Environmental and Economic Benefits of Bauxite Residue Management through the Use of Pressure Filtration, a Case Study

Andrea Pezzi[1], Francesco Kaswalder[2] and Richard Irons[3]

1. Sales Director North America, Canada and UK,
2. R&D Process development manager,
Diemme® Filtration, Lugo, Italy
3. Senior Process Consultant,
Alcoa of Australia, Australia

Corresponding author: rociomarian.ciraldo@bilfinger.com

Abstract

Filtration of Bayer process bauxite residue using filter presses permits efficient material handling and stacking. The low moisture content can also translate to improved soda recovery. The fine fraction of bauxite residue known as 'red mud' can be a relatively complex slurry, having a solid portion made up of a mixture of different phases which can influence the material's filterability. For this reason, detailed testing of the residue slurry is necessary to define the filtration conditions best suited to achieve the required performance. This paper describes the different phases of testing that Bilfinger Water Technologies follows in determining the filtration conditions best suited to a particular slurry. A case study is presented in which Diemme® Filtration undertook characterization testing on a particular bauxite residue slurry. This allowed Bilfinger experts to define the kind of filter most suitable for this application, to achieve the required performance targets and to meet the plant operational and safety standards.

Keywords: bauxite residue, filtration; filter presses; bauxite residue slurry testing pilot; cake filterability.

1. Introduction

Bauxite residue is a by-product of alumina production. The residue is typically alkaline and requires safe storage to prevent environmental contamination [1]. This residue is treated with a Counter Current Decantation (CCD) system for soda recovery, which results in its volumetric and causticity reduction. Despite this process, the tailings obtained still contain residual alkalinity. The alkalinity in the residue is present as soluble caustic and alkalinity, and alkaline solids. The alkaline solids can dissolve in rainwater and continue to release alkalinity after the soluble caustic has been removed from the residue. Consequently, it is very important that the fine residue (red mud) is stored safely in secure impoundments that prevent groundwater contamination from caustic and also ensure the long-term mechanical stability of the deposit.

2. Bauxite Residue (Red Mud) Composition

Bauxite residue is a chemically complex matrix, whose composition is related both to the kind of bauxite consumed and to the process conditions. The working conditions of the CCD residue washing system are very important also, since they determine some fundamental characteristics of the tailings such as the solid concentration and residual alkalinity. As for its chemical composition, the main elemental constituents are Fe, Al, Si, Na, Ca, Ti, together with other metals that are present in smaller quantities. These constituents have wide ranges of concentration, as can be seen in Table 1 [2].

Table 1. Typical Elemental Composition of Red Mud.

Element	Content (% w/w)
Fe	25-55
Al	10-20
Si	5-30
Na	5-15
Ca	0-5
Ti	0-15

The reason for such wide ranges is bauxite's nature (gibbsitic, boehmitic or diasporic), which determines the mineralogical composition, which is always complex since it includes both phases already present in the initial bauxite and the ones produced during the process.

A common characteristic of all kinds of red mud is the very fine PSD, in most cases the D90 value is lower than 50 micron with the main population distribution peak lower than 20 micron.

3. Dry Stacking as a Means to Manage Red Mud

There are currently two kinds of residue storage methods [3]: wet storage and dry stacking. The first method is the most common one, it consists of pumping the Bayer process residue slurry coming out from the CCD system directly into a secure, sealed impoundment. This method has several disadvantages compared to the current dry stacking method, which involves thickening the residue slurry then drying in layers within secure, under-drained storage areas. As it consolidates and dries, more mud is laid on top to form a stable residue stack.

Further thickening or dewatering of the slurry to obtain a solid residue, which is then stacked in secure impoundments, avoids several problems such as:

- the risks caused by inadequate mechanical stability of wet storage (see Ajka disaster in 2010);
- the potential for groundwater contamination;
- higher capital costs because of the need for a larger areas of residue impoundments; and
- lower soda recovery.

The residue thickening and drying methods generally used are paste thickeners, drum filters, vacuum filters and filter presses and solar drying.

Filter press technology has advantages that make it particularly suitable for bauxite residue treatment. Compared to other technologies, filter presses allow drier residue (with residual moisture lower than 30% w/w). As a consequence, the material handling characteristics of the cake obtained by using filter presses are far better than results achieved by alternative methods. The resultant residue is intrinsically mechanically stable, minimizing the chance of mechanical instability in the resultant residue deposit. The reduced liquor content of the residue reduces the potential for groundwater contamination.

There are several equipment options available to produce suitably dry residue material such as recessed or membrane chambers, solid blowing or washing, etc. A particular option can be selected based on the characteristics of a particular residue slurry.

Diemme® Filtration is leader in designing and producing filter presses. Each filter press is carefully customized to account for the specific process requirements. The final result is obtained after an in-depth analysis in several steps, starting from the complete characterization of the mud to be treated, following by several testing steps carried out in pilot plants to determine the process parameters in the most accurate possible way. All this allows a filter press offering that satisfies the customer's process requirements in every respect.

