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

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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.

2. Experimental Methodology

The red mud (RM) sample used in this study was produced by the Bayer process in an alumina refinery located in the state of Pará, Brazil and sampled from a tailings dam. As flocculants, we used two commercial polymers manufactured by BASF, Alclar 662® and Magnafloc LT7990®, referred to as AC 662 and MF LT7990.

Pulps with initial solids concentration (C0) of 10 % (w/w) were prepared with industrial water and then flocculated with both polymers and submitted to discontinuous sedimentation tests to evaluate the influence of the dosage and mixtures of flocculants on the sediment cohesion and supernatant quality. The experiment had a complete factorial design with two variables, three levels and triplicate at the central point (Table 1). The experimental error was obtained by the triplicate at the central point and reproduced for all results. To evaluate the efficiency of both flocculants, sedimentation tests were performed without the addition of flocculant, and with only AC 662 at dosages of 30, 45 and 60 g/t.

Table 1. Complete factorial experimental design.

Variables	**-1**	**0**	**+1**
AC 662 dosage (g/t)	30	45	60
MF Lt7990 dosage (g/t)	30	45	60

2.1. Characterization of Raw Materials

The flocculants and red mud were characterized for surface charge density with a Malvern Zetasizer Nano series, in the pH range of 2 to 12, using indifferent electrolyte solution (KCl 0.01 M), and dilute solutions of HCl and KOH, for pH adjustment. The mineral tailing's particle size distribution was determined by laser diffraction with a Malvern Mastersizer 2000.

2.2. Particle Aggregation and Thickening of Red Mud

The pulps were prepared and flocculated in a jar test device (Nova Etica model 218-6), composed of square vessels (D_{in}= 11.5 cm; H= 20 cm) and straight paddle type impeller. The flocculant solution was then added to the slurry and stirred at 300 rpm for 1 min, followed by slow stirring at 150 rpm for 2 min, to avoid excessive mixing after flocculation, and consequently the breakage of the flocs. The flocculation at the experimental points with polymer mixtures was carried out by first adding the polymer MF LT7990, followed by the polymer AC 662. The flocculated pulp was transferred to a 2 L graduated cylinder (H = 48 cm; D_{in} = 7.5 cm) for discontinuous sedimentation testing. After 1 h and 2 h of sedimentation, samples were taken from the overflow for turbidity analysis with a Digimed model DM-TU portable turbidimeter.

2.3. Characterization of Thickened Tailings

The graduated cylinder with the flocculated pulp was set aside undisturbed for 24 h, and then the supernatant liquid was removed and the sediment was studied to determine its properties, according to the following techniques.

2.3.1 Slump Test

This technique is used to determine materials' consistency and does not require any sophisticated instrumentation. Conventionally, the cone slump test is a technique applied to concrete. However, the adaptation to cylindrical geometry has shown good results in the literature to evaluate the consistency of mineral suspensions [13, 19]. We applied the same technique used by [19], as illustrated in Figure 1: a cylinder, $H = D_{in} = 2$ in, was filled with the bottom sediment formed in the graduated cylinder, and then removed vertically. Thus, from the height difference it was possible to calculate the slump height (% SH).

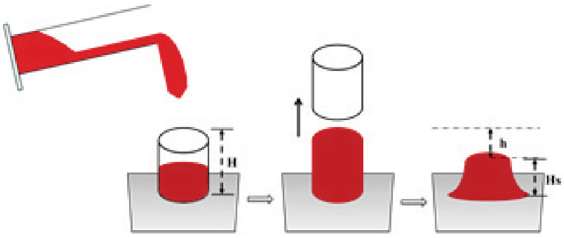


Figure 1. Diagram of the cylinder slump test.

