


# Sedimentation tests with chromium ore fine tailings using different flocculants


Jaciany Mayara Batista Soares<sup>1</sup> 


Elenice Maria Schons Silva<sup>1</sup> 


André Carlos Silva<sup>1,2\*</sup> 

Neilton da Silva Tapajós<sup>2</sup> 

Pablo Souza de Oliveira<sup>1</sup> 

André Figueiredo Nascimento<sup>3</sup> 

Ângelo Pereira Vieira Filho<sup>3</sup> 

Sirsasana Araujo dos Santos<sup>3</sup> 

## Abstract

Aqueous routes are of paramount importance in mineral processing. To adjust the solid contents, both concentrates and tailings, must be dewatered. A widely adopted method is the thickening, promoting the free settling of the mineral particles aided by coagulants or flocculants. This study analyzed the performance of different polyacrylamides as flocculants in the sedimentation of chromite tailings. Tests were carried out in graduated cylinders of 2.0 L for different types and dosages of flocculants and pHs. It was possible to make the settling more efficient with the addition of 30 g/t of BASF's Magnafloc 338 at pH 8.5, decreasing the average pulp turbidity from 740.33 NTU to  $31.74 \pm 1.16$  NTU after a few minutes.

**Keywords:** Dewatering; Tailings; Chromite; Flocculation; FERBASA.

## 1 Introduction

Brazil is the 11th larger chromium producer, with Companhia de Ferro Ligas da Bahia (FERBASA) being the largest producer. The company operates two chromite mines, located in the Center-North region of the state of Bahia, Brazil, ninety miles away from each other: Ipueira mine in the Chromite District of Vale do Jacurici and the Coitezeiro mine in the Chromite District of Campo Formoso. The Figure 1 shows the FERBASA simplified flowsheet for the chromite sand production. The run of mine (ROM) ore is feed in a series of crushers (primary and secondary crushing in universal jaw crushers). The secondary crusher operates in a closed circuit with a double deck vibratory screen. The fine fraction (-10 mm) and the products referred as disseminated ore feeds a gravimetric plant, where it will be grinded (two stage grinding, with ball mills) and concentrated using spirals and magnetic separators to produce chromite sand, used as steel casting. This is a wet circuit; therefore, the chromite sand (concentrate) needs to be dried in ovens before expedition. The plant produces two different tailings: a coarse and a fine tailing, which also need solid-liquid separation (aka dewatering). The coarse tailing is composed by cyclones underflow, and the fine tailings are fed to conventional thickeners (see Figure 2). Nowadays an anionic high molecular weight polyacrylamide (PAM) is used

as flocculant (10 g/t Flonex 910 SH manufactured by SNF Floerger diluted to 0.15%). The solids percentage feed in the thickener is normally below 2%. According to Dahlstrom and Fitch [1], dewatering is common in mineral processes plants, mainly because water as the main medium for processing and transport ores. The thickener overflow is sent to ponds for free settling, without additional flocculant additions, indicating that the thickener operation is not optimized. According to Bolto and Gregory [2], after the flocculant is added to a colloidal suspension the particles need to be mixed with the reagent. Then the adsorption of the reagent on the particles surface occurs, followed by rearrangement of the adsorbed chains and, finally, the flocculation takes place by bridging flocculation. This process increases the settling speed of the solid particles. This work aimed in reduce the solids in the thickener overflow by changing the PAM, flocculant dosage, and pulp pH.

## 2 Experimental

Samples from the tailing thickener feed were collected oven dried and sent to wet screening particle size distribution determination. For that eight screens were used according

<sup>1</sup>Programa de Pós-graduação em Gestão Organizacional, PPGGO, Laboratório de Modelamento e Pesquisa em Processamento Mineral, LaMPPMin, Universidade Federal de Catalão, UFCAT, Catalão, GO, Brasil.

<sup>2</sup>Programa de Pós-graduação em Ciências Exatas e Tecnológicas, PPGCET, Laboratório de Modelamento e Pesquisa em Processamento Mineral, LaMPPMin, Universidade Federal de Catalão, UFCAT, Catalão, GO, Brasil.

