AA01 - Improvement of Mud Circuit Efficiency while Processing East Coast Bauxite of India

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Abstract

With the ever-decreasing quality of Bauxite being processed in Bayer plants and the drive for increasing production, the stress on the mud circuit of modern plant is greater than ever. To facilitate the same, modern day thickeners have evolved from the earlier conventional settling tanks to the high rate decanters (HRD) and deep cone washers (DCW). These high rate decanters and deep cones meet the objective to process bauxite residue with high compaction, with minimal residence time in order to improve the separation efficiency.

Usage of synthetic polymers enhances the solid –liquid separation. Choosing a right flocculant for the regional bauxite to be processed, enables reduced variations in the circuit. Customized flocculant application is imperative to achieve the desired settling rate for a compact underflow and clear supernatant liquor.

At UAIL (Utkal Alumina International, Ltd), the Indian east coast bauxite (Baphlimalli Mines) is digested at medium temperature to extract alumina and the bauxite residue is processed through a Counter Current Decantation (CCD) circuit consisting of HRD's and DCW's before the residue is dry discharged to the residue disposal area via Pressure Filters.

This paper highlights the efficient bauxite residue processing at UAIL, by debottlenecking the mud circuit to enable processing of low THA bauxite (than design). Substantial gains achieved in terms of sustaining higher production rates, reduced chemical soda losses, and optimal flocculant consumption. This paper also describes the impact of introducing dry residue disposal and management for the refinery.

Key Words: Bauxite residue, Bayer's process, decantation, flocculant, tri-hydrate alumina & pressure filtration.

1. Brief Process Description

Utkal alumina refinery, located at Doraguda, in Rayagada district of Odisha, India is a 100 % subsidiary of Hindalco Industries Ltd., of the Aditya Birla Group. The project activities commenced since 2008, while the mining activities started in 2012. State of the art Rio Tinto Alcan Technology (RTA) was adopted to produce 1.5 Mio Tons of smelter grade alumina with a 95% plant availability. Cogen unit (3*30 MW, 2 running, 1 standby) supplies the power and steam. The plant has 2 operating trains of 0.75 Mio Tons / annum.

The plant was designed based on the bauxite source available at the Baphlimalli mines, situated appx. 20 km from the refinery site. The bauxite is transported through a long-distance conveyor

(LDC) spanning 18.2 km from the mines to the refinery stock yard. Around 600,000 MT of bauxite can be stacked at the plant stock yard. A stacker is in place to handle the bauxite at the yard, and a reclaimer is provided to reclaim the bauxite from the yard and feed to the system. This arrangement ensures uniform quality of bauxite being fed to the refinery on a daily basis.
Primary crusher at mines end reduces the size of the mined bauxite to -150mm (90 %), while the secondary crusher at the refinery end reduces the size further.3 rod mills (2 running, 1 standby) are used to grind the bauxite. The bauxite is fed from the independent mass flow silo through an apron feeder and a belt conveyor to the feed hopper, where the SFL is mixed for wet grinding. Bauxite grinding is facilitated by 80 % attrition and 20 % impact in the rod mills. This is a wet, open circuit grinding. The ground slurry is further transferred to PDS tanks through IBSH (indirect Bauxite slurry heaters). The residence time across the PDS is 16-20 hours. From the last PDS tank the bauxite slurry is charged to the 1st Digester of each train.

In the digesters SFL (strong feed liquor) is fed through a series of liquor heaters. Four liquor heaters use regenerative flash vapor, and across the remaining 2 liquor heaters, live steam of 4 bar and 12 bar is used to further raise the temp.

Both the SFL and bauxite feed slurry are charged to the digester via a mixing Tee. 4 numbers of digesters are provided to complete the reaction time. The digested slurry is flashed across a series of 4 flash vessels and finally pumped via the blow off pumps to the Mud separation & washing unit.

The Alcan High rate decanters are used to primarily separate the sodium aluminate liquor (PGL) from the residual solids. The HRD's are equipped with advanced rake mechanism, customized flocculant dosing lines, Mud sensors, and underflow pumps with recirculation and transfer lines. The overflow of the HRD's termed as PGL is pumped to the polishing filters. Diaster filters Gaudfrin make are installed to filter the PGL [1, 2].

The underflow from the HRD's is processed through series of DCW's (deep cone washers), wherein counter current flow of wash water and residue is arranged to wash the mud and maximize soda recovery from the bauxite residue before it is pumped via Geho pumps to the Red Mud Filtration (RMF) unit.

