A New Approach for Red Mud Disposal Based on Mineral Paste Production

Bruna Camara Trampus[1] and Sílvia Cristina Alves França[2]
1. Grantee of Institutional Training Program - Chemical Engineer, M.Sc.
2. Senior Technologist III - Chemical Engineer, D.Sc.
Center for Mineral Technology, CETEM, Rio de Janeiro, Brazil.
Corresponding author: btrampus@cetem.gov.br

Abstract

Tailings disposal is a problem in alumina refineries worldwide due to the high alkalinity of bauxite residue (red mud), which makes it a strong environmental contaminant. The concept of paste and thickened tailings technology can provide a number of specific benefits to disposal, such as the need for a smaller storage area, greater embankment stability and minimization of wastewater generation. This work focuses on the production of thickened red mud and proposes an easy process for surface disposal with reduced water consumption, and consequently more benign environmental impact. The rheological properties of tailings, such as yield stress, should be well understood to ensure maximum efficiency of thickening and disposal operations. Thus, the objective of this study was to evaluate the performance of different types of flocculant polymers, with different molecular weights and surface charge densities, to produce thickened red mud and to understand their influence on the sediment yield stress. The tailings were flocculated with two commercial polymers, here named AC 662 and MF LT7990, with anionic and cationic charge density, respectively. The efficiency of the process was analyzed by overflow turbidity, rheological and slump tests in order to define the optimal flocculant dosage to achieve higher underflow compaction and lower overflow turbidity. The results showed that polymer mixtures can play an important role to increase the quality of the liquid phase (overflow), and the sediment static yield stress (sediment cohesion), reaching paste characteristics when compared to the dewatering process with the use of a single polymer.

Keywords: red mud, paste tailings, rheology, yield stress, flocculant polymers.

1. Introduction

Brazil is the world's third largest producer of bauxite and alumina, in both cases behind only Australia and China [1]. Based on the latest data from the Brazilian Aluminum Association [1], in 2016 the country's production of bauxite and alumina was around 39 and 11 million metric tonnes, respectively. Studies show that each ton of Al_2O_3 extracted can generate up to 3 tons of tailings (red mud) [2,3], depending on the quality of the bauxite ore. However, applying the mean ratio of 1.5 t, in 2016 alone Brazil generated about 16.5 million tons of red mud.

Red mud is a mineral residue resulting from the alkaline processing of bauxite to produce alumina. Research shows that the chemical and physical properties of red mud depend on ore sources, that is, the bauxite mineralogy, and the refining processes [2, 4]. However, in general red mud is an aggregate of fine particles with large specific surface area [4]. The main components of red mud are Fe_2O_3, Al_2O_3, SiO_2, TiO_2, CaO and Na_2O, with traces of Cr, Cu, Pb, Ba, Sn, As, Hg, V, Ni and Zn [2,5], and its pH is reported to vary from 9 to13 [2]. It results from caustic digestion of bauxite ore in the Bayer process. Its classification as hazardous material is debatable, because studies report that red mud samples analyzed did not contain very high levels of heavy metals, that is, the contents of toxic elements were lower than the toxicity limits [4]. However, its high alkalinity, often above the Brazilian standard (NBR 10004) [6] for classification as hazardous material, means it is a strong contaminant to the environment.

The amount of red mud produced worldwide is enormous. In 2015, its global production was approximately 170 million t [2]. Because of this enormous volume and harmful impacts, its surface disposition is a common problem. Accidents involving mining activities are frequent throughout the world, drawing the attention of government authorities and society to the environmental impacts. With respect to red mud, in the last 10 years there were five environmental disasters involving the storage of this material [7]. These accidents were caused by high rainfall and/or failure of the containment structure, such as: tailings dam failure after heavy rain in January 2007, which led to the leakage of 2 million m^3 of mud in Miraí, Minas Gerais, Brazil; overflow of drainage channels around a red mud basin after heavy rain in Barcarena, Pará, Brazil in April 2009; tailings dam failure with a spill of 700 thousand m^3 of caustic red mud in Kolontár, Hungary in October 2010; failure of a tailings dam holding about 2 million m^3 of red mud in China in August 2016; and most recently, accusations of overflow of a red mud basin after heavy rain in Barcarena, Pará, Brazil in February 2018 [7].

