Considering residual flocculants and coagulants in recycled mine water on the surface chemistry of talc: Implications on flotation performance

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Abstract

Given the importance of dewatering processes to the question of water recovery (and therefore closed water circuit design) and tailings management, concentrators are putting in many interventions into ensuring that dewatering processes are designed and operated with maximum efficiency. This means that interventions such as the addition of dewatering chemical agents into dewatering unit processes are implemented in order to improve the efficacy of dewatering. These chemical agents often come in the form of flocculants and coagulants. Their effects on flotation are not well understood, this begs the question, how will residual flocculants and coagulants in recirculated process water affect flotation performance. This study therefore investigates the adsorption of CMC as a depressing reagent for talc in process water that contains residual flocculants and coagulants. The results of this investigation showed that process water containing residual concentrations of the coagulant resulted in higher CMC-talc adherence. It was also shown that the zeta potential of talc increased in process water containing the flocculant – indicating a passivation mechanism.

Keywords: Coagulants, flocculants, flotation, mine water, residual reagents

Introduction

The need for the implementation of closed water circuits in minerals processing has become an increasing necessity (Slatter et al. 2019). Challenges around the use of recirculated water in flotation are multifaceted owing to the complex nature of recirculated water compared to fresh water. The nature of recirculated process water may be largely different to that of fresh water due to several physicochemical factors, such as inorganic electrolytes leached out of the ores into solution, microbes possibly emanating out of other sources of water such as sewage treated water, residual reagents from flotation and residual reagents from the dewatering of flotation tailings and concentrates (Slatter et al. 2009). These very constituents that may be found in recycled process water also affect physical properties of water such as the pH, electrical conductivity, viscosity, total dissolved solids (TDS) and total suspended solids (TSS) (Manono et al. 2019a).

During the flotation of sulfide minerals, concentrates and tailings are dewatered through thickeners and filters. The dewatering of flotation products is aided using chemical reagents such as flocculants and coagulants into thickeners. The supernatant and filtrate recovered from dewatering processes may very well contain residual amounts of these chemical reagents. Given that the recovered water from dewatering processes is recycled back into milling and flotation, it stands to reason that the chemistry of these dewatering chemical agents may affect the pulp phase phenomena through possible interactions occurring at the mineral surface between fresh flotation reagents, residual flotation reagents, residual flocculants, residual coagulants and inorganic electrolytes in the recovered and recycled process water.

There however remails little or no information in the literature regarding how flocculants and coagulants affect the adsorption of flotation reagents into mineral particles. For example, polysaccharides such as sodium carboxymethyl cellulose (CMC) aid the hydrophilisation of non-sulfide gangue minerals such as talc to prevent such gangue minerals from diluting flotation concentrates but whether the presence of residual dewatering aids in process water would influence the adsorption behaviour of CMC or not, remains an unanswered question.

There is information in the literature regarding process water quality, effects on the adsorption of CMC onto talc given the critically of the management of gangue in flotation (Burdukova et al. 2008; Manono et al. 2019a, b, 2020). However, existing literature focusses on inorganic electrolytes and their increased concentrations in process water. Therefore, this paper aims to investigate the effect of residual flocculants and coagulants in recirculated mine process water on the adsorption of a depressant into a non-sulfide gangue mineral, talc, which is common in Cu-Ni-Pt mineral concentrators. Furthermore, the effects of residual flocculants and coagulants are investigated on the surface chemistry of talc by determining the influence of these residual dewatering agents on the zeta potential of talc to further explain the effects on CMC adsorption onto talc in recirculated mine process water containing these dewatering agents.

Methods

1 kg talc sample obtained from Ward's Science was first hammered to less than 1 mm, thereafter the sample was pulverised for 15 to 20 s. The pulverised sample was thereafter screened to obtain samples of particle size distribution of +38–75 µm to be used in adsorption studies and the fraction of particles with a size less than 38 µm was used for zeta potential studies. Particles that were above 75 µm were pulverised and screened again. The samples were packaged in labelled bags and refrigerated to preserve them. No nitrogen purging was conducted as talc does not undergo oxidation. Fig. 1 shows the mineral characterisation of the talc sample through X-Ray Diffraction (XRD) method.

