A NEW CONCEPT FOR DRY DISPOSAL OF ALUNORTE'S BAUXITE RESIDUE

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Abstract

Alunorte uses dry stacking based on the technology of Giulini (Schepers & Haerter 1975) for bauxite residue storage. The residue is washed and filtered in drum filters. A high solids content of 64 wt.-% is achieved and specific soda loss is low with less than 6 kg per ton of alumina. Effluent water from the RDA is cleaned and neutralized. The existing concept has a low environmental impact and the advantage of no water returning to the Bayer process.

This paper presents the study of a new concept to move from dry stacking to dry disposal for the next implementation phase of Alunorte's residue disposal area (RDA). A key element is the use of filter presses for residue washing and filtration. It will be possible to increase the residue solids content to about 80 wt.-%. This will result in a number of advantages, such as maximizing the residue storage capacity, increasing lifetime of the RDA, cost reduction and disposing a significantly lower amount of liquid. The environmental performance is kept and specific water consumption for residue washing will be reduced.

Tests which were performed at Alunorte demonstrate the viability of the concept. Field tests with pilot-scale filter presses gave good results. Process simulation was used to quantify process impacts resulting from the replacement of drum filters with filter presses. The water balance of the refinery, the risk of higher organics concentrations in the plant liquor and potential impacts on precipitation productivity are discussed.

1. Introduction

Alunorte is located in the state Pará in northern Brasil near to the city Belém. The plant started operation in 1995 and has expanded three times since then. The actual production capacity is close to 6.3 Mtpa. The latest Expansion 3 included the installation of process lines 6 and 7 and was commissioned in 2008 (Khoshneviss et al. 2011).

Alunorte uses dry stacking for bauxite residue disposal. This technology is considered as state of the art. It was implemented at start-up of the plant and Alunorte can look back to more than 15 years of operational experience with this technology. Although Alunorte considers this concept to be good (Alves Filho et al. 2011), there are ambitions to further decrease the environmental impact of Alunorte's bauxite residue storage. This can be achieved by increasing the solids content of the disposed residue and means a transition from dry stacking to dry disposal. There is a trend in the alumina industry to move towards a densification of the residue (Power et al. 2011). At higher solids content the amount of liquid disposed with the residue is reduced. More bauxite residue can be stored per unit area. This reduces the space requirement of the residue deposit area (RDA). Furthermore, the generation of liquid effluent is smaller since less rainwater is collected and there is the potential to decrease controllable soda loss. Capital cost can be reduced due to the larger mass of residue disposed per area RDA and the correspondingly extended lifetime of the deposit. In comparison to older wet disposal concepts no large perimeter dykes are required. The dumped residues, once in repose, form a very stable solid body, allowing trucks and dozers to traverse it and offering a significantly smaller risk of dyke failures (Cooling 1989 and Cooling & Glenister 1992).

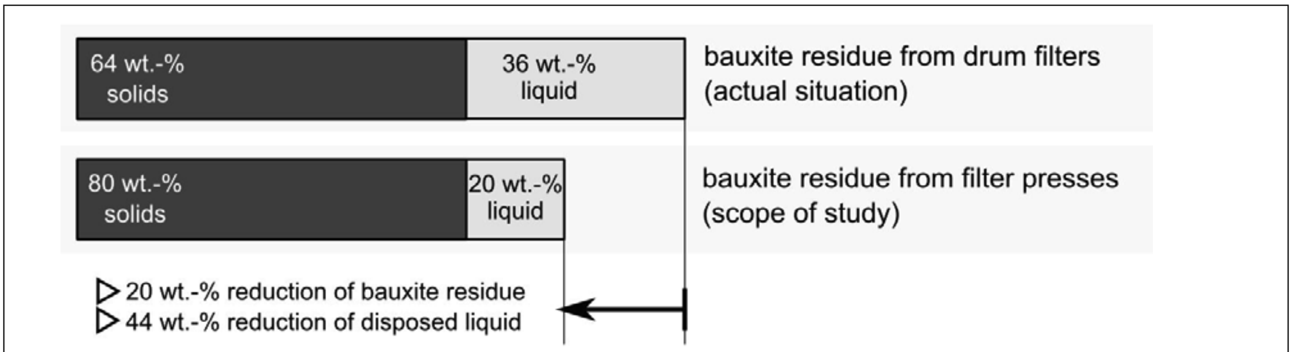

Figure 1. Comparison of bauxite residue from drum filters and filter presses.

