route and Equipment Selection

For the required process route to treat the intended feed capacities following steps need to be considered:

- Feeding of the treatment unit:
    - Fresh tailings as slurry
    - Stock tailings as bulk material
- Separation of oversized lumps – from the stock tailings
- Classification at 500 µm in 2 steps
    - 1st Hydrocyclone Desliming with AKA-VORTEX cyclones
    - 2nd Upstream Classification with AKA-SIZER hydrosizer
- Discharge of the separated, unwanted fines < 500 µm
- Dewatering and stockpiling of the beneficiated tailings

3.1.1 Draft Process Flows

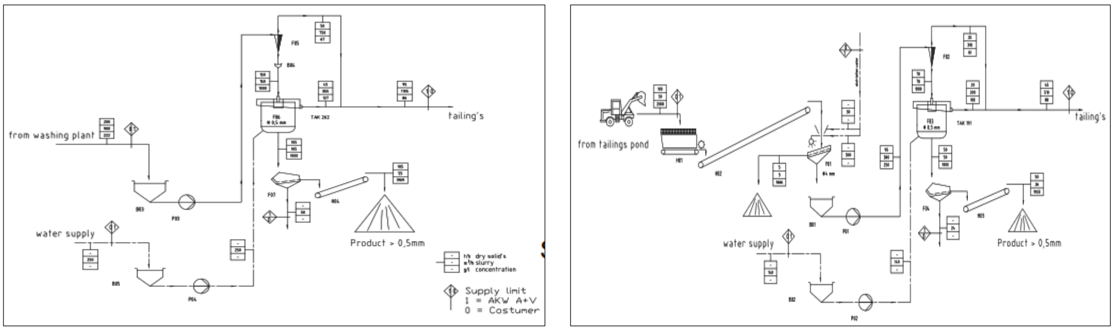


Figure 9. Left: Fresh tailings slurry from the discharge pipeline of the washing plant. Right: Stock tailings material fed by wheel loader to the beneficiation plant. (Both left & right sketches are excerpts from an engineering package by AKW Equipment + Process Design).

The fresh tailings slurry (left flow sheet) will be taken over directly at the discharge from the existing wash plant and pumped to a hydrocyclone for first desliming. It will be further processed by hydrosizer to separate the -500 µm and in the following dewatered by vibrating screen.

The stock tailings bulk material will be fed via boxfeeder to a pre-screen to separate oversized lumps. Then it will be pumped to a hydrocyclone for desliming in in the following processed by hydrosizer to separate the -500 µm. The valuable + 500 µm fraction will be dewatered by a vibrating screen.

3.1.2 Equipment Selection

The wet treatment units are fed with material in slurry form, either directly or from bulk material processed through a box feeder and wet pre-screening.

The principal task is the classification of material at 500 µm.

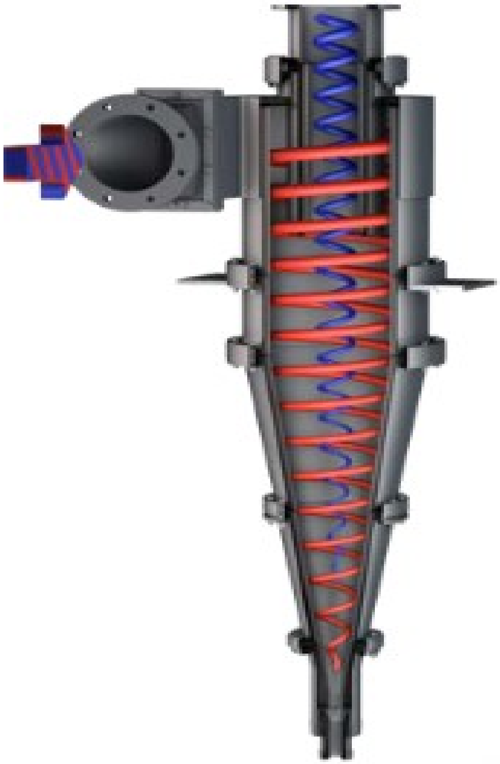
Based on the test results, 40–50% of the material consists of fines below 500 µm, which need to be separated to be discarded since it has the highest SiO_2 and lowest Al_2O_3 contents (see Table 7).