The DCW's are equipped with advance rake mechanism, E-duc (Feed well auto dilution arrangement), customized floculent dosing, Mud sensors, scale trap. The underflow pumps are provided with transfer and recirculation provisions.

Wash water used for mud washing is charged to the last stage, to generate the 1st washer overflow used to dilute the HRD feed slurry. Filtrate from the RMF unit, and process condensate is used as wash water.

The PGL from the security filtration area is cooled across the Plate Heat Exchangers (PHE's) in the HID (heat interchange dept.), whilst the SPL (spent liquor is heated) and pumped to evaporation unit to concentrate.
A part of cooled PGL is used to reslurry the fine seed and charged to agglomerator, while the major part is used to reslurry the coarse seed and charge to the 1st growth tank.

Each precipitation train comprises of 1 Agglomerator and series of growth tanks. Interstage coolers are installed on growth tank to enhance cooling across the precipitation circuit.

The precipitated slurry is classified in two stages of cyclones. Part of fines is recirculated to agglomeration, and the coarse seed is fed to coarse seed deliquoring filters and the cake is reslurried back with PGL to the 1st growth tank.

The product slurry is fed to the pan filters at the calciner area, wherein it is washed, and steam dried before feeding to the calciner. The filtrate from the pan filters is recycled back to seed area to reslurry the product hydrate.
Utkal has 2 calciners' installed with a capacity of 2500 TPD expandable to 3300 TPD. Alumina from the calciners' is transferred to the alumina silos, from where it is loaded into railway wagons bulkers for dispatch to internal smelters.

Condensate generated from the live steam usage is recycled back to cogeneration power plant as return condensate, while the process condensate is used in the mud wash circuit for washing the mud in the CCD circuit.

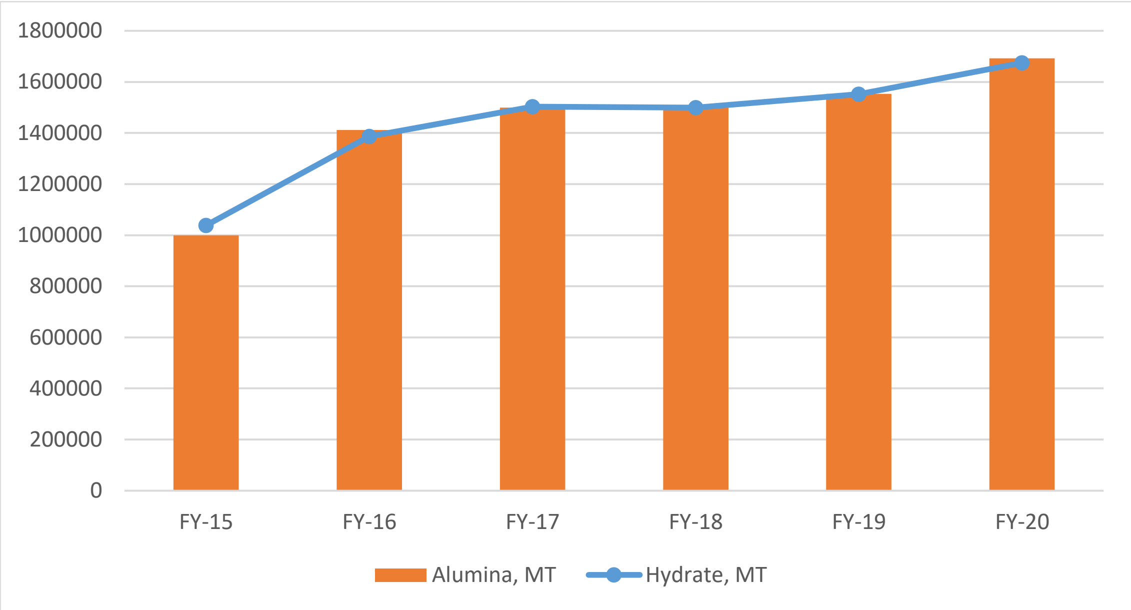

Figure 1. Yearly production, MT.

2. Bauxite Residue Processing

Utkal commenced production with one train in October-2013. The 2nd train was commissioned in May-2014. It was a strategic decision to process low quality bauxite in view of sustaining the bauxite availability from mines. In the first two years of operation Utkal achieved the fastest ramp up to its design capacity (Q3 in FY15). Utkal was designed to process bauxite having 40.62 % THA, but it started processing bauxite with 38 % THA (max). The % THA varied in the range of 35 to 38%.