2.3.2 Rheological Analysis

Yield stress (τ_0) is the minimum stress required for the thickened tailings to flow. Thus, it is an important property for study of the dewatering process efficiency [11]. τ_0 can be estimated by different rheometry techniques. However, two types of rheological analysis are most often employed for this purpose. One is the direct method, where the torque vs. time curve is obtained, and the maximum point is when the material yields, equivalent to τ_0. The other technique is the regression method, based on shear stress vs. shear rate curves [10, 11, 12, 13]. We used both techniques for τ_0 measurement, by using a vane sensor. Studies have compared different techniques of τ_0 analysis, and the major advantages of using the vane sensor include the lower sample disturbance/breakdown when inserting the rotor, minimizing the effects of wall slip, and the larger gap, reducing errors related to large particle size [10, 12]. Therefore, the τ_0 value was obtained for the bottom and top of the sediment formed in the cylinder, using a Haake RheoStress 1 rheometer, and the Herschel-Bulkley model (Equation 5) to fit the experimental results and obtain the τ_0 value by regression.

$$\dot{\gamma} \qquad (5)$$

The τ_0 values for the bottom and top sediment formed in the cylinder were obtained by both methods. For the direct method, a constant shear rate of 0.1 s^{-1} was applied for a maximum time of 300 s, to obtain the static τ_0. For the regression method, the flow curve was plotted as shear rate versus shear stress, defining shear rates of 0.01 to 100 s^{-1}, with ten points per decade and a maximum time of 5 min per point.

First, the value of τ_0 was obtained by the direct method, corresponding to the yield stress of the material from the thickener bottom. After this, the sediment was subjected to a high shear, 100 s^{-1}, in order to completely destroy the floc structure, and the yield point of this new sediment was analyzed by both methods (direct and regression), referred to as dynamic τ_0. However, only for the bottom sediment formed, before analysis of dynamic τ_0, were the samples analyzed according to the effects of shear rate and shear history [12]. Therefore, the sediment was subjected to different shear rates, 1 s^{-1}, 10 s^{-1} and 50 s^{-1}, in order to evaluate the degree of destruction of the floc structure and release of water. In this case, a constant shear rate of 300 s^{-1} was applied and the yield point was analyzed by the direct method.

2.3.3 Sediment Concentration Analysis

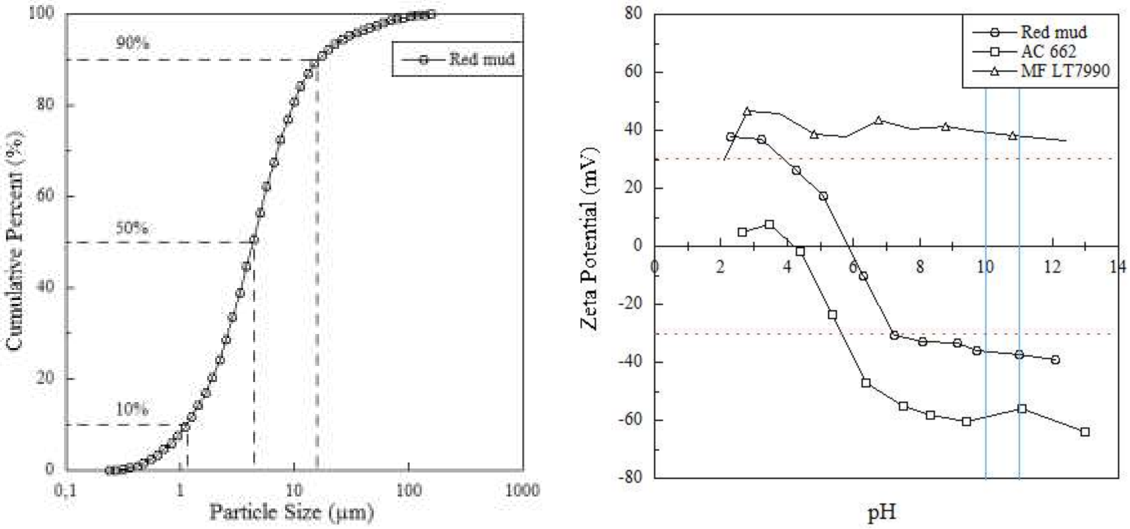
After the rheological analysis, the samples of both the top and bottom sediments formed in the cylinder were transferred to a moisture analyzer (Ohaus model MB23) and subjected to heating for indirect determination of sediment concentration (C_{sed}), expressed as percent solids.