Due to their sticky behavior in bulk form, this substantial amount of fine material is challenging to separate efficiently.

Therefore, a 2-stage classification strategy is the recommended solution, in a combination of:
- 1st stage Hydrocyclone Desliming with AKA-VORTEX cyclones
- 2nd stage Upstream Classification with AKA-SIZER

AKA-VORTEX Hydrocyclone:

Principle of Operation.
The hydrocyclone is in principle a slender full-jacket centrifuge. In contrast to rotating centrifuges, the body of the hydrocyclone remains at rest, while the flow is set into rotation through the tangential inlet under pump pressure. The rotational flow in the hydrocyclone consists of a downward-directed primary vortex and an upward-directed inner secondary vortex, whereby in both cases centrifugal forces lead to the separation of the suspension.



Figures: 10. Hydrocyclone principle of operation.

Design Features and Benefits:
- Optimum separation characteristic at varying operating conditions
- Modular system through the use of simple connectors and adaptors (feed part, overflow and underflow nozzle)
- Easy adaption to changing operation parameters
- Fast and trouble-free changing of wear parts
- Low weight of single parts
- Different materials for optimum lifetime: polyurethane, oxide- or SiC-ceramic, NiHard, titanium, steels
- Can be lined with high wear-resistant, chemical- and corrosion-resistant materials

AKW offer a wide range of AKA-VORTEX cyclones:
- Capacities from 1 to 1500 m^3/h
- Cut size d_{50} from 6–180 µm

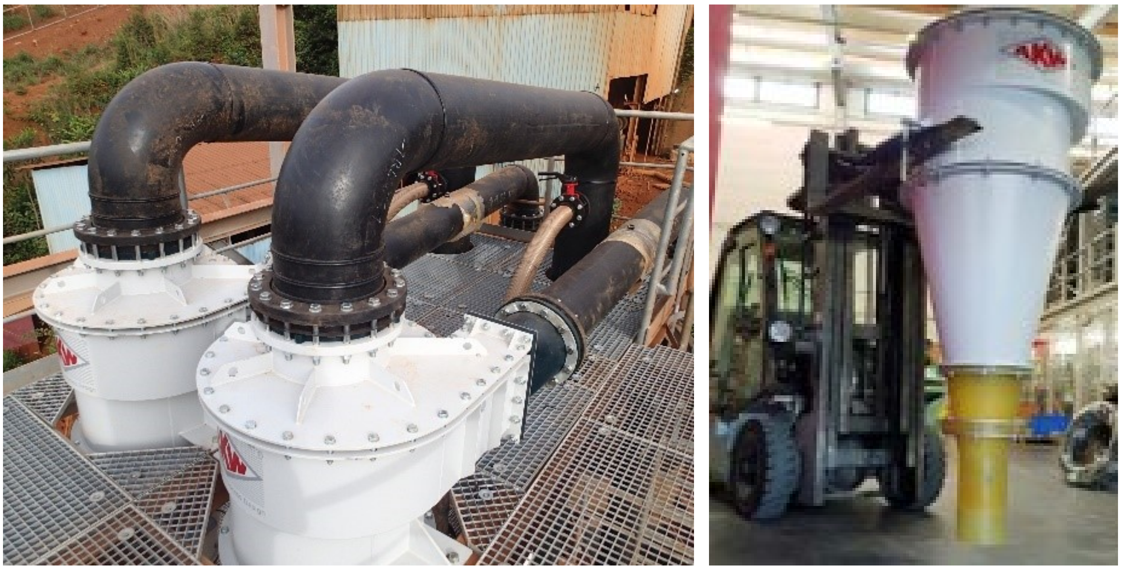
which can be carried out in combination with distribution systems for specific process capacities.