With the thrust on ramping up the production coupled with low THA lead to higher bauxite charge with commensurate larger quantities of mud generation for every ton of alumina produced. Handling of the higher bauxite residue across the CCD circuit started posing a major constraint. Though there are some margins (15 % typically) built in plant design with respected to mud handling systems of the plant, these capacities were also not adequate to handle the extra mud generation of 25 % through the circuit. With low compaction the underflow slurry handling became an issue. This issue was mitigated successfully.

The target THA of 40.62 % was arrived at by analyzing a representative bauxite sample from the Baphlimalli reserves, and therefore is an average quality for the entire deposit. Steady state bauxite feed rates and plant operational parameters, as well as mud generation, residue processing requirements were set based on the plant feed bauxite quality matching with this target THA content. However, with the revised strategy for long term sustainability of bauxite reserves, the trend below exhibits the actual bauxite quality against the design.

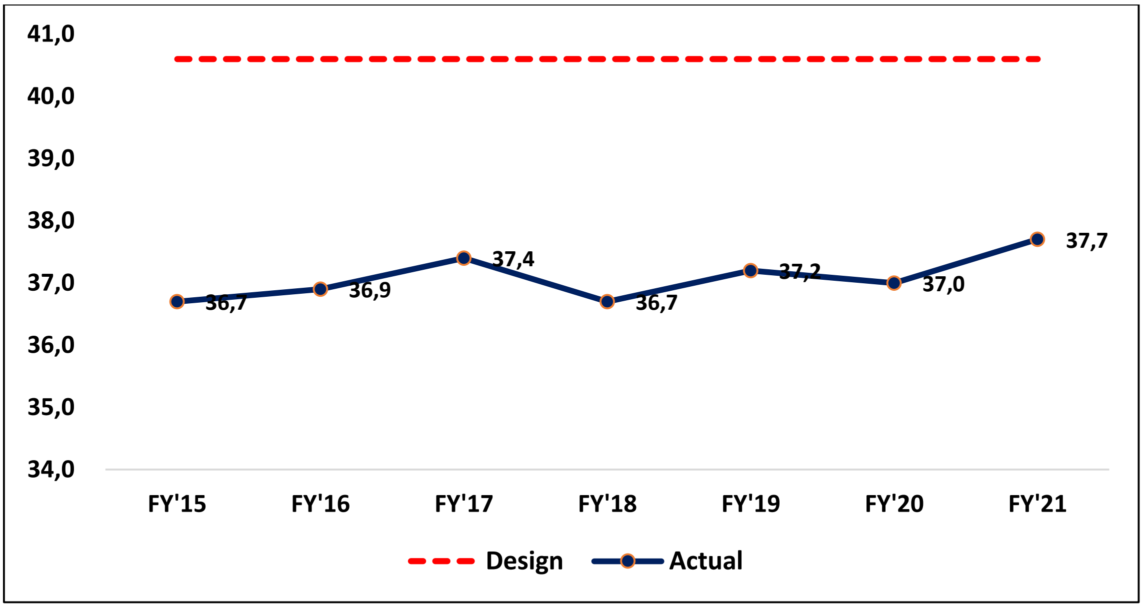

Figure 2. Yearly THA in bauxite, %.

Looking at the above trend, specific bauxite consumption as well as specific bauxite residue generation has been commensurately high due to the following reasons:

- Higher dry bauxite factor than design resulting in higher tonnage of bauxite processed leading to higher residue generation.
- Less compaction characteristics of mud due to the increased volumetric throughput across the CCD circuit. The higher throughput caused low solids compaction across the HRD's and DCW's. Against the design of 800 g/l solids in HRD U/F, only 750 g/l of solids were achieved, while in DCW's against the design of 1100 g/l, only 920 g/l were achieved

Table 1. Mud generation against bauxite quality.

No.	Description	UOM	Design with 40.62 % THA	Actual THA %	Deviation %
1	Dry Bauxite Factor	T/T alumina	2.59	2.9	11.96
2	Mud Generation	T/T alumina	1.06	1.34	26.41

In-house detail studies were undertaken to identify the bottlenecks and to propose design changes for facilitating the higher Residue processing across the CCD circuit as shown below [3]:

a) Velocity and flow calculations for suitability of piping size.
b) All existing pump curves were studied for proposing suitability of pumps, motor, drive speed, and VFD's.
c) Flocculant dosing system was also examined and found adequate to meet the higher dosing rate.
d) Laboratory experiments were carried out to explore the best suitable flocculants to improve the settling and sustain compaction targeting the reduction in liquor soda loss [4].
e) Operating variation was considered to a maximum of 15 %.