3. Results and Discussion

3.1. Characterization of Raw Materials

Figure 2 (A) shows that the sample of red mud studied had very fine granulometry, with 90 % by weight of particles smaller than 16.8 µm in diameter. The presence of fine material is indispensable for paste formation. Thus, this granulometry is an advantage for the paste production, because larger particle specific surface area results in greater area for interparticle interaction, and consequently greater consistency and yield stress [12]. However, from Figure 2 (B), it can be observed that at natural pH ($10 \leq pH \leq 11$), the solid red mud particles had high anionic charge. High alkalinity, small particle size and strong electrostatic repulsion impairs the natural sedimentation process [12].

Several factors affect the production of thickened tailings, among them the presence of flocculant, the particle-polymer interaction and the method of flocculant application [13, 18]. Polyacrylamides are widely used in the mining sector, due to their wide range of molecular weight and surface charge density, which are the most important characteristics to enable polyelectrolytes to act as flocculating agents with high sedimentation and compaction efficiency [16, 18, 20]. Figure 2 (B) also shows the surface charge analysis of both flocculants used in this study. The two are based on polyacrylamide with high but opposite ionic charges.



A B

Figure 2. Characterization of raw materials. (A) particle size distribution; (B) zeta potential of red mud and flocculants.

The polymer AC 662 is a new specific flocculant used to obtain more compact red mud sediments [16]. Due to its high molecular weight, its main mechanism of particle aggregation involves the formation of bridges (Figure 3-A), i.e., bridging of particles by polymer chains, and this mechanism does not require the polymer to have a charge opposite to the particles [16,18,20]. However, its high anionic charge density increases the anionic character of the medium and consequently increases the electrostatic repulsion of the fine particles, impairing the overflow clarification [16, 18]. In view of its advantage and disadvantage, we analyzed flocculation with a polymer mixture, adding a polymer which aggregates particles by the charge neutralization mechanism (Figure 3-B). For this purpose, we used MF LT7990, because this mechanism is characteristic of polymers with low molecular weight and high opposite charge density to the particles [18, 20]. Previous studies have shown high efficiency of overflow clarification for red mud flocculated with MF LT7990, and then thickened [17].

With respect to flocculation by applying the polymer mixture, first the cationic polymer (MF LT7990) was added to the pulp, followed by the anionic polymer (AC 662). This procedure was applied because according to [18], in case of polyelectrolyte mixture adsorption, the flocculation performance is influenced by the order of adding the mixture components. The highest efficiency is achieved by adding polycations followed by polyanions. The reason is that the adsorption of polycations provides adsorption sites for the polyanions, which can then form bridges with other particles [18].

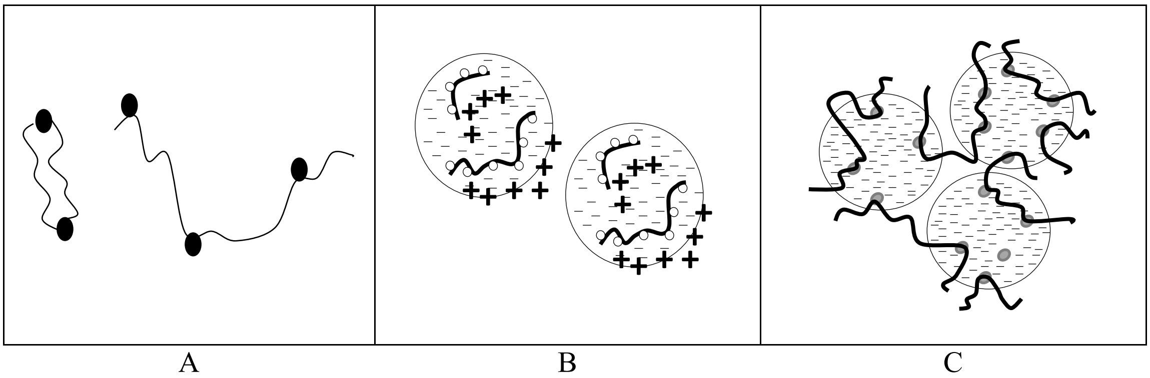


Figure 3. Mechanism of particle aggregation by polymers. (A) formation of brides; (B) formation of charged clumps; (C) polymer mixtures – cationic followed by anionic [18, 20].