The XRD results show that talc had trace impurities of dolomite and biotite. It can be said that this talc sample was highly pure.

3 SPW is a synthetic plant water recipe of a certain concentration of ions that was prepared using deionised water to mimic industrial process water quality as shown in Tab. 1. A volume of 2 L of deionised water in a beaker was placed on a magnetic stirrer and the required salts of analytical grade were added to make the synthetic plant water (3 SPW).

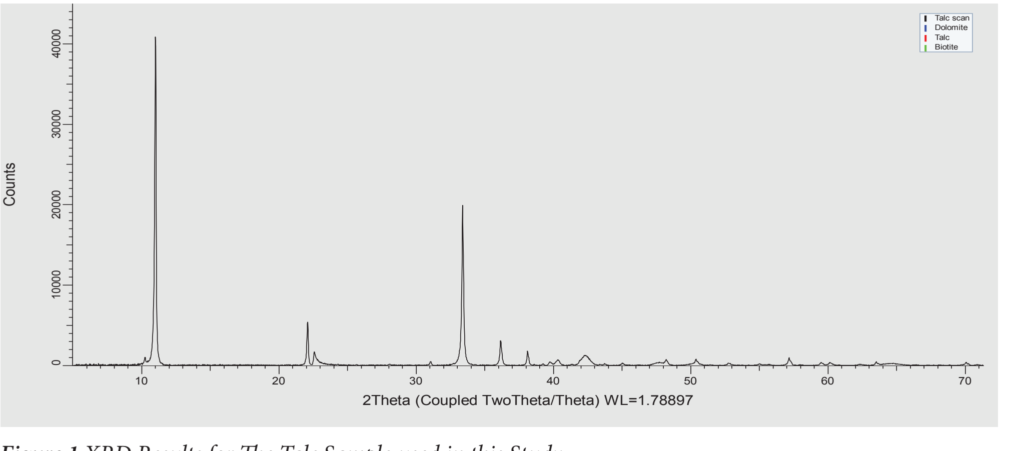

***Figure 1** XRD Results for The Talc Sample used in this Study*

Table 1 Concentration of Ions in Synthetic Plant Water in mg/L, Adapted from Wiese et al. (2005)

	Ca^{2+} mg/L	Mg^{2+} mg/L	Na^{+} mg/L	Cl^{1-} mg/L	SO_4^{2-} mg/L	NO_3^{-} mg/L	CO_3^{2-} mg/L	TDS (mg/L)
3 SPW	240	212	459	861	719	527	51	3069

The type of CMC used in this study is Depramin 267 and was supplied by Akzo Nobel in a powder form. A stock solution of 1 vol.% was prepared by adding 1 g of CMC in 100 mL of deionised water in a beaker and stirred for 3 h on a magnetic stirrer until completely dissolved. A new batch was prepared every 5 days. The stock solution was also refrigerated at the end of every test day.

The flocculant and coagulant used are acrylamide acrylate copolymer (WM7530) and polyhydroxyalkylene dimethyl ammonium chloride (WM8305) respectively. The flocculant is anionic in nature whilst the coagulant is cationic in nature. A solution of 1 vol.% was prepared by adding 1 g per 100 mL of deionised water in separate and distinct beakers for the flocculant and coagulant. These were also placed on a magnetic stirrer for 2 h. A new batch was prepared every 5 days. The stock solutions were refrigerated at the end of every test day.

A 5 vol.% solution of phenol supplied by Merck was prepared by weighing 5 g of phenol powder and mixing it into 100 mL of deionised water. This was done under a fume cupboard because phenol is very toxic when inhaled.

Tab. 2 summarises the flocculant and coagulant dosages that were added to 30 mL of synthetic plant water (3 SPW) for each test. These dosages were added to mimic recycled mine water with residual dewatering reagents.