The selected AKA-VORTEX Hydrocyclone to treat the tailings:

- Hydrocyclone: AKA-VORTEX Type RWL 132.30
- Capacity: 500 m^3/h (2 pieces for fresh tailings) (range 275–600 m^3/h)
- Pressure drop: 0.8 bar (0.7–1.2 bar)
- Material: Steel case with PU lining
- Cut size d_{50}: approx. 120 µm

Other important details are described below:

- Evolute feed design for reduced wear impact
- Modular system combining overflow nozzles, feed parts, cylinders, cones and apex nozzles
- Special Carbon steel with PU liners available in different diameters for high flow rates in heavy duty applications
- Available in conical and flat bottom versions



Figures: 11. Selected AKA-VORTEX Hydrocyclone Type RWL 132.30.

AKA-SIZER Hydrosizer

Principle of Operation.
An optimum distribution of upstream water from the bottom via a self-closing nozzle plate results in a homogeneous and undisturbed teeter bed enabling a precise separation.

By varying the water flow, different cut sizes can be achieved.

A specially designed discharge regulation system, controlled by the density of the fluidized bed, ensures a uniform cut size – even in case of fluctuations of the feed conditions (grain size, concentration).

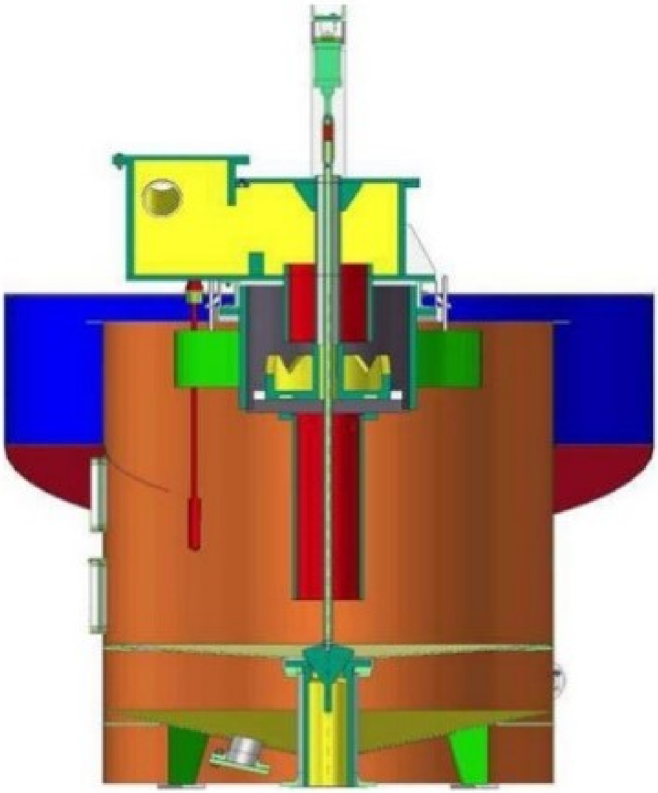


Figure 12. Upstream classifier principle of operation.

Design Features and Benefits:

- Effective teeter bed control system
- Self closing nozzles
- Special designed discharge valves
- No dead zone above the discharge valves
- Adjustable and sensitive density sensor
- Central feeding for an effective distribution inside the tank

AKW offer a wide range of AKA-SIZER Upstream Classifiers:

- Diameters from 1.2 to 3.6 m
- Cut sizes ranging from 200 to 700 µm

The selected AKA-SIZER Upstream Classifier to treat the tailings:

- Upstream Classifier: AKA-SIZER Type TAK 262 for fresh tailings

AKA-SIZER Type TAK 191 for stock tailings

- Capacity: 200 t/h for fresh tailings

100 t/h for stock tailings

- Classifying area: Respectively 5.3 and 2.8 m^2 for fresh and stock tailings
- Material: Steel case, nozzle plate with rubber nozzles
- Cut size: approx. 500 µm

Other important details are described below:

- Central feed design for high feed concentrations to avoid shortcuts of coarse particles to the overflow.
- Specially developed control system to ensure a stable and homogeneous teeter bed.
- Continuous discharge by unique dart valves, up to 3 valves for large diameters.

- High wear resistant PU parts and self-closing upstream rubber nozzles.