3.2. Characterization of Thickened Tailings

The sediments obtained in the graduated cylinder after flocculation and sedimentation were analyzed at the top and bottom, because there is variation of the solids concentration in the sediment compaction zone [11, 12, 21]. For all the cases studied, the solids concentration at the top of the sediment was 17 to 22 % lower than at the bottom. Figure 4 (A) shows that the flow properties of concentrated mineral suspensions varied significantly with solids concentration [11, 12]. Both static and dynamic τ_0, values are lower at the top of the sediment than at the bottom, mainly the static τ_0. Figure 4 (A) also shows that, as reported by [10], the measurement techniques used (direct method and by regression) produced very similar values, since the dynamic τ_0 obtained by the direct method overlaps the flow curve.

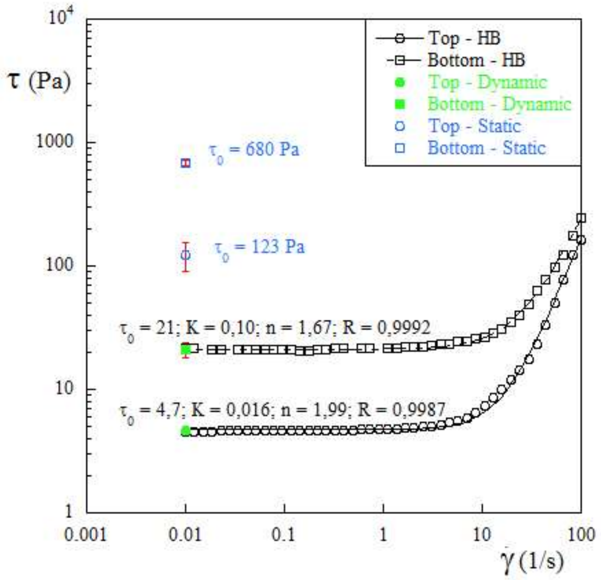


Figure 4. Rheological characterization for 30 g/t AC 662 and 30 g/t MF LT7990, C_{sed} top = 44.3 % and C_{sed} bottom = 57.1 %.

Figure 5 illustrates the strong dependence of the yield stress with the type and dosage of flocculant polymer.

Figure 5 (A) shows the importance of the flocculant AC 662 in the stress. Even the lowest dosage studied, 30 g/t, was sufficient to promote an increase of almost 900 % in the static τ_0 compared to sediment without flocculation, leaving it above the specific value of the pastes. This shows the relevance of applying this new flocculant to increase the cohesion/consistency of the thickened red mud sediments [16]. It can also be observed that with the increase of 45 g/t to 60 g/t of the flocculant AC 662, the static τ_0 did not change, i.e., for C_0 = 10 % (the maximum consistency), the polymer-particle interactions were achieved with 45 g/t of AC 662.

Figure 5 (B) illustrates the influence of the polymer mixture on the thickened sediment's stress. The initial objective of adding the MF LT7990 was to reduce the supernatant turbidity [17], because as reported by [16], the flocculant AC 662 increases the cohesion of thickened red mud sediments, but leaves high turbidity in the overflow. However, Figure 5 (B) shows that besides influencing turbidity, the polymer mixture produced an increase of static and dynamic τ_0 with the increase of MF LT7990 dosage. This occurred because the polymer mixture influences the adsorption mechanism of the particles, and thus the shape and structure of the flocs formed, affecting the settling velocity and sediment cohesion [12, 18]. In addition, for flocculation only with polymer AC 662, there was repulsion between charged segments, causing some chain expansion and consequently less cohesion [18].

With respect to the dynamic τ_0, in the flocculation only with polymer AC 662, the increase of dosage (Figure 5-A) led to polymer-slurry interaction and storage of more water inside the flocs, reaching higher values of static τ_0, but after the complete destruction of the floc structure, the sediments exhibited the same behavior, i.e., the same dynamic τ_0. In the cases with the polymer mixture, the increase of the MF LT7990 dosage (Figure 5-B) led to a small increase of the dynamic τ_0, reaching maximum values of 23 Pa. Thus, in the case of complete destruction of the flocs, the thickened tailings did not achieve paste consistency. However, since for the pastes the centrifugal pump is replaced by the positive displacement, the intensity of destruction may be lower.