Following was the outcome of the in-house studies:

i) Increase speed of the underflow and overflow pumps in the wash circuit to achieve higher pumping capacities. Adequacy of the drives was evaluated and confirmed for the increased capacity.
ii) Increase all underflow line sizes to the next correct size to maintain the required velocity and pressure drop.
iii) Increase overflow line sizes of a few wash stages to contain pressure drop with the existing drive sizes.
iv) On the flocculant front, based on laboratory scale settling studies, Nalco-RRA was selected for the lead washers (1/2/3/4), and Nalco-85144 for the end washers (5/6).
v) Operation philosophy of Geho pumps also had to be altered. Instead of One operating and other standby with a swing blind, it was changed to ensure availability of both the Geho pumps to run in parallel for increased residue throughput.
vi) With the increased throughput, wash water consumption increased. To ensure the temperature of the wash water, the inline heater provided in the original design was replaced with a coiled heater inside the wash water tank. This increase in wash water flow and the impact of the same in terms of evaporation load was also studied and taken care of.
vii) To increase the effectiveness and optimize the flocculant consumption – the secondary diluent was changed from fresh water to condensate [5].

Alcan's latest thickener technology is based on designing relatively narrow and tall tanks in order to achieve high underflow solids. These deep thickeners can produce mud dense enough and viscous to support coarse particles and thus eliminate the need to separate the sand from the fine mud prior to feeding the thickeners, as is generally done in other technologies. The performance of a thickener fitted with an off-center feed well is significantly improved, compared to the one where the feed well is centered. The rake torque and underflow solids are more consistent [6].

The economical thickening of red mud slurry always poses a challenge to the alumina industry. The ever-decreasing quality of bauxite reserves brings about a challenge with larger tonnage of mud to be processed in plant. Utkal was no exception to this. Over the last several decades, use of synthetic organic water-soluble polymers in solid / liquid separation processes has increased dramatically. These polymers have gained wide acceptance in the alumina industry.

Proper flocculation, dosing points, and choice of a flocculant plays a vital role in obtaining good performance of the HRD's and DCW's in the separation of red mud from liquor [7].

Based on the nature of the bauxite to be processed, the flocculant proposed by RTA after extensive studies were as follows:

- HRD – Copolymer dosing comprising of Polyhydroxmate (Hx-300 to be dosed in Feed well to control interface), and Polyacrylamide (to be dosed in the feed line to achieve settling rate and compaction). This was altered to only hydroxamate flocculant (Hx-600) injected in both feed well and feed line.
- DCW's – 100 % anionic polyacrylate was recommended on the lead washers (stages 1/2/3/4), whereas 70 % anionic polyacrylate on the end washers (stages 4/5/6). This was changed to Nalco RRA on the lead washers (stages 1/2/3/4), and Nalco-85144 on the end washers (stages 5/6).

The above changes ensured desired settling rates, acceptable overflow clarity, and underflow compaction on a sustainable basis.

Table 2. Flocculant types and application details.

Tanks	Type of Floc.	Primary Conc.	Secondary Dilution	Dosing Point
High Rate Decanter (HRD)	HX-600	1% (Sodic condensate)	0.18/0.2 % (Process condensate)	Feed well& Feed line
Lead Washers (DCW 1,2,3 and 4)	Nalco-RRA	0.8 % (Sodic condensate)	0.15 % (Process condensate)	Before E-Duct and 0 deg.in Feed well
End Washers (DCW 5 and 6)	Nalco-85144	1% (Sodic condensate)	0.20 % (Process condensate)	Before E-Duct and 0 deg.in Feed well

3. Bauxite Residue Management

Utkal adopted wet disposal of Red Mud Slurry (Wet Ponding) in a single Pond with solids (approx. 50 % / <900 g/l). In the original design, 2 ponds were supposed to handle the wet slurry, but only one was completed. With the single pond in use since October 2013, and slurry being pumped at low solids concentration against the design of 1100 g/l, the life of the pond was fast depleting. As per the design 30 % of the area had to be kept free to collect the supernatant liquor. In addition, stability of stored red mud was always a threat, because the mud dumped would dry to a maximum of 64 % solids only over a period of time. As per the original design, ponds A and B had to be taken into service. The envisaged upstream rise was after the 7th year. This meant that appx 9 500 000 m^3 of mud slurry was to be stored. However, with a single pond in operation and faster ramp up, 11 500 000 m^3 of Red mud slurry was pumped in the pond by the 3rd year of operation. This was also coupled with the fact that low quality bauxite was processed, and the slurry solids were low. To tide over the situation, every alternate year height of the embankment required to be raised. Looking into the prevailing situation and the strategic decision of processing inferior quality of bauxite, the Red Mud Filtration project (Cost 930 million INR in September 2015) was envisaged to increase the pond life and mitigate the environmental threat. The project commenced commissioning in June 2017, and it was imperative to achieve zero wet ponding as early as possible.