Actually with Alunorte's dry stacking technology a solids content of about 64 wt.-% of the disposed residue is achieved. With a new dry disposal concept the aim is to achieve up to 80 wt.-%. The benefits in terms of environmental impact are shown in Figure 1. The total amount of bauxite residue is reduced by ca. 20 wt.-% compared to the actual situation and the amount of liquid disposed is reduced by 44 wt.-%.

The main technical challenges for this solution are to find an adequate filtration technology with the desired performance and the integration of this technology into the existing plant. There is some experience in the alumina industry to use filter presses for bauxite residue. Rousseaux et al. 2008 report successful use of filter presses in the two refineries Gardanne and Aluminium of Greece. A residue solids content of about 72 wt.-% is reported. Filter presses are in particular suitable for applications where the material has poor filtration characteristics, e.g. due to very fine particle size distribution, and seems therefore to be an attractive choice for bauxite residue filtration.

Alunorte has initiated a series of test campaigns in order to evaluate the performance of filter presses. In contrast to a green field project, where the characteristics of the filter press operation can be integrated into the process concept of the Bayer plant from the very beginning there are a number of process constraints to be respected when filter presses shall be integrated into an existing process. It needs to be ensured that the current plant performance is at least maintained. Production rate, consumption of fresh caustic, available evaporation capacity and steam consumption are the main parameters to look at. These parameters are affected in a complex manner through several factors and its evaluation requires careful testing of the filters and a thorough process analysis.

2. Alunorte's RDA concept

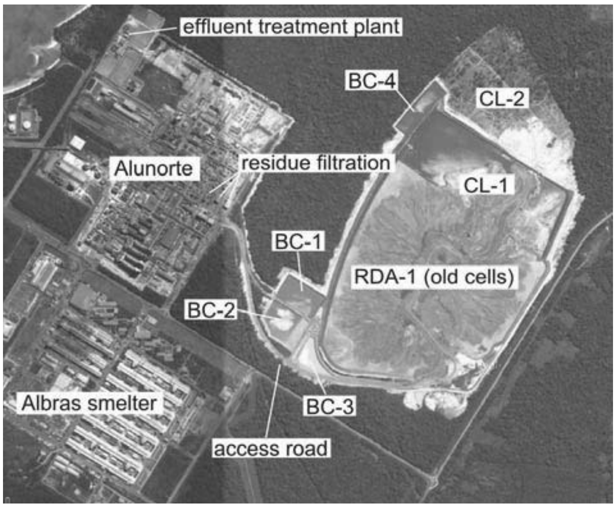

Figure 2. Alunorte's bauxite residue storage area.

Alunorte uses the dry stacking technology which is considered as state of the art for bauxite residue disposal. The concept used at Alunorte was developed by the German company Giulini Chemie Gmbh (Schepers & Haerter 1975) and reviewed by Alcan. In the following a short description of the existing system and the residue disposal concept is given. More details are found in Alves Filho et al. 2011.

After the separation of the non-soluble components of the plant liquor in high rate decanters the residue is washed in a series of five washers to recover soda from the bauxite residue. Alunorte has moved from conventional washers to Alcan deep thickeners. These thickeners are designed as relatively narrow and tall tanks in order to achieve a high underflow solids concentration (Peloquin & Simard 2002). The pre-thickened underflow of the last washer has an average solids content of about 40 wt.-%. It is sent to vacuum drum filters where it is washed and filtered. The solids content of the filter cake is about 64 wt.-%. Washing is done at high efficiency at a net wash (mass of wash water used per ton of dry mud) of 0.8 to 1.2. A controllable soda loss of about 6 kg NaOH per ton of alumina produced is achieved.