<sup>3</sup>Companhia de Ferro Ligas da Bahia, Andorinhasw, BA, Brasil.

\*Corresponding author: [ancarsil@ufcat.edu.br](mailto:ancarsil@ufcat.edu.br)



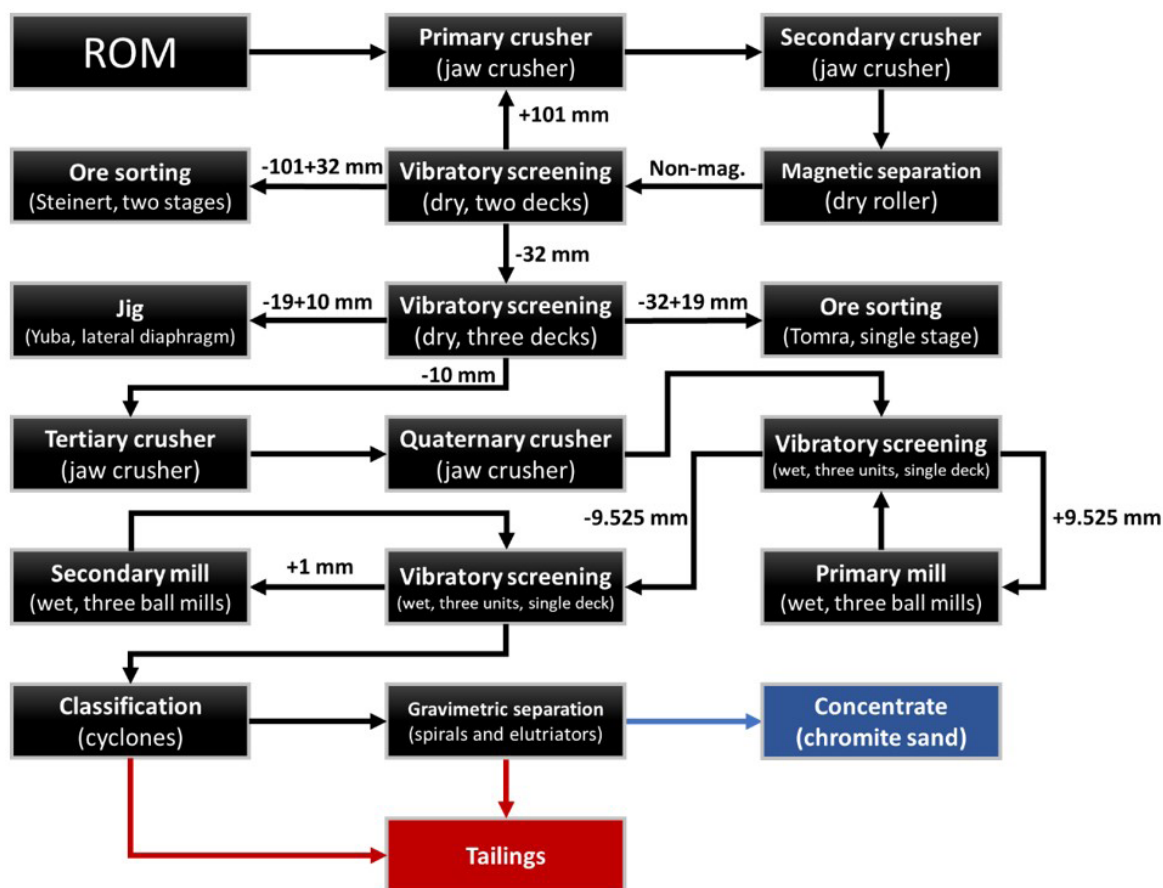


Figure 1. FERBASA simplified mineral processing flowsheet for the chromite sand production.

to a Tyler series. The screening duration was 15 minutes, and 20 L of water were used. Sodium metasilicate (1% v./v.) was used as dispersant (6 mL). The fractions produced after the wet screening were sent to optical microscopy using a Bresser Biolux NV - Technic Professional Microscope. A head sample and two samples from the wet screening (+400# and -400#) were chemically analyzed in a Rigaku ZSX Primus IV x-ray fluorescence spectrometer at CRTI/UFG.