4. Bauxite Residue Mud Characterization

The residue used in the test work reported in this paper comes from the CCD washing plant of Alcoa's Kwinana refinery (Western Australia). The product has been evaluated in several test campaigns between 2012 and 2014, and in each campaign, a complete chemical and physical characterization has been carried out. This allowed the collection of very important information about its variability.

The solid concentrations of the slurry are indicated in Table 2. The high degree of consistency in the values is guaranteed by the counter current washing thickeners.

Table 2. Slurry Data.

Sample	Slurry density (Kg/l)	Solid content (% w/w)	pH
A (Apr 2012)	1,40	43,5	12,9
B (Jul 2013)	1,38	40,0	13,5
C (Jul 2014)	1,38	40,8	13,5

The slurry PSD shows typical bauxite residue characteristics, a dominant clayey component with a very small percentage of coarse material. In all cases, typical of this kind of slurry, the rare presence of corrosion flakes having different dimensions up to a few centimetres can be noted.

Figure 1 shows the granulometry of the different samples, while Table 3 sums up those trends.

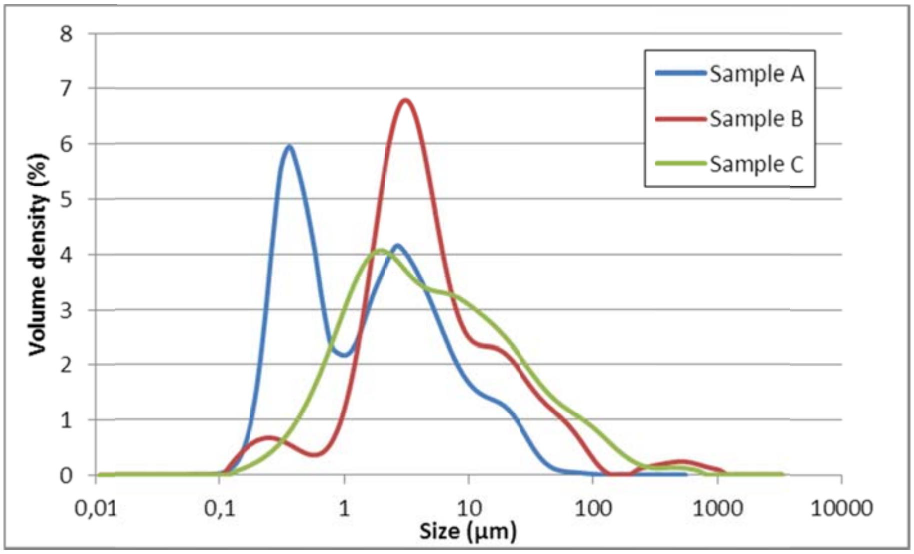

Figure 1. Particle Size Distribution.

Some variability can be noticed, even if the argillaceous silt fraction (< 10 micron) is predominant.
All this considered, a similar filterability can be expected for all samples.

Table 3: Slurry PSD Percentile Data.

Sample	D_{10} (µm)	D_{50} (µm)	D_{90} (µm)
A	0,27	1,37	9,46
B	1,27	4,01	30,1
C	0,80	4,41	43,1

It should be noted that sample A has been measured using a different instrument, with a less sensitive detector than that used for samples B and C. As for chemical characterization, a bauxite residue having a boehmitic and gibbsitic origin is clearly indicated.

Table 4. Elemental Composition (from XRF Analysis).

Component (%w/w)	**Sample A**	**Sample B**	**Sample C**
Fe_2O_3	32,4	31,8	26,5
Al_2O_3	27,3	24,5	27,2
SiO_2	13,1	15,4	15,1
Na_2O	3,98	3,85	4,34
CaO	5,16	5,52	4,56

TiO_2	3,63	2,72	3,04

Table 5. Mineralogical Composition (from XRD Analysis, Amorphous Content Neglected).

Phase (% w/w)	Sample A	Sample B	Sample C
Hematite Fe_2O_3	15,7	14,8	11,8
Calcite $CaCO_3$	6,9	7,0	5,3
Quartz SiO_2	10,7	13,0	17,0
Boehmite AlO(OH)	8,3	9,8	9,4
Gibbsite $Al(OH)_3$	4,1	4,6	6,4
Sodalite $Na_8Al_6Si_6O_{24}Cl_2$	8,0	5,8	6,2
Muscovite $KAl_2(AlSi_3O_{10})(F,OH)_2$	8,4	8,0	8,9
Anatase TiO_2	2,1	2,0	1,7
Al-Goethite $Al_xFe_{1-x}O(OH)$	35,8	35,0	33,3

5. Filtration Tests

Filtration tests have been carried out in separate campaigns, using pilot plants of different scales, to provide as complete a picture as possible of the results that can be achieved under various process conditions.