The Jingjin supplied Red Mud filters are plate and frame type which facilitate pressure filtration. The following are the details of the Red Mud filters installed at Utkal to produce residue cake with 75 % solids, and filtrate of < 100 mg/l solids. The feed slurry is fed to the filters, and after the filtration cycle, dry cake is discharged on the conveyors, from where it is sent to the pond. After the discharge the same is loaded onto the haul vehicles, which haul the same inside the pond to the designated places and dump. This dumped mud is dozed with dozers and compacted with a vibro roller compacter.

The filtrate from the filters is collected in a filtrate tank and recycled back to the plant as a process water. The cloth washing of the filters is done with fresh water, and the same is sent to the filtrate tank for recycling. Schedule cloth washing helps to enhance the cloth life. The maintenance practices adopted at Utkal help to ensure availability of the filters thereby giving us the cushion to handle higher residue [8].

After the commissioning and gaining experience on the operation of the Red Mud filters, Utkal carried out certain changes in the operational philosophy to stretch the filters to further reduce the moisture in the reside cake.

Table 3. Pressure filters – operating parameters.

Parameters	**Design**	**Operating**
Feed Pressure	785 kPa	637 kPa
Feeding Time	240 s	200 s
Squeezing Pressure	16 kg/cm^2	11.5 kg/cm^2
Squeezing Time	720 s	180 s
Washing Frequency	once in 40 cycles	once in 45-50 cycles
Cloth Life	3780 cycles	~ 4300 cycles
Cycle Time	30 min	27 min

4. Results and Discussion

After commissioning Utkal achieved the fastest ramp up to its design production capacity. As per the strategic decision to process low quality % THA bauxite, Utkal achieved consistent production to its design capacity of 1.5 Mt in FY17, FY18, and surpassed the design capacity in FY19.
This has been achieved primarily due to the efficient handling of the bauxite residue across the CCD circuit, and disposal of the same in an environmentaly friendly manner. In the process of achieving the same, many benchmarks have been achieved. The trends for the same are appended below.

Owing to the low THA bauxite processed, the technological modifications across the circuit, enabled handling of the increased residue, continuous focus on optimizing the flocculants, coupled with routine lab studies, resulted in higher compaction with optimized flocculant consumption. Against the design of 412 g/t (as is), the flocculant consumption is in the range of 390 – 400 g/t (as is).

Schedule tanks turn around on a timely basis reduces the scaling load and ensures faster turnaround. This is important to achieve higher availability of the tanks on line to sustain the processing of higher residue generation.

The successful commissioning and ramp up of the Red Mud Filtration Unit (RMF) in three months enabled 100% dry disposal, thus contributing immensely in reducing the liquor soda losses and improve the stability of the pond, by reducing the hydraulic thrust on the embankment dykes.

Commissioning of the dust suppression system with a dust seal chemical across the pond helped us to mitigate the environmental challenge of fugitive dust generation.

