

State-of-the-art Bauxite Tailings Disposal Facilities and Techniques

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Abstract

The tailings from the bauxite beneficiation process and the caustic residue, generated by the alumina refining process, have always been a major issue for the bauxite & alumina industry. Hydro, as a major player in the industry, is proactively addressing this unavoidable challenge. By adopting the best available technologies, Hydro has built newer and safer tailings storage facilities in its operations in the state of Pará, Brazil - such as the Paragominas bauxite mine Plateau Dam and Alunorte's enhanced residue dry stacking process, the DRS2 area. The Paragominas recently commissioned Plateau tailings disposal site represents a technological advance when compared to other dams. The Plateau dam is designed for continuous rotation between disposal quadrants, each quadrant receiving a 50 cm layer of tailings at each cycle, allowing for solar drying of the layers deposited at the other adjacent quadrants. Prior to disposal, the tailings go through a gravity settler that promotes solid-liquid separation. Alunorte's DRS2 is a state-of-the-art dry stacking disposal area that uses press filtration, pipe conveyors and in-situ mechanical compaction. The filter presses produce a dry cake, quite different from the residue produced by previous technologies. The press-filtered residue is transported to the DRS2 disposal site by using a pipe conveyor. At the deposit, the dry cake is spread out in layers and then compacted using machinery. This paper presents results obtained and key aspects of these two facilities – such as increased solids content, better drainage conditions and increased geotechnical safety – and how they compare to previously used technologies.

Keywords: tailings, bauxite residue, dams, filter press.

1. Introduction

Hydro currently owns two major operations in Brazil: the Paragominas bauxite mine and the Alunorte alumina refinery. Paragominas is located in the municipality of Paragominas, state of Pará, Northern Brazil. The mine production capacity is approximately 11 Mtpy and it has started operations in 2006 [1]. Alunorte, the largest alumina refinery outside China, is located in the municipality of Barcarena, near Pará state capital city of Belém. The plant started operations in 1995 and has undergone three expansions since. The current alumina nameplate production capacity is close to 6.3 Mtpy [2]. Hydro acquired both operations in 2012.

This paper will use the term "bauxite tailings" to describe the byproduct generated in the bauxite ore mining and beneficiation processes at Paragominas through the continuous stages of comminution associated with the process of desliming, and "bauxite residue" for the solid byproduct of the Bayer process at Alunorte, resulting of the filtration and washing after extraction and liquor desilication [3, 4].

Bauxite tailings and residue and their appropriate management is of increasing concern to the environment and to the industry. With more than 130 years since the invention of the Bayer

process, the bauxite residue inventory is estimated to be over 5.0 billion tonnes [5]. In Brazil, this concern is especially reinforced due to the recent dam failures from the iron ore industry.

After acquiring Paragominas and Alunorte, Hydro also became responsible for all of their existing tailings dams and bauxite residue deposits. Since then, Hydro has taken a number of measures in order to guarantee the long-term structural stability and safety of the legacy storage facilities, such as Valley Tailings Disposal System, at Paragominas and Solid Residue Deposit 1 (DRS1), at Alunorte.

This paper has the objective of presenting the main facts and the best practices that were performed for tailings and residue management in both Mineração Paragominas and Alunorte. Furthermore, this paper will present the newer, recently commissioned, state-of-the-art facilities at these two sites.

2. Tailings Management

According to the International Commission on Large Dams, water has played a fundamental role in either cause or consequence of most dam failures recorded [6]. Hydro, as a major player in the industry, has been proactively addressing the unavoidable challenge of managing the tailings generated by the bauxite mining and alumina refining processes, namely by:

- I. Adopting the best available practices and techniques to manage legacy facilities, such as the Valley TSF (Tailings Storage Facilities) and Alunorte DRS1;
- II. Adopting the best available technology to thicken and filter bauxite tailings and residue and thus build newer and safer tailings disposal facilities, such as the Paragominas Plateau Dam (RP1) and Alunorte Solid Residue Deposit 2 (DSR2);

Hydro is positioning itself as a technology leader in the industry through the early adoption of state-of-the-art sustainable solutions to manage bauxite mining and alumina refining tailings [7], coupled with robust investment in R&D to develop utilization alternatives for the tailings and modifications in the alumina refining process to reduce the amount of caustic associated with the bauxite residue.