A flocculant screening was carried out with eleven different PAM (see Table 1) through sedimentation tests in graduated cylinders (2.0L of internal volume). The objective of this stage was to choose one PAM to be further assessed (optimization stage). According to Bolto and Gregory [2], flocculants are broadly characterized by their ionic nature: cationic, anionic, and non-ionic. Since the use of cationic polymers are not usually for mineral particles, only anionic (with different charge densities) and non-ionic flocculants were tested in this work. The flocculant dosage was fixed at 22.5 g/t for all flocculants and the solid percentage of 1.0% (w./v.). The pulp pH was not controlled, only measured, with average value of 8.5. The pulp turbidity was measured at seven different times (from 0 to 30 minutes every 5 minutes after initial agitation) using a Hanna portable turbidimeter model HI-93703 (0 to 1,000 NTU). Turbidity indicates the degree of attenuation that a beam of light undergoes



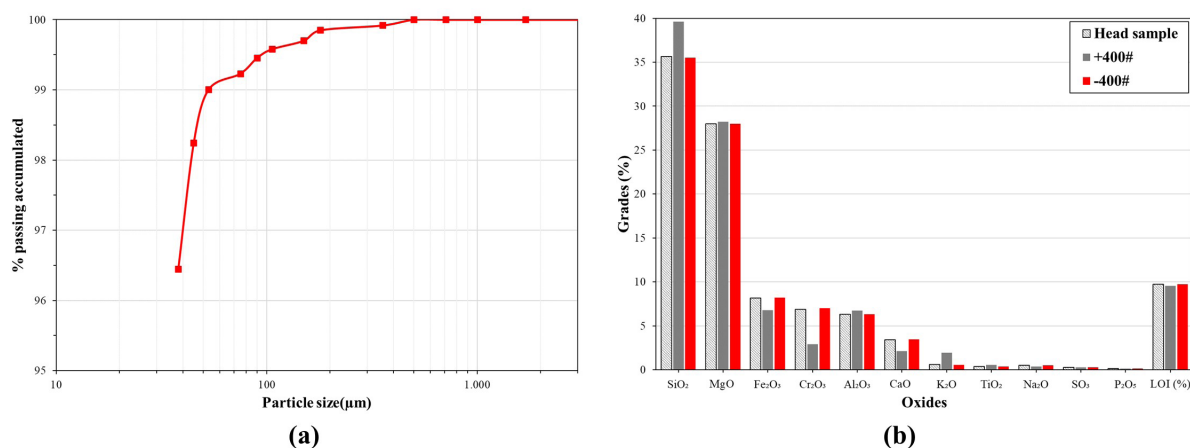
Figure 2. View of one of the chromite tailings thickeners operating at Ipuera/FERBASA.

when passing through water. This attenuation occurs by the absorption and scattering of light caused by suspended solid particles. This parameter was adopted since Brazilian regulations establish that industrial water must be returning to environment with turbidity below 5 NTU [3].

Additional tests (optimization stage) were carried out in three different pHs (7.5, 8.5, and 9.5) and three dosages (15, 22.5, and 30 g/t) with the best flocculant selected after the screening. According to Nozaic et al. [4], there is a greater sensitivity to incorrect dosage of flocculants with

**Table 1.** PAM used in the experimental test work

Flocculant	Molecular weight	Charge	Manufacturer	Recommended dosage (g/t)
Magnafloc 10	Very high	Slightly anionic	BASF	2-200
Magnafloc 155	High	Anionic	BASF	2-500
Magnafloc 336	High	Anionic	BASF	50-200
Magnafloc 338	Moderated	Anionic	BASF	2-200
Magnafloc 351	High	Non-ionic	BASF	2-100
Magnafloc 919	Ultra-high	Anionic	BASF	2-200
Magnafloc 1011	Very high	Anionic	BASF	2-200
Magnafloc 3230	–	Low anionic activity	BASF	-
Rheomax DR 1050	–	Anionic	BASF	2-200
MKFLOC ASV 3060	High	Anionic	MK	-
FLONEX 910 SH	High	Anionic	SNF Floerger	10-15