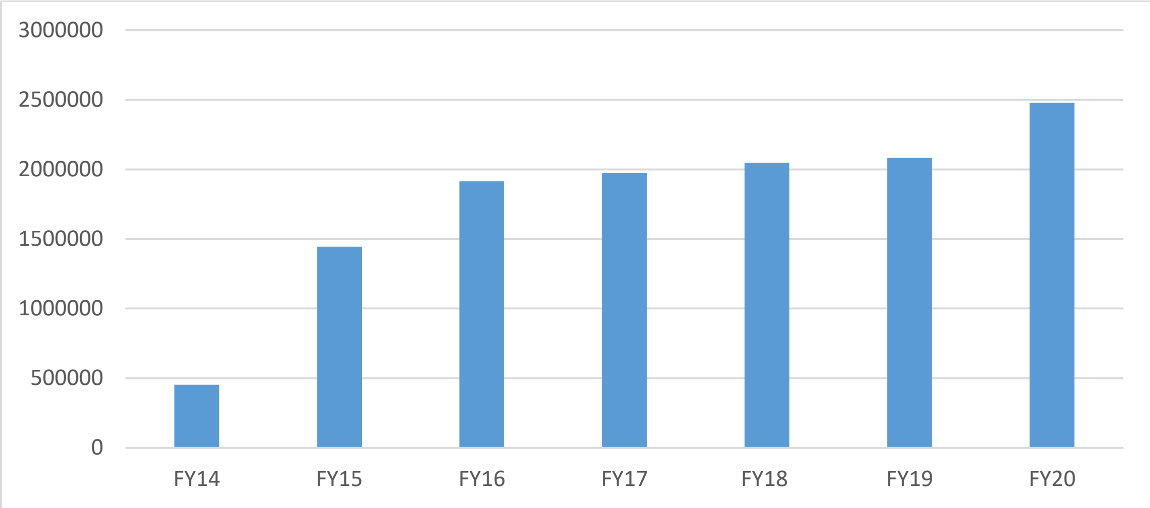

Figure 3. Yearly bauxite residue generation, tonnes.

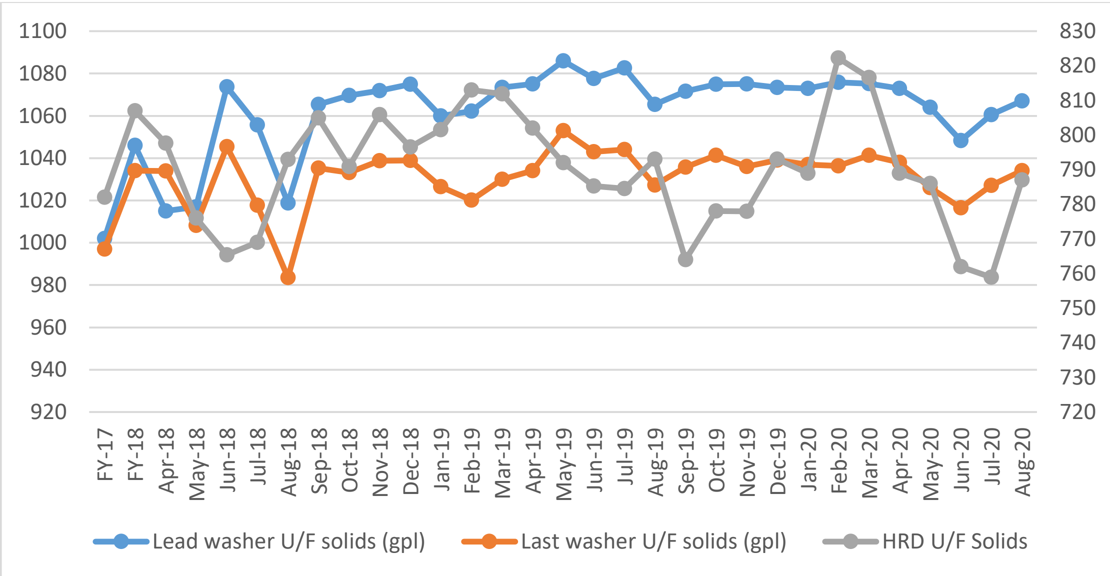

Figure 4. CCD underflow solids, g/l.