The filtered residue is transported by trucks to the RDA where it is disposed. After unloading, the paste flows down the slope without segregation or settling to form layers of uniform thickness at an angle of repose of about 5 º. Through further dewatering and drying a final solids content of ca. 70 % is reached (Power et al. 2011). Effluent water from the RDA is collected and sent to a treatment plant where it is neutralized and cleaned before it is sent to the adjacent Pará river. The system was upgraded and improved in 2007. A detailed description is found in Alves Filho et al. 2011 and Aldi 2009.

In Figure 2 the layout of the existing bauxite residue disposal area is shown. The RDA is located south of the alumina plant, approximately 1,600 m, straight, and 2,500 m from the effluent treatment plant, with an operational area of 170 ha. The existing residue disposal area consists of the RDA-1 old and new cells, the surrounding channel that collects the runoff water, the runoff collection ponds and the pumping and piping system that direct the water to the effluent treatment station. As old cells are filled up, new cells are added to the RDA-1 deposit. CL-1 cell lifetime is running out, and CL-2 is ready to start operations. The cells have dimensions of around 1,000 x 100 m each.

3. Concept Study Dry Disposal

The presented study to use filter presses for bauxite residue treatment is part of the planning for an extension of the bauxite residue storage area. A main element of the study is the increase of the residue solids content. At higher solids content the environmental impact of the bauxite residue is reduced. The space requirement for the deposit area is smaller and the amount of liquid disposed with the residue is significantly reduced. The lower space requirement is caused by two factors. As shown in Figure 1 the total amount of bauxite residue is reduced by 20 wt.-%. In addition, the storage behaviour changes in a positive way. At higher solids content the stacking angle of the residue will increases from today's about 5 º. First tests revealed that a stacking angle of at least 14 º will be possible. This results in a better use of the available deposit area. In addition, existing deposits can be filled up with new material so that also their lifetime can be increased. Investment costs for the RDA per annual production ton will decrease.

3.1 Filter presses

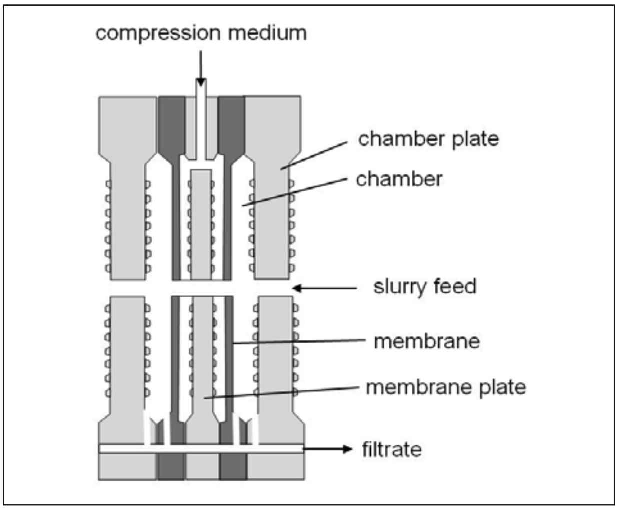

Figure 3. Membrane of filter press.

The main element to enable the new disposal concept is the replacement of the existing drum filters with filter presses. Filter presses with membrane plates are considered for this study. They consist of chamber plates and membrane plates (Figure 3). The latter contains a membrane which can be pressurized for compressing the filter cake. As compression medium either water or air is used. Pressures in the range of 10 to 14 bar are typically applied. Filter presses are operated batch-wise. The steps of operation are shown in Figure 4. In a first step the chambers of the filter press are closed and filled with bauxite residue slurry. During filling the filtration starts promoted by the pressure of the feed slurry. This filtrate has a caustic concentration close to the caustic concentration of the feed slurry. In a second step the membranes of the filter presses are pressurized to pre-compress the filter cake, which is then washed with condensate. The filtrate contains wash water and inter-particle liquor which is replaced or removed from the cake. In the third step the cake is compressed. Air is blown into the cake to further dry it. More inter-particle liquid is removed and the cake has reached its final moisture content. In a fourth step the chambers are opened and the cake is discharged.