Studies are being conducted to find alternative environmentally friendly and cost-effective methods to dispose of or utilize red mud [2, 4, 5]. The need for safe disposal led to the process of dewatering tailings. Currently, most red mud is stored behind conventional dams, in large ponds, and before any dewatering treatment, thickening or filtration, it can contain more than 80 % water [2]. Due not only to environmental and safety issues, but also to water scarcity, there is a growing tendency to apply dry and semi-dry processes, such as paste production before disposal [2, 9]. In China, the largest alumina producer, studies show that in 2011, of the 19 existing red mud reservoirs, dry or semi-dry processes were only applied at three [4]. But of the 10 sites that were under construction, three of them will use dry process, and two will use the semi-dry process [4].

The concept of dewatering tailings produces significant advantages for disposal, such as the need for a smaller storage area, greater stability and minimization of waste water. In addition, it reduces the potential for catastrophic failures [10, 11, 12, 13]. Depending on how much water is removed, pulps exhibit characteristics of high-density thickened tailings, or even pastes, that have as advantages low moisture content (10 – 25 % w/w), homogeneous nature and no segregation of particles [10, 13]. The pastes are non-Newtonian fluids and usually exhibit Bingham fluid behavior, with minimum yield stress (τ_0) of 200 Pa [10, 14, 15]. Yield stress is a crucial component in the rheological characterization of thickened tailings, because it affects factors such as the transportation energy requirements and the deposition slope. Thus, a good understanding the rheological properties of paste is important for the mining industry [10, 12].

In the Bayer process, following leaching, the liquor is recovered via counter-current washing/decantation and is then pumped for further thickening and final disposal [10, 12]. The red mud disposal based on mineral paste production depends mainly on the efficiency of solid-liquid separation and consistency of the material for sedimentation. Pastes must contain at least 15 % (w/w) solids with particle size below to 20 µm to reach the desired consistency, making the segregation process difficult [12, 13]. Studies show good application of polymers with high molecular weight and ionic charge as flocculants [16, 17]. In general, several physico-chemical factors can influence the flocculation and dewatering of mineral suspensions, such as pH, solids concentration and particle size distribution [12, 16, 17, 18].

This paper presents the results of rheological studies of flocculated red mud thickened under various conditions, including polymer mixtures as flocculant. The objective is to optimize flocculant type and dosage in order to produce paste tailings and to obtain good solid-liquid separation with clear overflow (quality of recovered water) for water reuse.

the turbidity of the supernatant, because of increased cationic charge density and consequently neutralization and adsorption of the colloids [18]. According to [18], when using polyelectrolytes, the optimum dosage is that which produces nearly complete charge neutralization [18]. Therefore, possibly the dosage of 45 g/t of MF LT7990 was sufficient to achieve, or to approach, complete charge neutralization.

4. Conclusion

Mining can generate high environmental impacts. Rheology is an essential tool to evaluate the production of thickened tailings, which is increasingly important to minimize the negative impacts on the environment and society. Various physical and interfacial chemistry factors influence the rheological properties of sediments. Therefore, they are increasingly exploited to optimize operation and production of paste.

This paper presented and discussed the effect of the use of flocculent mixtures to obtain thickened red mud sediments. We observed that the polymer mixture system presented better flocculation/thickening then either single polymer, because the mechanism of floc formation allowed greater efficiency in the adsorption of particles. Thus, thickened and flocculated sediments were produced with maximum yield stress of 825 Pa, i.e., it was possible to achieve sediments with high compaction/consistency, and yield stress higher than the paste's normal characteristic. In addition, the great advantage of using the polymer mixture as flocculant is turbidity reduction of the recovered water. Therefore, the densification process studied is efficient for particle aggregation, allowing reduction in the amount of free water in the tailings ponds, which reduces the risk of environmental accidents, besides allowing recovery of the process water.

Based on the experimental planning of this study and the low cost, the best flocculant dosages for red mud pulps with initial solids concentration of 10 % (w/w) are 30 g/t of AC662 and 45 g/t of MF LT7990. With these dosages, there is high underflow compaction and overflow clarification.

5. References

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