Table 2 Coagulant and Flocculant Dosages for Experimental Tests Conducted

Condition	Coagulant Dosage (µL)	Flocculant Dosage (µL)
3 SPW 0 0	0	0
3 SPW L 0	2.25	0
3 SPW H 0	4.50	0
3 SPW L L	2.25	2.25
3 SPW H H	4.50	4.50
3 SPW 0 L	0	2.25
3 SPW 0 H	0	4.50

The maximum concentration of CMC used was 10 mg/L as determined from the required dosing of 100 g/t of talc. The Du Bois phenol-sulfuric technique was followed to allow for the absorbance of CMC to be read-off at a wavelength of 490 nm (du Bois et al. 1956).

As represented in Tab. 2, seven test conditions were investigated for their possible effects on the adsorption of CMC onto talc. These tests were performed in triplicates in conical flasks for each of the different dosages of coagulant and flocculant as well as conditions where neither a coagulant nor flocculant was present in the system. A mass of 3 g of talc was weighed on a scale and was added to conical flasks and each dosed with a constant concentration of 10 mg/L of CMC from the stock solution. Using a volumetric syringe, 30 mL of 3 SPW was added to each flask. Each test was placed in an Ecobath shaker at a temperature of 25 °C, at its natural pH, and a speed of 141 rpm was maintained for 15 min. Once this was done, the slurry solution was then filtered using a 0.45 µm vacuum filter. The du Bois phenol-sulfuric technique was followed to determine the residual concentration of CMC in each test.

A talc sample of 0.0375 g was weighed on a scale and added to 30 mL of 3 SPW in a glass beaker with the respective flocculant and coagulant dosage for each test condition shown in Tab. 2. Zeta potential studies were performed on each test in the absence of CMC at the natural pH of the solution. The respective amount of coagulant and flocculant to make the dosages shown in Table 2 was added to the beaker using a micro-syringe. 0.0375 g of talc was weighed and added to the beaker. The slurry was placed on a magnetic stirrer for about 1 min. 1 mL of the mineral dispersion was pipetted into a folded capillary zeta cell ensuring that there are no bubbles in the cell. The cell was then placed in the zeta sizer nano series to measure the zeta potential. Each test was repeated in triplicates for more accuracy.

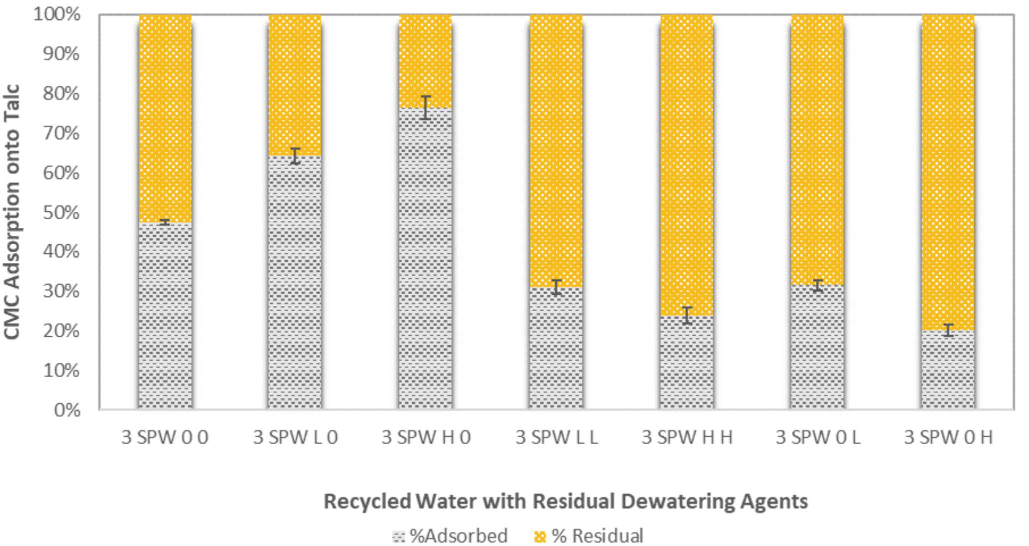

Figure 2 *Percentage of CMC Adsorbed onto Talc in Synthetic Plant Water Containing Residual Dewatering Agents*

Results

Adsorption of CMC onto Talc in Recycled Mine Water with Residual Dewatering Agents

Fig. 2 therefore shows the CMC adsorption results obtained for all the test conditions. Fig. 2 shows that in the absence of a coagulant and a flocculant about 50% of CMC adsorbed onto talc.