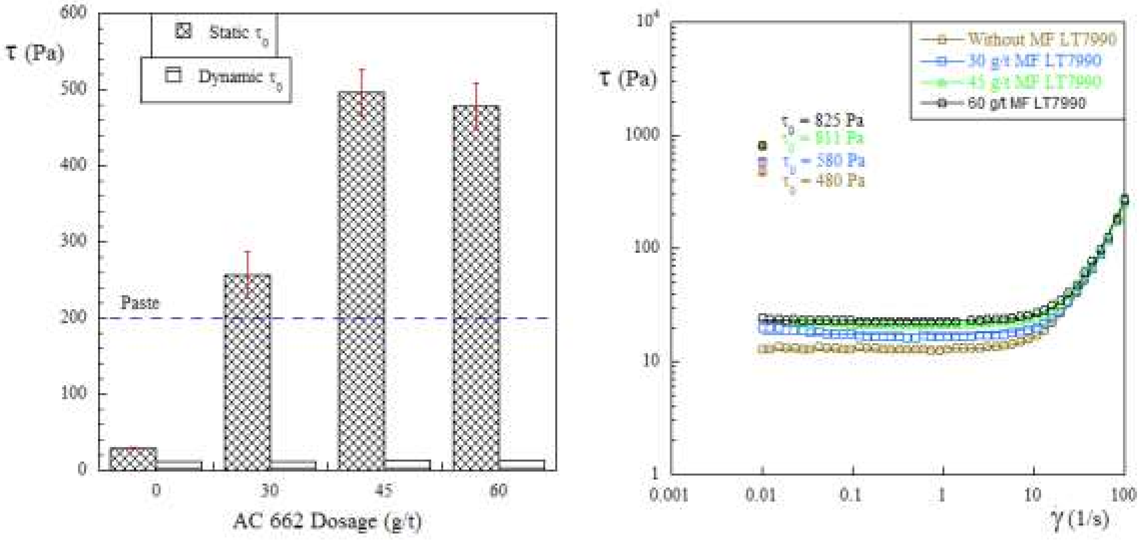


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Figure 5. Static τ_0 and flow curve for the bottom sediment. (A) influence of the addition of AC 662 alone; (B) influence of addition of MF LT7990 and AC 662 dosage of the 60 g/t.

Figure 6 illustrates the degree of destruction of the floc structure as a function of the applied shear, and its relationship with the yield stress. The paste's τ_0 is very often dependent on the shear rate and the shear history [12]. It can be observed that in the case of the static τ_0, the sediment exhibited thixotropic behavior, i.e., there is growth of stress until reaching a maximum value, when the material yields, but decreases with the shear time. This behavior occurs because the structure of the flocs formed is weak, since even a small shear rate, 0.1 s^{-1}, causes rupture of the floc structure, releasing the contained water. This causes a gradual decrease in yield stress. It can also be observed that the increase of shear rate to 1 s^{-1} abruptly reduces the sediment consistency and hence reduces the τ_0 value. With this shear rate, 1 s^{-1}, the stress reaches a maximum point, but does not vary with time. However, with shear rate of the 50 s^{-1}, the flocs are totally destroyed and the yield stress does not change.

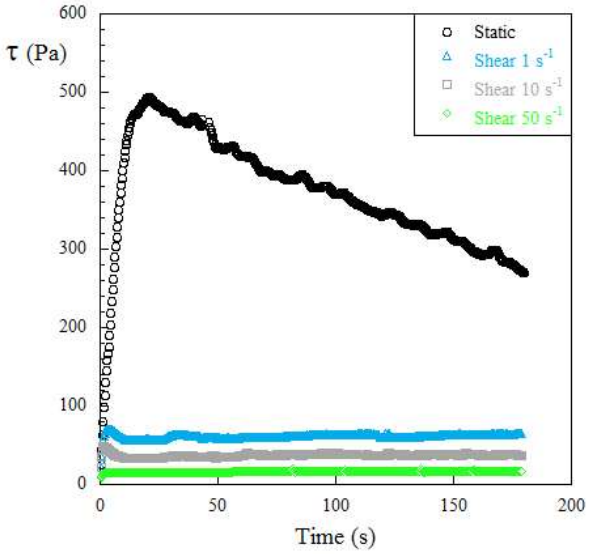

Figure 6. Shear history analysis relationship for 30 g/t AC 662 and 60 g/t MF LT7990, C_{sed} bottom = 57.7 %.