**Figure 3.** Tailings particle size distribution (a) and chemical composition (b).

turbidity, which motivated the dosage investigation. The two flocculants available at FERBASA (Flonex 910 SH and MKFLOC ASV 3060 manufactured by MK) were used as benchmark in all tests. The pulp turbidity was measured at three different times (0, 5, and 10 minutes) Sodium hydroxide and sulfuric acid (both 10%) were used as pH regulators. Tap water were used throughout the experiments. All tests were carried out in triplicate.

In total, thirty-three tests were carried out in the screening stage and eighty-one in the optimization stage.

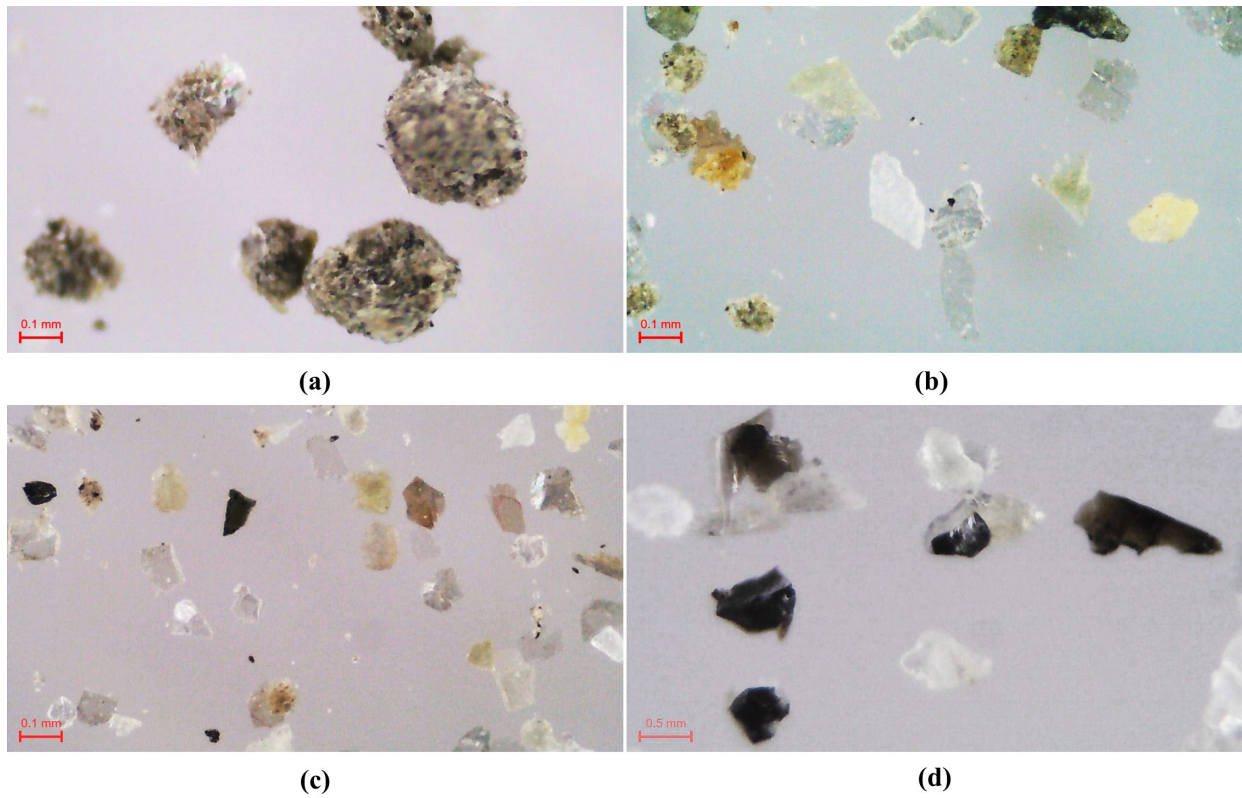
### 3 Results and discussion

Figure 3 shows the tailings samples characterization. It is possible to notice that the tailings were very fine, with average of 96% of the mass below 400# (-38 μm). Regarding the chemical composition the tailings are composed by SiO<sub>2</sub> (35.66%), MgO (28.00%), Fe<sub>2</sub>O<sub>3</sub> (8.18%), Cr<sub>2</sub>O<sub>3</sub> (6.86%), Al<sub>2</sub>O<sub>3</sub> (6.33%), and CaO (3.40%). The low chromium oxide content and the fine granulometry makes impossible to gravimetric recover the remaining chromium particles in the tailings. Figure 4 presents same optical microscopy images of the tailings. It was possible to notice the presence of micas (vermiculite and/or muscovite) on it.