An increase in the adsorption of CMC onto talc was observed in increasing concentrations of residual coagulant in recycled process water. The presence of residual flocculant in recycled mine water resulted in a decrease in CMC adsorption as seen from the results for 3 SPW 0 L compared to 3 SPW 0 0, a further increase in the residual amount of the flocculant in simulated mine recycled water led to an even stronger decrease in CMC adsorption onto talc.

Zeta Potential of Talc in Recycled Mine Water with Residual Dewatering Agents

Fig. 3 shows the zeta potential of talc particles in recycled process water containing residual coagulant and flocculant. The zeta potential of talc in recycled water in the absence of a coagulant and flocculant is also given in Fig. 3. Fig. 3 shows that the presence of a coagulant in recycled process water resulted in a less negative zeta potential for talc. Increasing the residual amount of the coagulant in recycled process water, resulted in a further reduction of the negative nature of the zeta potential of talc.

Fig. 3 also shows that the presence of a flocculant in recycled process water resulted in a less negative zeta potential; increasing the residual flocculant concentration in recycled water resulted in a positive zeta potential. The combination of both the coagulant and flocculant in low concentrations also resulted in a less negative potential whilst higher concentrations of these dewatering agents resulted in a positive zeta potential.

Discussion

Adsorption studies were done to better understand how the adsorption of CMC on talc would be affected by residual flocculant and coagulant in recycled process water. The CMC adsorption studies gave an indication of the residual amounts of CMC after the adsorbed amount onto talc. The adsorption of CMC in the absence of both the coagulant and flocculant was used as a reference or baseline for comparison against recycled