The yield stress increases exponentially with the solids concentration, because it is directly related to the material density [10, 11, 12], that is, a small increase in the solid concentration leads to growth of τ_0 (Figure 7). All the cases analyzed in this study, using only AC 662 or the polymer mixture as flocculant, showed static τ_0 above 200 Pa for the bottom sediment, reaching maximum values of 825 Pa for 60 g/t of AC 662 and 60 g/t of MF LT 7990, with C_{sed} = 57 %.

The % SH is an empirical measure of the tailings consistency, and it has an indirect relation with the material density [14, 19]. It can be observed that the addition of only AC 662 or the polymer mixture as flocculant produced more consistent sediments, which is evidenced by the reduction of % SH. The curves presented in Figure 7 show an inverse relationship of % SH with static τ_0 and C_{sed}. An example of the slump test is illustrated in Figure 8.

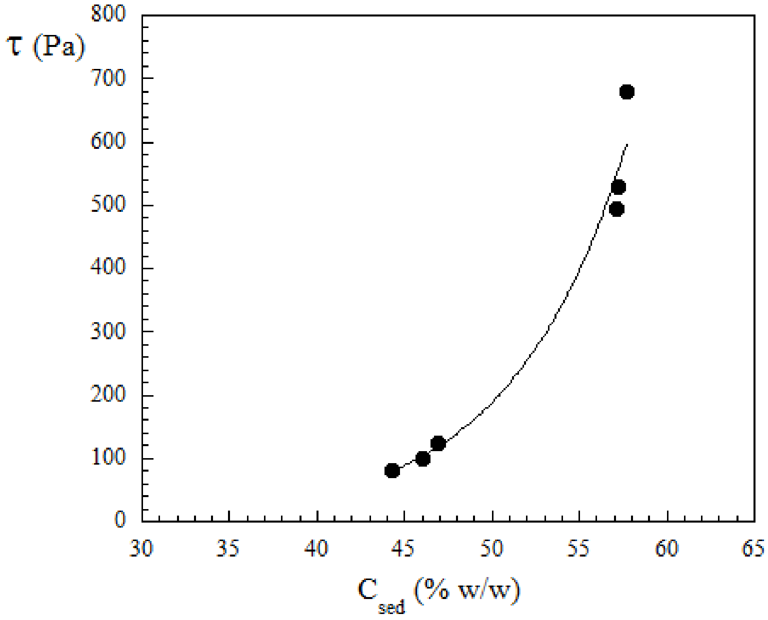

Figure 7. Relationship between static τ_0, C_{sed} and % SH for the sediment after flocculation with AC 662 = 30 g/t, and MF LT 7990 = 30, 45 and 60 g/t.


A
B

Figure 8. Slump test for the sediment formed with 30 g/t of AC 662 but varying the MF LT7990 dosage. (A) without MF LT7990; (B) 60 g/t of MF LT7990.

The addition only of the polymer AC 662 as flocculant produced the highest values of C_{sed}, for the bottom sediment, compared to the polymer mixture as flocculant, i.e., for AC 662 dosages of the 30, 45 and 60 g/t, the C_{sed} were 59.3, 60.3 and 60.5 % (w/w), respectively. However, they produced the lowest static τ_0 values. The thickened sediments after flocculation with the polymer mixture had C_{sed} ranging from 56.2 to 57.7 % (w/w) for the bottom sediment, but they reached the highest values of static τ_0. Thus, the use of the polymer mixture as flocculant allowed the formation of more cohesive sediments, i.e., in these cases, there was a greater amount of water accumulated inside the flocs. The different efficiencies between the studied polymers can be explained by the existing polymer-slurry interaction difference, i.e., interaction type (bridging particle flocs or neutralized charge particle flocs) [12, 16, 18]. However, for a better understanding, it is necessary to elucidate the polymer's structures and characteristics.