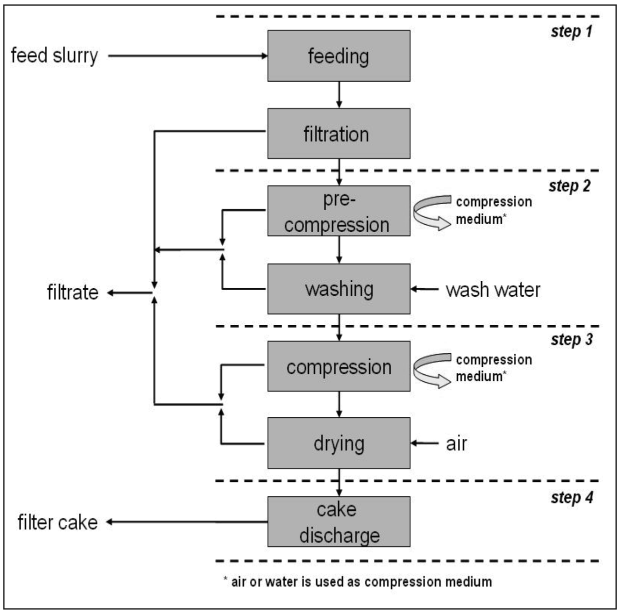

Figure 4. Operation steps of filter press.

3.2 Pilot-scale field tests

A good filter performance is required to be able to integrate filter presses in an existing process. In co-operation with filter press suppliers Alunorte performed a series of tests. Aim of the tests was to verify that the filters have a sufficient performance. The target was to reach at least 78 wt.-% solids content in the filtered bauxite residue. The residual moisture of the filter cake x_L is the ratio of mass of liquid m_L and mass of moist filter cake, i.e. dry cake $m_{S,cake}$ and liquid in the cake $m_{L,cake}$:

$$x_L = \frac{m_L}{m_{S,cake} + m_{L,cake}} \quad (1)$$

The final soda content in the filter cake changes with the amount of wash water used. This soda is considered as controllable soda loss in contrast to non-contrallable soda loss which is chemically bound in the bauxite residue. The soda content of the bauxite residue filter cake $\xi_{soda,cake}$ is the mass of soda (expressed as Na_2CO_3) in the inter-particle liquid phase of the sample.

$$\xi_{soda,cake} = \frac{m_{soda}}{m_{S,cake}} \quad (2)$$

The specific water consumption for washing the cake in a filter β is expressed as mass of water used for washing m_{ww} in relation to the mass of dry mud $m_{S,cake}$.

$$\beta = \frac{m_{ww}}{m_{S,cake}} \quad (3)$$

While the specific water consumption is characteristic for a single filter the net wash is defined for the clarification area. The definition is identical to eq. 3, namely the mass of water used for washing per mass of dry bauxite residue. However, this figure may include other water source in addition to the water used for washing in the filters.

The washing efficiency of the filter ε_{wash} is defined as the fraction of inter-particle liquid phase of the feed slurry that is replaced with wash water during washing. It can be calculated from the difference of soda concentrations C_s between feed slurry and filter cake.

$$\varepsilon_{wash} = \frac{C_{s,feed} - C_{s,cake}}{C_{s,feed}} \quad (4)$$

Tests with filters with one to up to ten chambers were performed. Plate dimensions were in the range of 500 x 500 mm^2 to 800 x 800 mm^2 depending on the filter used. The filters use either air or water as compression medium and compression pressures of up to 15 kgf/cm^2 were applied in the tests.

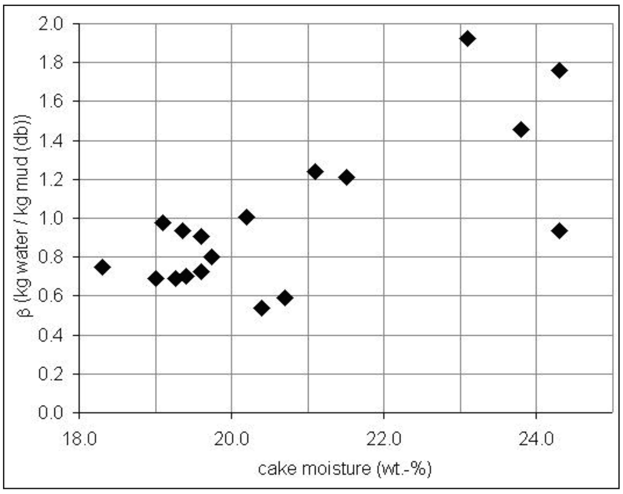

Figure 5. Achieved cake moistures and wash efficiencies during pilot-scale filter tests.