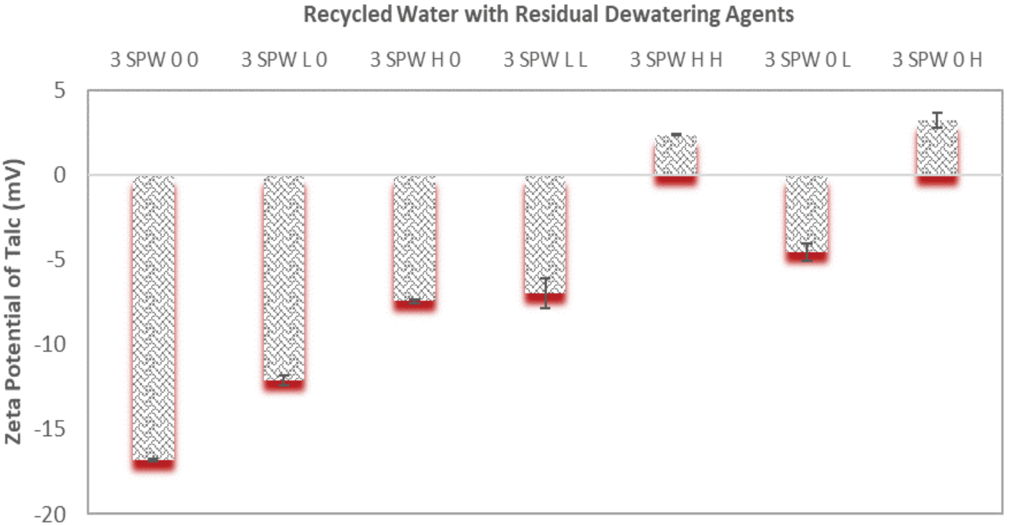

***Figure 3** The Zeta Potential of Talc in Synthetic Plant Water Containing Residual Dewatering Agents*

process water containing residual dewatering agents. To further understand the effect of residual dewatering agents in process water at the mineral-water interface, zeta potential measurements were conducted. Fairhurst (2013) describes the zeta potential as a measure of the charge at the shear plane of the electrical double layer and it gives an idea of the surface charge. The zeta potential allows for an understanding of the dispersion of particles. A large magnitude in zeta potential, whether positive or negative shows that like charged particles are further apart because of the electrostatic repulsive forces between them. The zeta potential of such a suspension lies outside the range of positive and negative 30 mV. Zeta potential values closer to 0 mV typically from −8 to 3 mV indicate more flocculated particles as they are attracted by van der Waals forces. As established from literature, the mineral particles are electronegative and that the coagulant is cationic while the flocculant used is anionic. It is also known from previous studies that polyvalent cations result in more flocculation of talc particles (Manono et al. 2019a, b). As seen in the adsorption results presented in Fig. 2, the increase in the adsorption of CMC in the presence of a coagulant in recycled process water can be explained from the fact that the chosen coagulant is positively charged, passivating talc particles hence the reduction on the negative charge of talc as seen from the zeta potential results in Fig. 3. The passivation of talc in the presence of the coagulant reduces the electrostatic repulsive force between the negatively charged talc particles and the negatively charged CMC. This allows for the negatively charged CMC to adsorb onto the talc mineral. The fact that about 50% of CMC adsorbs onto talc even in the absence of a coagulant suggests that talc has more active sites on its surface in the presence of recycled water in the form of 3 SPW, this behaviour has been seen in previous studies (Manono et al. 2019a, b).

The addition of a coagulant and flocculant at low and high concentrations caused a decrease in the adsorption of CMC onto both talc even though the mineral surface seems to have been more passivated under these conditions as the zeta potential of talc had seen a strong reduction from being negative to positive. Although both the coagulant and the flocculant are positively charged, the coagulant primarily functions by neutralising the charge of particles whereas the flocculant aids in bridging and aggregating particles. Therefore, as seen in the zeta potential results for talc, it was expected that the adsorption of CMC would be higher under these conditions, but this was not the case.

It is therefore implied that the combination of flocculant and coagulant adsorbs onto the mineral surface and reduces the number of active sites, meaning the is a reduction in surface area available for CMC adsorption after the talc surface has been in contact with the coagulant-flocculant combination. The results of this study also showed that increasing the flocculant concentration in recycled water leads to a strong passivation of talc particles, however such a passivation results in a decrease in the adsorption of CMC. Therefore, it can be said that the adsorption of the flocculant on talc reduces the number of active surfaces for CMC adsorption.

Conclusions

Adsorption studies showed that the adsorption of CMC onto talc was greater when recycled process water contained residual amounts of the coagulant compared to recycled water that containing residual amounts of the flocculant. Recycled water containing a flocculant as well as the combination of both the coagulant and flocculant decreased the adsorption of CMC onto talc. The zeta potential measurements showed that the presence of the flocculant led to a greater passivation of talc, thus supporting a strong affinity between talc and the flocculant. This, however reduced the number of available sites for CMC adsorption hence the decrease in CMC adsorption in flocculant containing recycled process water. Therefore, it is concluded that recycled water containing only residual concentrations of the coagulant is beneficial for the adsorption of depressants such as CMC onto non-sulfide gangue minerals in flotation and may benefit the depression of gangue and thus improving valuable mineral grades.

Acknowledgements

The authors would like to acknowledge Jill Joan Musoke Nalugwa and Thandeka Nsibande who conducted the experimental work as part of their research project in fulfilment of the requirements for the degree of Bachelor of Science in Engineering in Chemical Engineering at the University of Cape Town. This work benefited from financial contributions made by the University of Cape Town and the National Research Foundation (NRF). Special thanks to Mpho Ramonotsi and Pilanesberg Platinum Mines (Pty) Ltd for providing our lab with the coagulant and flocculant.

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