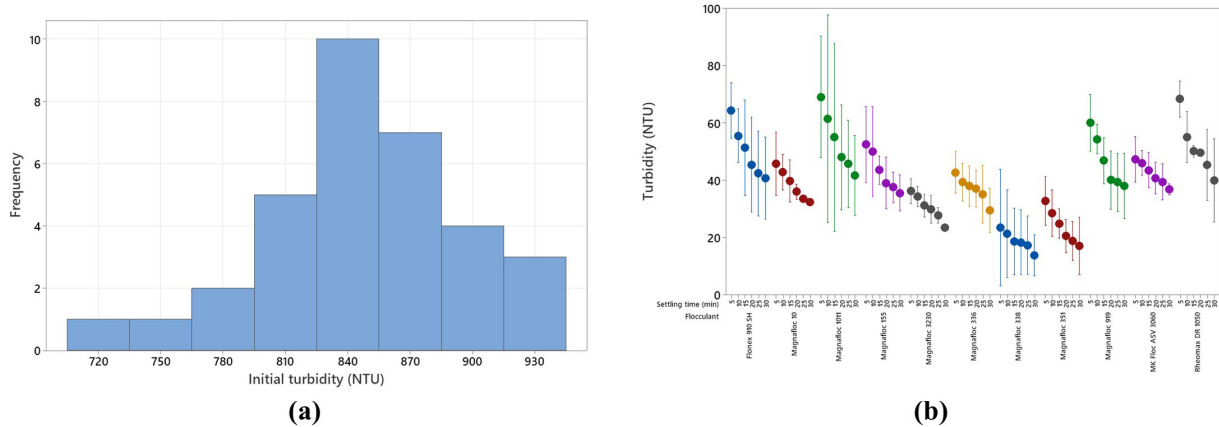
Figure 5 presents the flocculant screening results. It is possible to notice that the solid percentage of 1.0% (w/v.) produced pulps with initial turbidity in the reading range of the turbidimeter (< 1,000 NTU). The sedimentation tests results can be seen in Figure 4b. Since the initial turbidity its more than ten times the final turbidity, the figure was plotted without this point. The Magnafloc 388 was produced the best results in this stage, with final turbidity of  $13.75 \pm 2.87$  NTU. The PAM used in Ipuera/FERBASA produced a residual water with turbidity almost three times higher ( $40.71 \pm 5.76$  NTU for Flonex 910 SH and  $36.84 \pm 0.77$  NTU for MK Flocc ASV 3060).

Figure 6 present the results for the two flocculants used in Ipuera/FERBASA (Flonex 910 SH and MK Flocc ASV 3060) versus the Magnafloc 338, manufactured by BASF. In general, the increase in the pH increased the final turbidity (after 10 minutes of settling) when using Flonex 910 SH, for all tested pH. Similar behavior was only seen with 30 g/t of MK Flocc ASV 3060.