The filters are fed with slurry from the last washer underflow. The solids content was in the range of 37 – 46 wt.-% and the feed slurry caustic concentration in the range of 82 to 98 g/l. The causticity of Alunorte's liquor is close to 98 %, so that the soda concentration is slightly higher than the caustic concentration.

The results of the tests are shown in Figure 5. Only data points which fulfil the condition of a residue soda content $\xi_{soda,cake} < 7.7$ are shown. This is the actual controllable loss of soda with the residue. As part of the concept it is required that the replacement of existing drum filters do not increase the controllable soda loss compared to the actual situation. The specific water consumption β is for some of the tests shown in Figure 5 lower than the actual net wash of 0.91 and for some of them higher. Since the new filters shall be integrated into an existing test the available evaporation capacity has to be respected. Thus, there are a number of points with high specific water consumption shown in the figure that are no feasible operation points when the filters shall be integrated into the process. This will be studied in more detail in the following. The test results show furthermore that a residual moisture of 20 wt.-% and even slightly below could be achieved. This performance fulfils the requirements of the concept study and is one of the very important outcomes of the pilot-scale tests.

4. Process Impacts

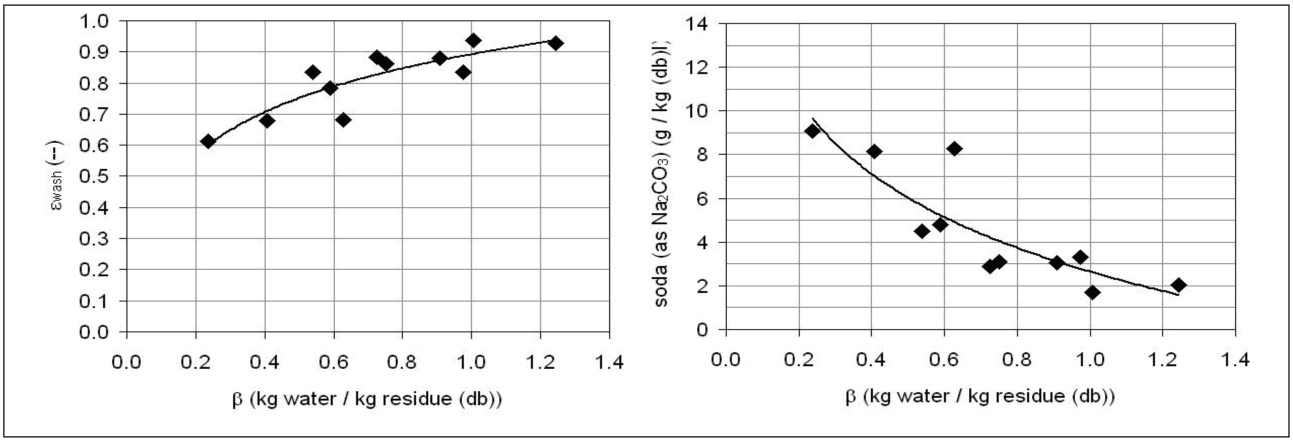

Figure 6. Washing efficiency of the filter (a) and corresponding bauxite residue soda content (b) in dependence of specific water consumption.

With the help of steady-state flowsheet simulation the impact of replacing the existing drum filters with filter presses was investigated. To simulate the filter presses the correlation between specific water consumption and filter washing efficiency is required. Figure 6a shows an example of this correlation and in Figure 6b the corresponding bauxite residue soda content is shown. These values result from the pilot-scale field tests.

4.1 Use of wash water

The parameter which can be adjusted during operation is the amount of wash water to the filters, i.e. the specific water consumption β. The feasible points of operation with regard to the use of wash water are constrained:

The controllable loss of soda shall not exceed the loss of soda under actual operating conditions. This defines the lower bound of the specific wash water consumption β.

The use of wash water is limited by the available evaporation capacity. This defines the upper bound of the specific wash water consumption β.