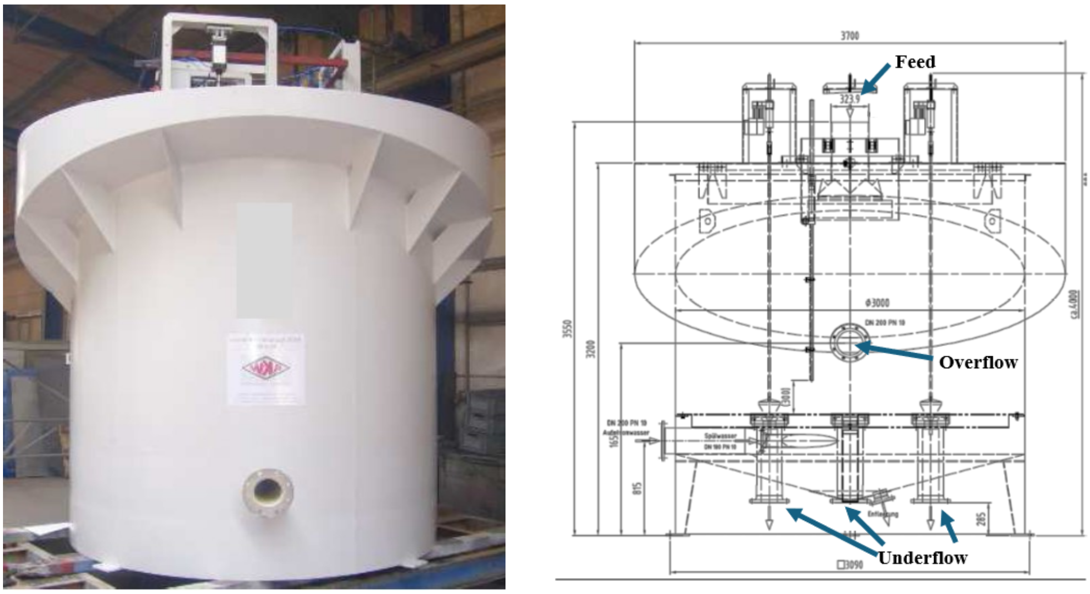


Figure 13. AKA-SIZER design.

3.2 General Arrangement

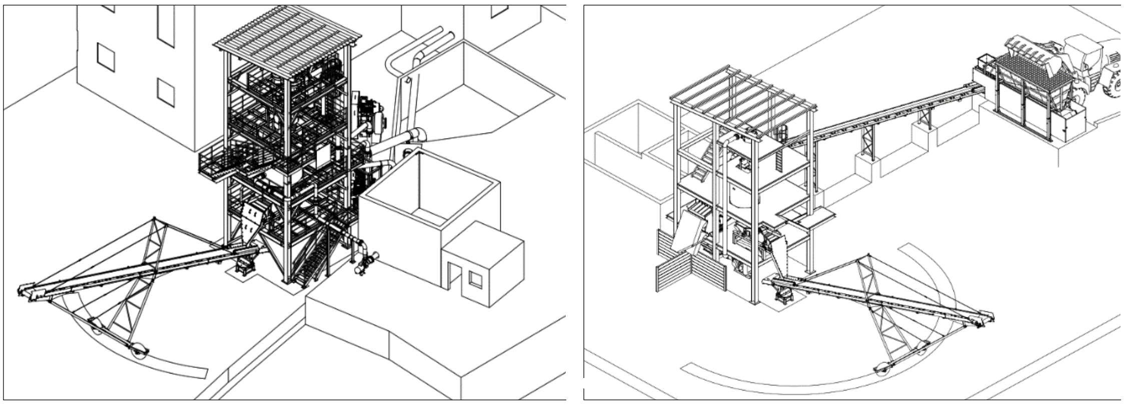


Figure 14. Left: General arrangement drawing fresh tailings, Right: General arrangement drawing stock tailings. (Both left & right sketches are excerpts from an engineering package by AKW Equipment + Process Design).

The fresh tailing beneficiation plant is located near the existing old wash plant for direct takeover of the discharged tailings slurry. The stock tailings beneficiation plant is an independent unit nearer by the to be treated tailings dams.