Magnafloc 338, on the other hand, showed a decrease in the turbidity with the increase of the pH. The increase in the flocculant dosage produced small to no changes in the final turbidity for Magnafloc 338 and MK Flocc ASV 3060. The lower final turbidity found for the Flonex 910 SH was  $43.12 \pm 0.38$  NTU at pH 7.5 and 22.5 g/t. For the MK Flocc



**Figure 4.** Optical microscopy of the tailings in four fractions: -45+80# (a), -140+170# (b), -200+270# (c), and -325+400# (d).



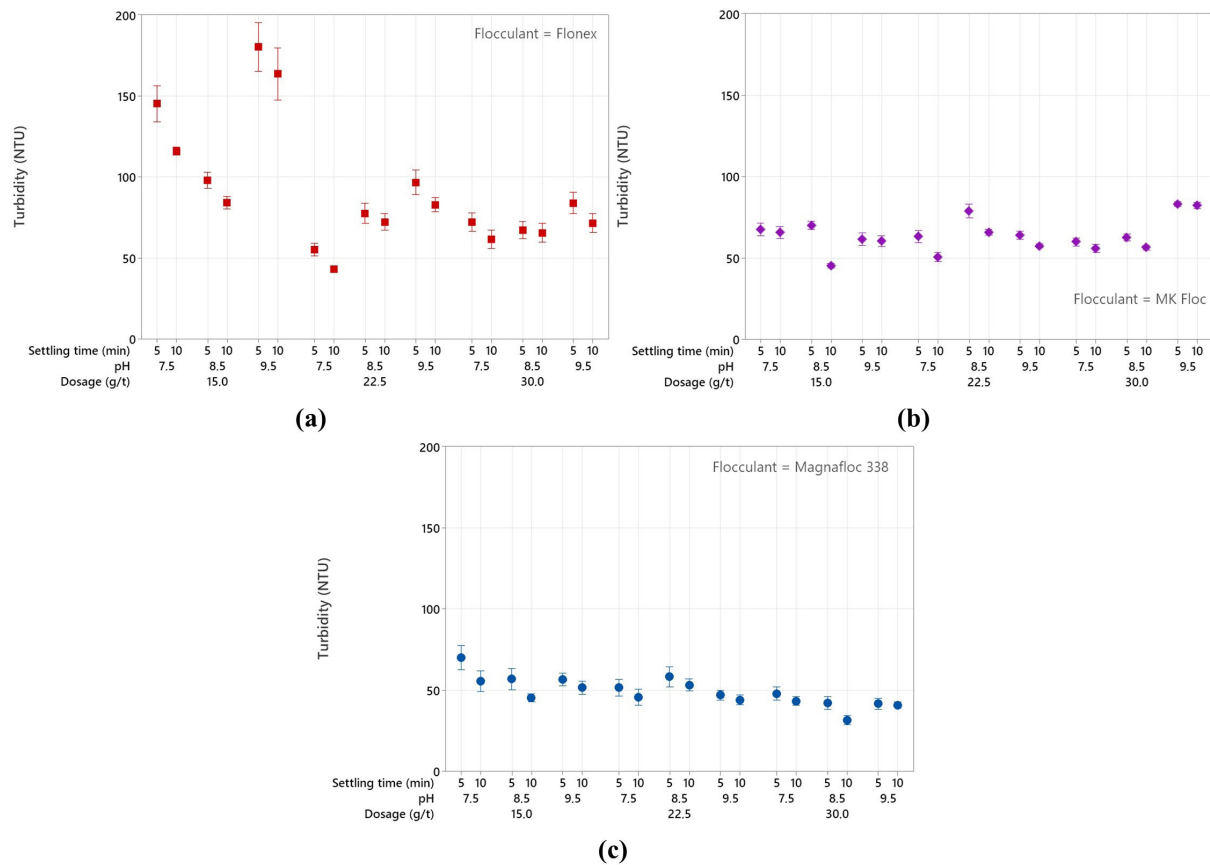
**Figure 5.** Flocculant screening results: initial turbidity histogram (a) and interval plot of turbidity without the initial turbidity (b).