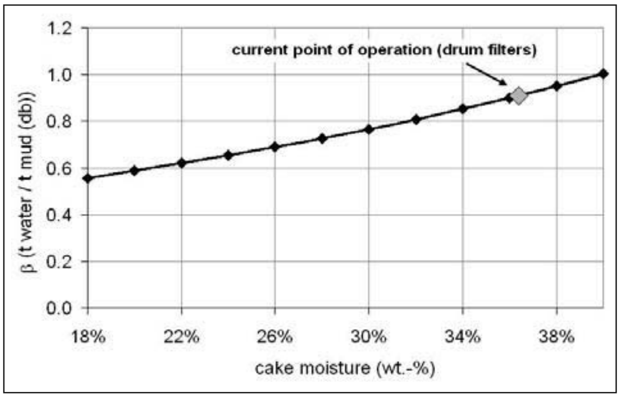

Figure 7. Maximum tolerable specific water consumption in dependence of residue moisture under conditions of constant filtrate flow from filters to last the last washer.

Compared to the actual net wash of 0.91 t/t the amount of wash water that can be used with filter presses must be smaller than actually. As shown in Figure 1, the amount of liquid that is disposed with the residue becomes smaller at higher solids content. In Figure 7 the specific water consumption β is plotted in dependence of the cake moisture of the filtered bauxite residue for a constant filtrate flow. If a residual moisture in the bauxite residue of 20 wt.-% shall be reached the specific water consumption has to drop from 0.91 to about 0.6. A change of the specific water consumption will affect the water balance of the refinery and change the demand for evaporation. The caustic concentration profile along the washers will change as well as the filtrate flow with some effect on the residence time in precipitation and precipitation productivity.

4.2 Liquor impurities

Plant production and precipitation productivity is affected by the concentration of organics in the plant liquor. Plant liquor impurities are purged as part of the inter-particle liquid phase with the bauxite residue. Organics will accumulate in the liquor when the moisture content of the residue decreases and the soda concentration of the inter-particle liquid is kept unchanged. With increasing concentration of organics the solubility of gibbsite and boehmite at digestion conditions increases at a lower slope than at precipitation conditions with a net negative effect on plant performance (Figure 8).

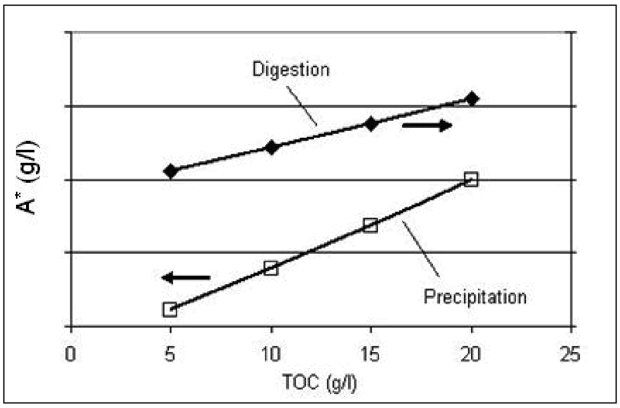

Figure 8. **Solubility of gibbsite A* at digestion and precipitation conditions in dependence of liquor organics content.**

Alunorte operates with an organics content of about 5 g/l. This value is well below the critical oxalate concentration. A significant increase of the liquor organics would lead to a lower plant production and possible operational issues due to oxalate co-precipitation which so far have not been experienced. Therefore operating conditions when using filter presses have to be found that ensure a low level of liquor organics concentration.

4.3 Process simulation and results

The operation of the plant with filter presses instead of drum filters will affect the entire process. Due to a different washing efficiency of the filters and a changed net wash the caustic profile along the washers will change. Changes of the net wash might impact on the filtrate flow. When the LTP flow decreases due to a lower net wash the residence time in precipitation will increase. This results in a higher productivity. The organics concentration in the plant liquor will increase when the bauxite residue soda content decreases. This results in a higher solubility of gibbsite and it is possible to charge more bauxite in digestion. In the actual study the supersaturation ratio (eq. 5) in the liquor filtration area was kept constant at the actual level.

$$\text{SSN ratio} = \frac{A/C}{A^*/C} = \frac{A}{A^*} \qquad (5)$$

A is the actual concentration of sodium aluminate $NaAl(OH)_4$ expressed as mass Al_2O_3 per volume of liquor. A* is the corresponding saturated alumina concentration. C is the caustic concentration expressed as mass of sodium carbonate Na_2CO_3 per volume of liquor.