3.3 Processing Plants

For both beneficiation plants, fresh and stock tailings treatment, the process route is same, only different in capacity: first desliming by hydrocyclone/s and then coarse cut size at 500 µm by hydrosizer, below this a vibrating screen for dewatering of the valuable fraction.

Figure 15. Left: Processing plant fresh tailings, Right: Processing Plant stock tailings.

3.4 Process Plant Design

The fresh tailings plant takes the tailings slurry directly from the discharge pipe of the existing bauxite washing plant. Whereas the bulky stock tailings material will be handled by wheel loader and fed into a box feeder. Then the material passes a wet protection screen to separate oversize lumps. The slurry of the bauxite tailings will be transported by wear resistant pumps to the next treatment steps by hydrocyclones. AKA-VORTEX hydrocyclones for first desliming and to adjust the process concentration are installed. These hydrocyclones – made of Special Carbon steel – are equipped with high wear resistant Polyurethane (PU) liner. The hydrosizer AKA-SIZER, also known as teeter bed classifier, classifies the feed slurry by upstream water which will be supplied from the bottom through a nozzle plate. By the so created upstream the fine particles will be directed to the overflow and the coarse particles discharged by a special dart valve to the underflow. By controlling the density and adjusting the discharge opening the specific cut size will be adjusted. The separated fines below 500 µm will be discharged from the AKA-SIZER overflow back to the tailings dams. The valuable material above 500 µm will be dewatered by linear moving dewatering screens and stockpiled by inclined conveyor belts. To combine these specific process equipment to a functional processing unit, it needs to be completed with

- Piping
- Cabling
- Electric control system
- Steel structure

AKW Equipment + Process Design, as a supplier of turnkey solutions, would therefore take care of all the key steps, from the beginning of the project with all the test work to process design, equipment selection and plant design.
All this can be further completed by supervision of erection and commissioning up to the fulfillment of the guaranteed performance parameters.

3.5 Capacities

Fresh tailings processing:

Solids feed capacity:	approx. 200 t/h
Slurry feed capacity:	approx. 1000 m^3/h
Process water demand:	approx. 250 m^3/h
Installed electric power:	approx. 180 kW
Electric power demand:	approx. 120 kW

Tailings from stock processing:

Solids feed capacity:	approx. 100 t/h
Moisture of feed:	approx. 10–12 % (14–16 %)
Process water demand:	approx. 450 m^3/h

Installed electric power: approx. 140 kW
Electric power demand: approx. 95 kW

4. Project Realization / Timeline

Previous Test work
For the test work to determine the tailings composition and to define the upgrading process a time period of at least 4–6 weeks needs to be considered.

Manufacturing/lead time

Depending on the required upgrading plant capacity and the specific process design, the necessary equipment need to be selected and sized accordingly. Including the steel structure for equipment installation, as well as the pipework and electrical control systems, the total manufacturing time is estimated at approximately 10 to 12 months. The required period for shipment to site depends on the final location of the plant.

Erection/installation

For the described upgrading units and installation, a period of 6 weeks was required by starting on completed foundations.

Commissioning

After installation and finishing the water supply as well as feed and discharge logistics, the commissioning phase started. The project concluded with a successful start-up following two commissioning phases, each lasting approximately two weeks. To support the on-site commissioning team, particularly in remote locations, remote access to the electrical control system has proven to be highly beneficial.

5. Summary

Figure 16. Processing plant fresh tailings. Vertical process arrangement: 2 hydrocyclones on top, static flow to the hydrosizer AKA-SIZER and direct discharge of the valuable fraction to the dewatering screen below.

Figure 17. Processing plant stock tailings. The box feeder on the right side will be filled by wheel loader with the bulky stock tailings material and the same vertical process arrangement as the fresh tailings.

The implementation of bauxite tailings washing units has delivered remarkable results, marking a significant advancement in resource efficiency and sustainability:

- 50% increase in valuable product recovery from the bauxite washing plant has extended the operational life of the deposit while substantially reducing tailings discharge.
- 50% recovery of valuable material from existing tailings has unlocked additional product capacity and enabled the productive reuse of legacy tailings dams.

These achievements not only enhance the economic performance of the operation but also contribute meaningfully to environmental stewardship and long-term resource management.

6. References

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