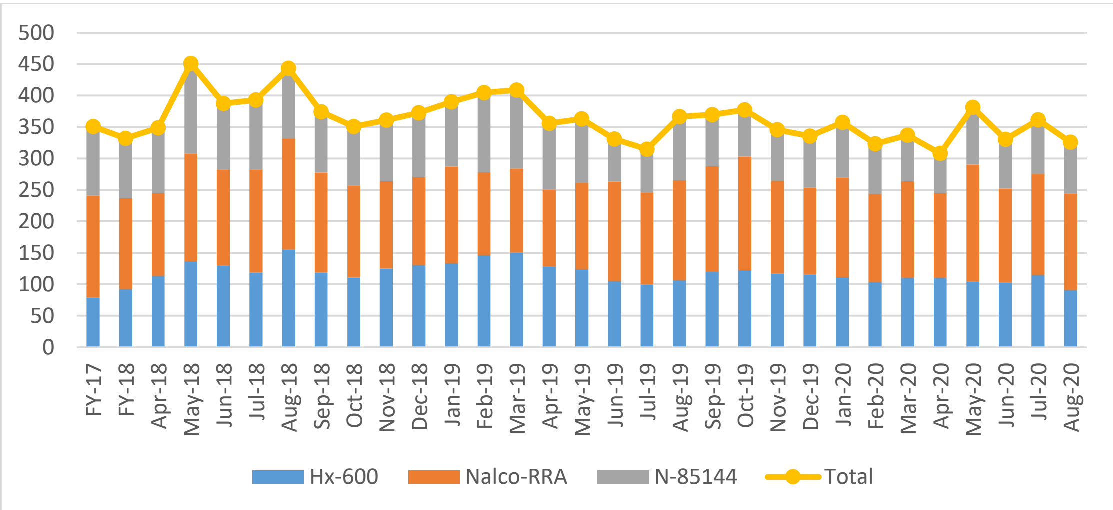

Figure 5. Flocculant consumption, g/t.

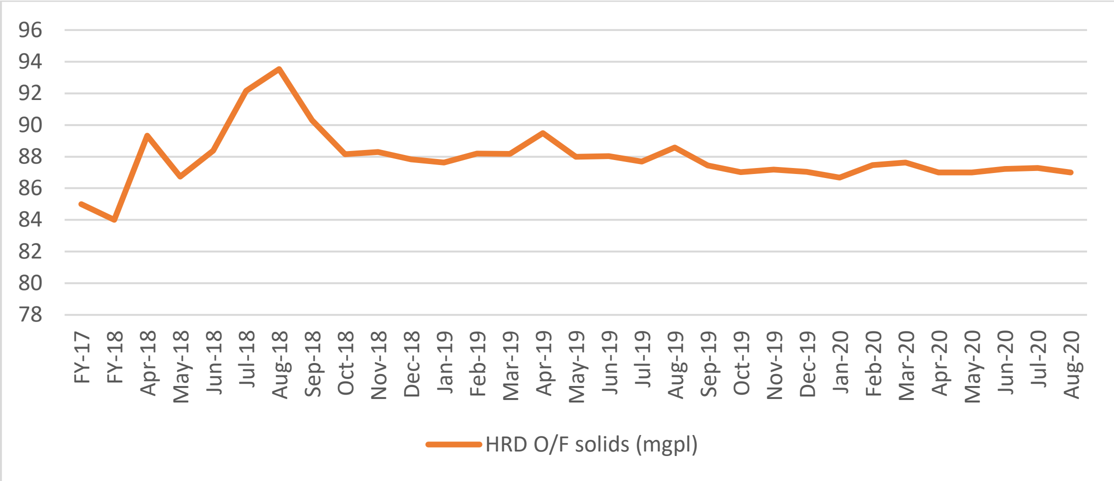

Figure 6. Solids in HRD overflow, mg/l.

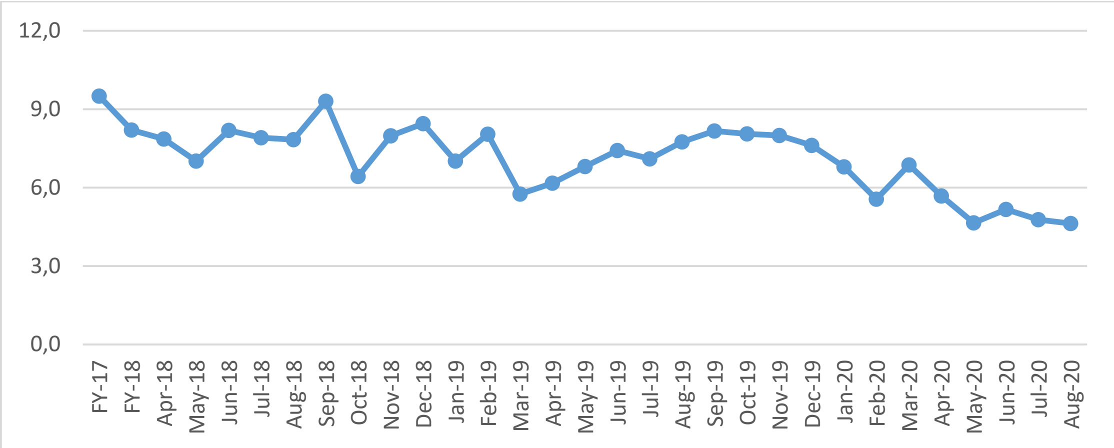

Figure 7. Last washer caustic, g/l Na_2CO_3.