Table 1. Results of process simulations for selected cases (lines 6/7).

		drum filters (base case)	filter presses (case 1)	filter presses (case 2)
total liquid soda in dry residue	kg/t (db)	7.7	3.0	7.3
net wash	t/t	0.91	0.77	0.52
production difference*	ktpa	0	loss > 10,000	gain < 4,000
soda consumption difference*	kg/t	0	- 3	+/- 0
test tank TOC	g/l	5.5	14.2	5.8
evaporation feed flow difference*	m3/h	0	+ 160	- 180
steam consumption difference*	t/t alumina	0	+ 0.045	- 0.025

* compared to actual situation with drum filters.

In Table 1 results of the flowsheet simulation study with Alunorte's SysCAD model are shown. Two cases are compared with the actual situation (base case). In the first case intense washing of the bauxite residue is assumed. The controllable soda loss decreases to less than half of the actual loss. However, the simulation shows that this can only be achieved with a significant loss of production, mainly due to an increase of the liquor organics concentration. The demand for evaporation is higher than at present and would exceed the available evaporation capacity of the plant. Together with the demand for evaporation the steam demand will increase. Thus, this scenario is not feasible and is therefore not considered further.

Case 2 shows a better result. The net wash is adjusted to a level where the controllable soda loss is slightly lower than at present. The concentration of organics in the liquor remains close to the actual concentration so that its negative impact on production and precipitation productivity is small. A low net wash and the correspondingly lower digestion dilution flow affect the process positively. The smaller pregnant liquor flow leads to an increase of precipitation residence time and increases precipitation productivity and plant production. The demand for evaporation decreases and a positive effect on specific steam consumption is resulting. This scenario represents a feasible case and shows that the filter press technology can be integrated into Alunorte's process. The simulation results show that some positive effect on plant production and steam and soda consumption can be expected.

5. Conclusions

Alunorte has studied a concept of dry disposal of its bauxite residue. Compared to the dry stacking technology actually in use the benefits would be an increase of the residue solids content from actually 64 wt.-% to about 80 wt.-%, a reduction of the overall amount of bauxite residue by 20 wt.-% and a reduction of the liquid disposed with the residue by 44 wt.-%. This improvement is associated with an increased lifetime of the bauxite residue storage area, i.e. the environmental impact is reduced by reducing the space requirement for the RDA per ton produced alumina. This improvement is on one hand due to the smaller amount of residue produced per ton of alumina and on the other hand due to an increased possible stacking angle of the residue. Furthermore, the amount of rain water to be collected at the RDA reduces due to the lower space requirement of the RDA.

The required residual solids content of the bauxite residue cannot be achieved with drum filters. Pilot-scale field tests with filter presses were conducted in order to evaluate their performance. Main performance parameters are the achievable residual moisture of the bauxite residue and the wash efficiency of the filters. The challenge for Alunorte is to ensure that the new filters can be integrated into the existing process without negative impacts on the process. It must be ensured that plant production and specific caustic soda consumption are at least kept and that other process constraints such as the available evaporation capacity are respected.

The pilot tests gave positive results and showed that the required residual moisture in the bauxite residue can be achieved. Furthermore, it is possible to recover sufficient soda to achieve a controllable soda loss equal or even lower than actual. Flowsheet simulation was used to study the impact on the overall process. A key issue is the control of organics in the plant liquor. An increase of organics concentration will lead to significant losses of production.

The simulation results show that it is possible to respect all constraints and to integrate filter presses for bauxite residue filtration into the existing process. By choosing adequate operating conditions a small positive effect on the overall process performance can be expected. Filtration with filter presses could be qualified as viable concept for the Alunorte refinery. Moving from dry stacking to dry disposal is possible and the environmental impact of bauxite residue storage can be further improved.

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