ASV 3060 the best result found was  $45.33 \pm 0.58$  NTU at pH 8.5 and 15 g/t. Magnafloc 338 lower final turbidity was  $31.74 \pm 1.16$  NTU at pH 8.5 and 30 g/t. This result is 35.84% and 42.81% lower than the best results found for Flonex 910 SH and MK Floc ASV 3060, respectively.

Sousa [5] produce mineral paste from tailings using different flocculants. Flonex 910 SH was produced the higher sedimentation speed among all tested flocculants at a dosage of 30 g/t. This result was similar to what was observed for this flocculant in the same dosage. Karmakar et al. [6] were able to obtain supernatant

turbidity below 0.8 NTU using polysaccharide-based graft copolymers. However, the authors dewatered Indian chromite ore with particle size distribution relatively coarser (-200#).

No work using the MK Floc ASV 3060 was found in the literature. Although this polymer is being using at FERBASA for over a year by the Geology team when dewatering samples recovering during drilling campaigns. Therefore, more studies are required in order to better understand the industrial application of this polymer in the chromium tailings dewatering.



**Figure 6.** Results for the three tested flocculants: (a) Flonex 910 SH, (b) MK Flocc ASV 3060, and (c) Magnafloc 338 for different dosages and pHs.

Applications of the Magnafloc 338 in the mineral industry can be found for different ores and tailings, such as spodumene, phosphate rock and sulphates [7-9]. However, no application for chromium tailings, or even ore, was found.

#### 4 Conclusions

Flocculation tests with fine tailings from a chromium mine were carried out in order to evaluate the operational parameters and the flocculant. The found results indicated that the change from high molecular weight anionic PAM such as Flonex 910 SH and MK Flocc ASV 3060 to a moderated

molecular weight anionic PAM (Magnafloc 338) can decrease the turbidity of the clarified effluent produced.

Although no test could reduce the pulp turbidity below 30 NTU, the authors believe that an increase in the Magnafloc 338 dosage could produce even better results.

#### Acknowledgements

The author would like to acknowledge FERBASA for the permission to carry out this work and to allow the data publication. We also thank the CRTI/UFG, Federal University of Catalão and Modelling and Mineral Processing Research Lab (LaMPPMin).

#### References

- 1 Dahlstrom DA, Fitch B. Thickening. In: Weiss NL, editor. SME mineral processing handbook. New York: SME Editor; 1985.
- 2 Bolto B, Gregory J. Organic polyelectrolytes in water treatment. *Water Research*. 2007;41(11):2301-2324.
- 3 Viana DB, Daniel MHB, Magalhães TB, editores. Diretriz nacional do plano de amostragem da vigilância da qualidade da água para consumo humano. Brasília: Ministério da Saúde; 2016. 53 p.
- 4 Nozaic DJ, Freese SD, Thompson P. Long term experience in the use of polymeric coagulants at Umgeni Water. *Water Science and Technology: Water Supply*. 2001;1(1):43-50.
- 5 Sousa PA. Tecnologia em preparação de pastas para disposição de rejeitos [dissertação]. Belo Horizonte: Universidade Federal de Minas Gerais; 2017.

- 6 Karmakar NC, Sastry BS, Singh RP. Flocculation of chromite ore fines suspension using polysaccharide based graft copolymers. *Bulletin of Materials Science*. 2002;25(6):477-478.
- 7 Alves JVS, Pires NJ, Oliveira MS. Estudo para remoção dos íons  $\text{Ca}^{2+}$  e  $\text{Mg}^{2+}$  da água por Magnafloc 338 e Alginato de sódio em um sistema de flotação por ar dissolvido. *Tecnologica em Metalurgia, Materiais e Mineração*. 2023;20:e2744.
- 8 Pérez K, Moraga C, Herrera N, Salinas-Rodríguez E, Gálvez E. Effect of the addition of flocculants and KCl on sedimentation rate of spodumene tailings. *Metals*. 2021;11(6):986-1001.
- 9 Pushkarov M, Velichkova R. Experimental investigation of acid mining water. *E3S Web of Conferences*. 2020;207:02016.

Received: 8 Dec. 2023

Accepted: 28 Mar. 2024