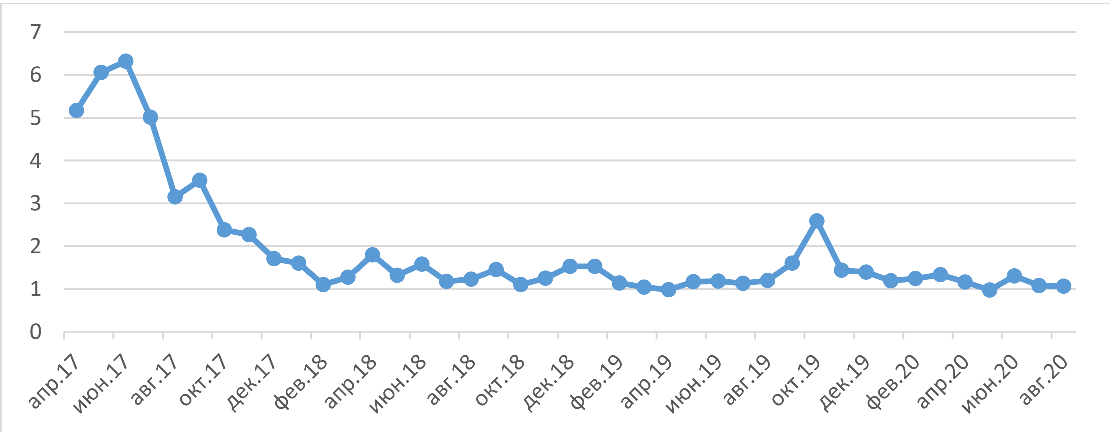

Figure 8. Residue Soda Loss, kg/t NaOH.

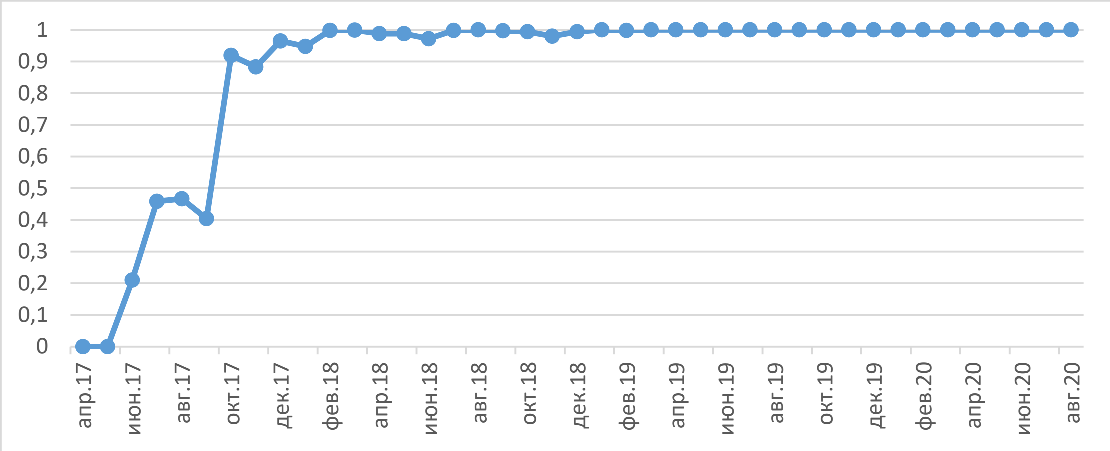

Figure 9. Residue processing time through pressure filters.

5. References

1. Alcan Red Side Process Manual, Vol-23, *Technology Document.*
2. *Utkal Greenfield Project Training Manual* – Mud Separation (Area 240), Mud Washing (Area 241), Mud Pumping and Storage (Area 242, 243).
3. Internal Capital Proposal Note for debottlenecking of Mud circuit for 1.5 Mio Tons alumina production with < 38% THA, CP/PROV/02/R/UAIL/15-16.
4. L.J. Conelly and P.F. Richardson, Coagulation and flocculation in Mining Industry*, "Solid Liquid Separation and Mixing in Industrial Practice"*, Pittsburgh Section of AIChE, 1984, October 10.
5. Pierre Ferland, John Malito, Everett Philips, Effects of temperature and method of solution preparation on the performance of typical red mud flocculant, Reprint 866.
6. Guy Peloquin, Guy Simard, *Improved Thickener for Red Mud, Proceedings of the 6th International Alumina Quality Workshop*, Brisbane, Australia, 2002, September 8-13.
7. R.B. Kahane and C. Mcrae, *Improved Bauxite Residue Settler Performance, Fourth International Alumina Quality workshop*, Darwin, 1996, June 2-7.
8. *Operation Instruction of Jingjin filter press contents* - O&M Manual.