3.3. Turbidity Analysis

Turbidity is used as an indicator of the suspended solids concentration, and thus the supernatant quality. The Brazilian environmental regulations, contained in CONAMA Resolution 357/2005 [22], establish quality conditions for the classification of water. This resolution has fixed limits for several variables, such as total phosphorus, nitrate, biochemical oxygen demand and turbidity, among others. Therefore, the needs of the process with respect to water quality must also be considered. The overflow can be discarded or the water reused if its turbidity is less than 100 NTU [22].

We evaluated the overflow quality regarding only turbidity. The curves presented in Figure 9 show that in all cases, the recovered water did not present turbidity less than 100 NTU but showed significant reductions. As reported by [16] and corroborated by our results, the flocculant AC 662 has the advantage of greater compaction of the underflow. On the other hand, due to its high anionic charge density, there is greater destabilization of the fine particles, caused by strong electrostatic repulsion [18]. Figure 9 (A) illustrates this influence of the AC 662 dosage on turbidity. The use of flocculant AC 662 led to increased overflow turbidity in comparison to pulp sedimentation without flocculation. Furthermore, the higher the dosage of flocculant polymer, the stronger the anionic charge and electrostatic repulsion and the bigger the overflow turbidity were.

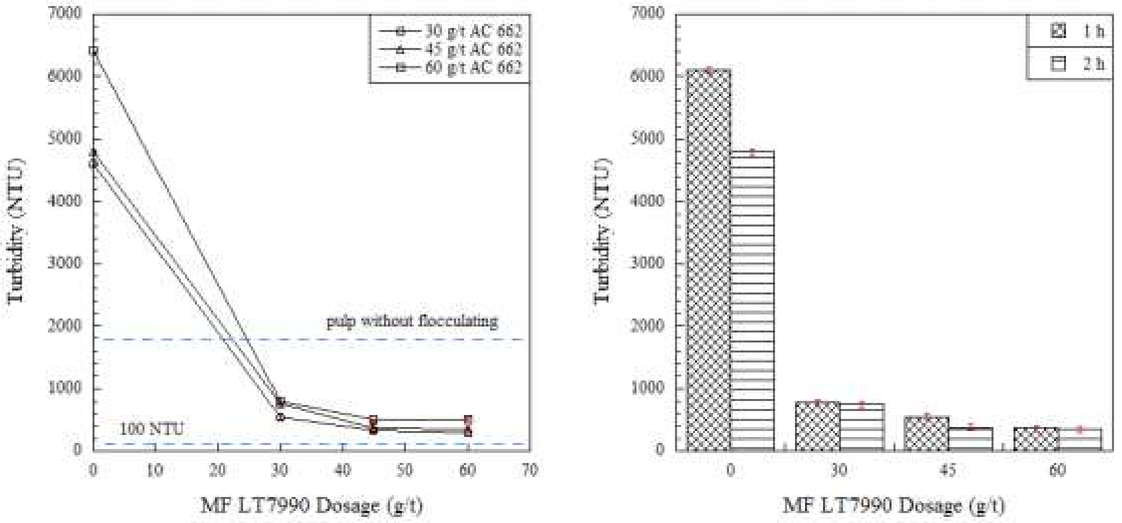

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Figure 9. Relation between turbidity of overflow and dosages of flocculants (A) after 2 h of sedimentation; (B) 45 g/t of AC 662.

As reported by [16], a challenge to the use of AC 662 as flocculant is the need to reduce the overflow turbidity. Figure 9 (A) shows that the polymer mixture of AC 662 and MF LT7990 led to reduction of the overflow turbidity by up to 95 %, after 2 h of sedimentation. As reported by [17], the polymer MF LT7990 has good efficiency to reduce turbidity when applied as flocculant to red mud. This occurs because, due to its high cationic charge density, there is mostly neutralization of the particle charge followed by strong adsorption affinity [18]. This indicates the effect of charge density on the destabilization of colloids. Figure 9 (B) illustrates that for cases with polymer mixture, no change in overflow turbidity occurred after 1 or 1 hours of sedimentation. It can also be observed that the most significant reductions in turbidity occurred with the use of 30 g/t and 45 g/t of MF LT7990. The use of 45 g/t and 60 g/t of MF LT7990 showed very similar turbidity results.