2.1. Legacy Facilities

The Valley Tailings Disposal System was built when mining operations began in Paragominas. The system is comprised of 6 dams, named B1 to B6. B1 to B4 dams were used for bauxite tailings disposal, B5 dam was built to allow the environmental preservation of the springs at the upstream edge of the valley and B6 dam, the downstream-most dam, was used to contain run-off water and to allow its reuse in the mining process.

Ever since takings over operations, Hydro has taken safety measures to adequately increase the safety of the Paragominas Valley Tailings Disposal System, including (i) the construction of reinforcement downstream berms, (ii) adopting operational procedures that minimize the volume of surface water and (iii) installing enhanced instrumentation and monitoring programs. These safety measures combined guarantee the long-term structural stability and safety of the Valley dams. Figure 1 shows the Valley Tailings Disposal System.



Figure 1. Valley Tailings Disposal System: (a) at beginning of operations (b) currently.

Alunorte's DRS1 is a Solid Residue Deposit built when the plant first started its operations. The deposit was designed to operate using dry stacking technology receiving drum filtered bauxite residue of about 64 wt.% solids [8]. The residue is discharged by trucks and deposit freely, forming 3 ° to 4 ° deposition angles from a plateau at the top of the reservoir.

The perimeter dyke has an upstream slope of 1V:2.5H and a downstream slope of 1V:2H and was built by using compacted soil from the excavation of the contour channels. The dyke, channels and basins are covered by an HDPE (high-density polyethylene) geomembrane layer varying from 1.0 to 1.5 mm. Throughout its lifetime, DRS1 received drum filtered residue with approximately 64 % solids.

DRS1 has technically reached the end of its useful life in October 2018. Since then, drum filters have been decommissioned and Alunorte is exclusively disposing press-filtered residue in the area, in order to re-shape its entire surface, the first step in the process of rehabilitation. Figure 2 shows DRS1. Due the implementation of the press filtration method it was possible to extend significantly the life cycle of the DRS1, achieving an increase of the deposit slope up to 5.8 ° [9].



Figure 2. Solid residue deposit DRS1.

2.2. Newer State-of-the-Art Facilities

The Paragominas recently commissioned new Plateau tailings disposal facility represents a technological advance when compared to the Valley TSF. The Plateau project was designed for continuous rotation between disposal quadrants, each quadrant receiving a 50 cm layer of tailings at each cycle, allowing for solar drying of the layers deposited at the other adjacent quadrants. The structure of the Plateau dams does not incorporate natural embankments, as is the case for the Valley Disposal System.

RP1 dam is located in a previously mined area, delimited by peripheral dykes – the construction material used was obtained from sampled soil deposits selected for their physical and geotechnical properties.

The Plateau TSF presents an evolution in the disposal of bauxite tailings, when compared to the Valley TSF, since it presents from the very beginning of the operation larger areas that allow greater efficiency in the drying of the tailings. In addition, the Plateau TSF can be defined as large perimeter low height reservoirs, which minimizes the stresses at the wall as well as the potential energy of the tailings. RP1 dam has never been raised but all future raisings will be built either by the centerline or downstream methods – the safest raising methods for tailings dams [10].

All the tailings generated go through a solid-liquid separation in a gravity settler prior to disposal. Tailings are disposed at the dam at 35 % solids but reach 60 % solids within 30 days after disposal, due to the effects of evaporation and sedimentation. This technique, combined with the design of RP1 dam, results in dams that are virtually free of any surface water, thus reducing geotechnical risks. RP1 dam also presents 8 clarification basins where runoff and rain water are collected, clarified and recirculated to the plant for use in the process. Figure 3 shows the Plateau tailings disposal system.