Preliminary data has been obtained with a laboratory scale filter, which allows a small scale simulation of the functioning of any kind of industrial filter configuration, reproducing results with excellent scalability factors. Figure 2 shows the above-mentioned plant. The results achieved have been confirmed and improved through the following test sessions, which have been carried out by using a pilot filter on a semi-industrial scale. This pilot filter is skid mounted, as shown in Figure 3. The method adopted is the following:

- Test on sample A with a laboratory scale filter: screening of all possible process options to identify the most interesting ones and focus on more effective tests during the following steps;
- Test on sample B with pilot filter: tests previously made on sample A are repeated and improved to define and confirm the best operational conditions to achieve the requested 69% solids target.
- Test on sample C with pilot filter: further tests to define the dependence of the achievable dry values on the process parameters (especially compaction time). This allows optimization of the overall cycle time.

Table 6 shows some of the figures related to the plants used for this scope, while table 7 shows the main results achieved.

These are average values, since several tests have been carried out to confirm the figures obtained. The following conclusions can be drawn:

- The requested 69% solids target can be reached, and the use of the recessed chamber plate pack seems to be the best compromise between cost and performance. The membrane squeezing brings a slight improvement, while air blowing is not so efficient since the cake has a high resistivity.
- To guarantee this target, a feed pressure of at least 12-13 bar is advised, as well as to respect the appropriate compaction time. The advised filtration time is 18 minutes. This time has been calculated by taking into account the tests performed on sample B.
- By considering the different test sessions carried out, it can be said that the product is quite constant from the chemical and physical point of view, and its filterability behaviour is quite steady, as shown by comparing the results of tests in the different sessions. It is worth considering also that the shorter filtration time obtained on sample A is due to the filling time not being simulated at laboratory scale.
- The advised chamber thickness is 35 mm, to improve the productivity during each cycle without overextending the filtration time.
- It is possible to guarantee the automatic cake discharge by using an appropriate filter cloth, in this way operator supervision is not required.

Table 6. Filtration Test Results.

Sample		A				B			C	
Tipo impianto		Lab rig				Pilot			Pilot	
Tipo di camera		CC	CC	CM	CM	CC	CC	CM	CC	CC
Spessore camera		25	35	50	50	25	35	40	25	25
Feed	Time (min)	6,5	8,5	6	6,5	13	18	10	8	12
	Pressure (bar)	12	12	7	7	13,5	12	6	12	12
Squeezing	Time (min)	-	-	5,5	-	-	-	7	-	-
	Pressure (bar)	-	-	15	-	-	-	13,5	-	-
Blow	Time (min)	-	-	-	4	-	-	-	-	-
	Pressure (bar)	-	-	-	5	-	-	-	-	-
Cake dryness (% w/w)		67,5	67,0	70,0	70,0	69,0	68,9	70,5	62,6	66,7

Figure 2. Laboratory Rig Test Unit.

Figure 3. KE500 Pilot Filter Press.

6. Sizing and Characteristics of the Filter Press Provided

Once testing was completed, model selection and sizing commenced. Diemme® Filtration has a wide range of filter press models (side beam, overhead beam, pull to close, push to close) and sizes (from 500x500 mm plates up to 4000x3000 mm). For this specific case, the drivers in equipment selection were the heavy duty conditions of operation and the high tonnages to be treated. In general, for similar cases, the selected models are the GHT-P or GHT-F model.

During the interactive cooperation between Diemme® Filtration and Alcoa, it was discussed and agreed to proceed with the GHT-P model.

In view of providing a suitable model for several Alcoa refineries worldwide, the parties studied a solution with one filter press model to be adapted for at least 4 or 5 Alcoa refineries. The model is the GHT.2500.P18 with recessed 35 mm plates, having 2500x2500 mm plates. P18 means that the maximum plate pack length is 18 meters when full of plates (184).

The sizing of the filters depends on the calculation of a total filtration volume. In this calculation the parameters considered are daily tonnage of solids to be treated, achieved cake dryness, wet cake density, squeezing factor (if applicable) and number of daily cycles.

It is evident that, except for the daily tonnage (which is an input from the client), all the other information is a consequence of test results and vendor expertise. The number of plates is linked to the total filtration volume and for other Al refineries, Diemme® Filtration is still proposing the GHT.2500.P18 with a varying number of plates suitable for every specific case.

The achieved agreement is then a smart arrangement to deal with the several refineries with a kind of “modular approach” for both parties.

7. References

1. Sutar et al., American Science Journal, 4, 2014, 255-279
2. Red mud Project, http://www.redmud.org/Characteristics.html
3. http://www.arribaconsulting.com.au/PDF/Review%20of%20Current%20Bauxite%20Residue%20Management%20Disposal%20Storage_Aug09_sec.pdf
4. M. Gräfe, G. Power, G. Klauber, Review of bauxite residue alkalinity and associated chemistry, CSIRO Document DMR-3610, 2009
5. X. Liu X, N. Zhang. Waste Management & Research, 29, 2011, 1053-1063
6. P.E. Tsakiridis, S. Agatzini-Leonardou, P. Oustadakis., Journal of Hazardous Materials, B116, 2004, 103–110