The larger presence of colloidal particles in flocculated pulps only with AC 662 compared to flocculated pulp with the same AC 662 dosage but adding MF LT7990 can be observed in the images in Figure 10. With the naked eye (Petri dish images) it is possible to observe the presence of large quantities of fine particles suspended when using only AC 662 as flocculant (Figure 10-A). However, with the use of the polymer mixture as flocculant, the amount of fine particles in suspension is much lower (Figure 10-B). With the use of optical microscopy this comparison becomes even clearer, revealing that the flocs formed by the polymer mixture are slightly larger.

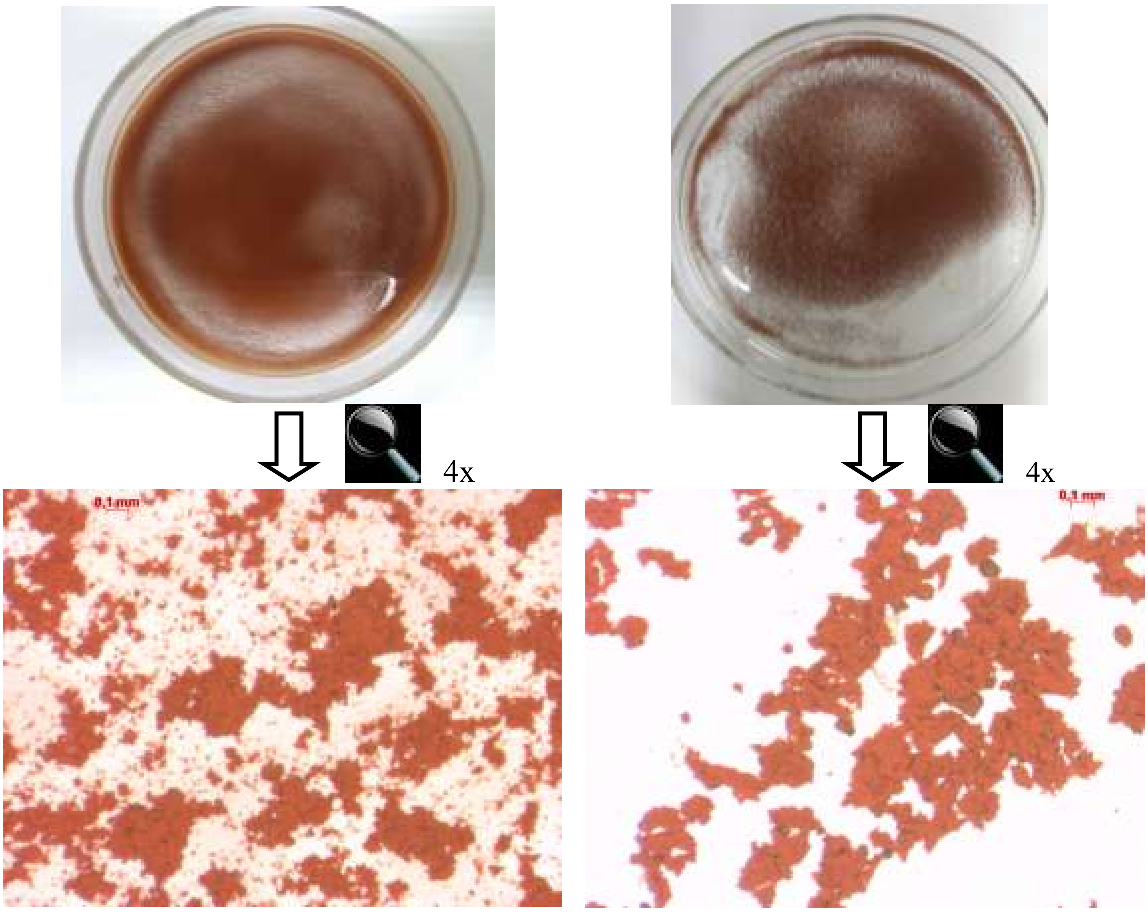

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Figure 10. Images of the pulp after flocculation. (A) with only 60 g/t of AC 662; (B) 60 g/t of AC 662LV and 60 g/t of MF LT7990.

As expected, Figures 9 and 10 show that the use of the polymer mixture as flocculant produced good overflow clarification, because of the of the particle adsorption mechanism difference, as previously discussed in this study. Moreover, the increase of the MF LT7990 dosage reduced 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.

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