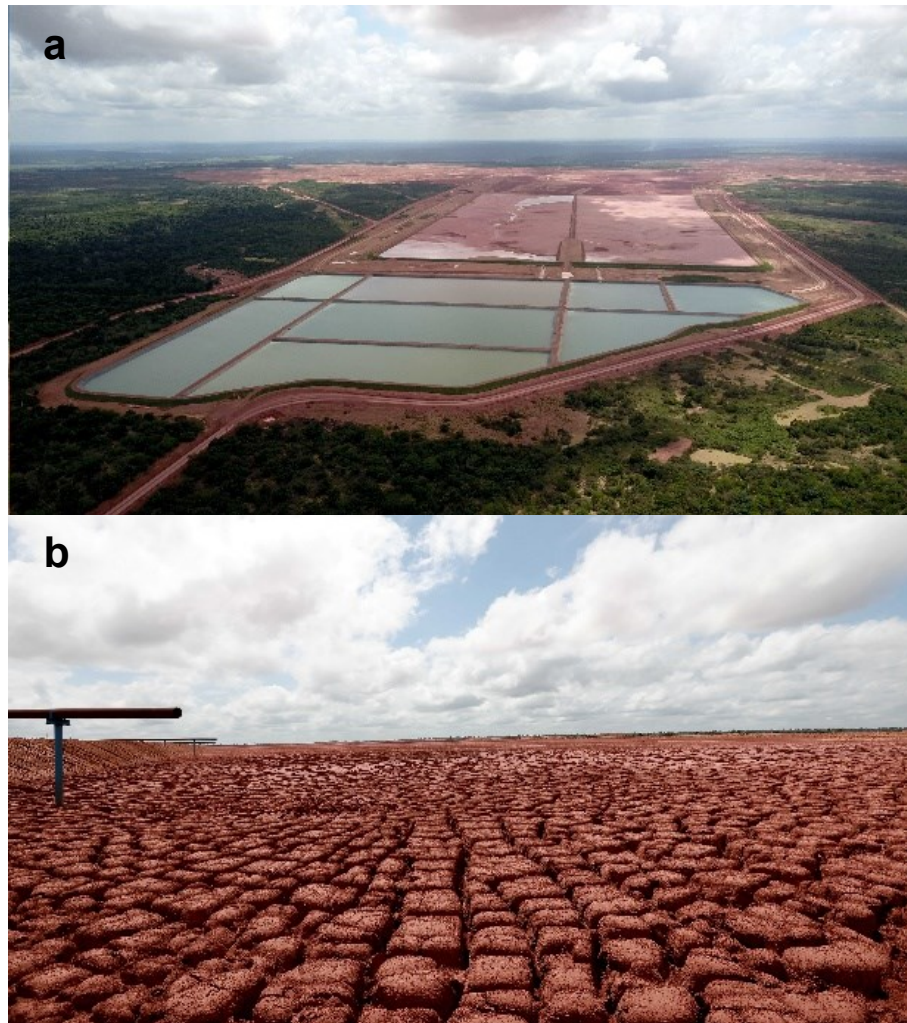


Figure 3. Plateau tailings disposal system (a) overview (b) reservoir.

Between 2011 and 2013, a number of pilot scale tests were carried out by Hydro Alunorte, for the press filtration of its bauxite residue. The tests allowed to establish the geotechnical performance of the filtered residue, which in turn, allowed the design of DRS2, Alunorte's new bauxite residue deposit [9].

DRS2 represents the best available technology and a full-scale reference for the industry. The project comprises press filtration facilities, pipe conveyors and a dry stack with in-situ mechanical compaction.

The filter presses, in operation since 2017, produce a solid cake with approximately 78 wt.% solids content. Filter presses were designed to generate a residue with the optimum-for-compaction moisture. The press-filtered residue is transported to DRS2 by using a pipe conveyor, thus eliminating the previous mode of transportation by trucks. The dry cake is then spread out in layers at DRS2 and compacted by using specialized machinery. Figure 4 shows Alunorte's filter presses.



Figure 4. Alunorte's filter presses.

The use of filter presses implied on several benefits for DRS2, such as: a) approximately 30 % reduction of the volume per unit of dry residue generated – due to the higher solids content; b) increase of the deposit slope to 23 °; and c) reduction of runoff water after mud disposal [9]. Figure 5 shows Alunorte's press filtered bauxite residue.

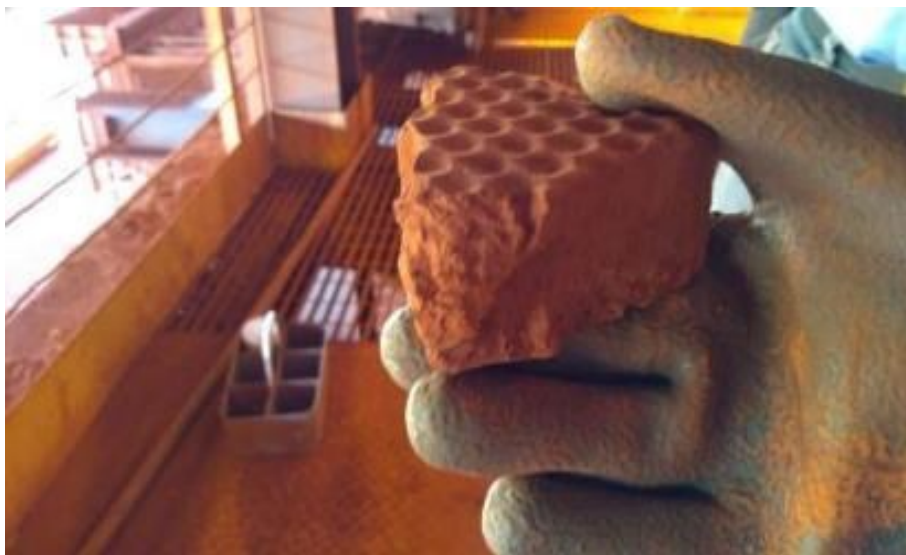


Figure 5. Press filtered bauxite residue at Alunorte.

The deposit is divided in two zones. The structural outer zone will be constructed in the dry period, with press-filtered residue in optimum-for-compaction moisture and achieving a compaction degree of at least 95 % Normal Proctor.

The inner zone will be built during the Amazon rainy season. At this time of the year – when accumulated rainfall might exceed 2,500 mm in 6 months - compaction is jeopardized and thus a

minimum compaction of 90 % Normal Proctor was set as operational standard. DRS2 also has surface drainage and pumping systems that ensure that reservoirs are kept free of water. Figure 6 shows the designed cross-section for DRS2.

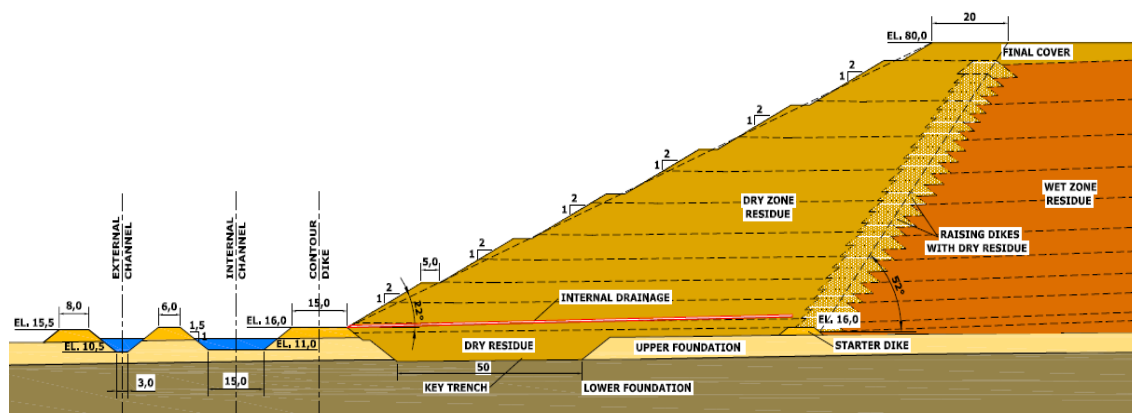


Figure 6. Design cross section for DRS2.

The design of DRS2 associated to the use of press-filtered residue allowed a fourfold increase in the tailings to area ratio, when compared to DRS1. The better use of land reduces environmental footprint and is of paramount interest for Hydro in its operations in Brazil.

Hydro's two state-of-the-art facilities, RP1 Dam and DRS2, follow the same basic principle: that by reducing and appropriately managing water, the resulting facility is safer in geotechnical terms. Furthermore, both RP1 dam and DRS2 underwent periodic independent third-party review both during design and operations – a best practice adopted by Hydro in tailings and residue management.

3. Conclusion

Hydro will continue to pursue and further consolidate the position of technological leadership regarding the safe management of mining tailings and alumina refining residue, adopting state-of-the-art technologies and practices to design and operate its geotechnical structures, such as:

- Thickening and subsequent solar drying of bauxite tailings;
- Adopting robust dam heightening methods, namely downstream and centerline;
- Using compacted soils, instead of tailings, as constructive material;
- Pioneering the full-scale press-filtration and in-situ compaction of bauxite residue;
- Periodic independent third-party reviews of projects;

The aggregate result of these systematic efforts is a high standard of operational safety in the management of mining tailings and alumina refining residue.

4. References

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