Proceedings of the 7th International Conference of Recent Trends in Environmental Science and Engineering (RTESE'23)
Canada – June 04 - 06, 2023
Paper No. 134
DOI: 10.11159/rtese23.134

The Impact of Residual Flocculant on Flotation Performance of Platinum Group Metal Ores

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Abstract – The recycling of process water in the mineral processing plants is of paramount importance due to scarcity of fresh water. However, it has many challenges specifically on flotation performance. This research work focused on the impact of residual flocculant on flotation performance of Platinum group metal (PGMs) ores in terms of recovery. The impact of residual flocculant on PGMs recovery using recycled process water from a chrome processing rougher plant was investigated. Water samples from the flotation circuit and chrome plant were analysed for elemental composition, total dissolved solids (TDS), electrical conductivity (EC), pH, turbidity and total hardness. The effect of residual flocculant on settling was determined using settling test. The impact of high concentration of residual flocculant on PGMs ore in terms of recovery were investigated by comparing flotation circuit stream and chrome plant stream using Denver flotation cell. Results revealed that the chrome plant stream contained a higher concentration of ions compared to the was high flotation circuit stream. The chrome plant water had a pH of 8.41, TDS of 1331mg/l, EC of 217 mS/m, Turbidity of 2.42NTU and total hardness of 476 mg/l whilst the flotation circuit water had a pH of 7,73, EC of 87.3, TDS of 461, Turbidity of 1.025 NTU and total hardness of 224,7 mg/l. The recycled process water showed high settling rate compared to fresh water suggesting the existence of residual flocculant in the recycled process water. The flotation circuit pulp stream always showed higher recoveries of PGMs [70-78%] compared to CRD (54 – 62%).

***Keywords*:** Platinum group metals, flotation, water streams, residual flocculant, Bushveld Igneous Complex

1. Introduction

Fresh water is very scarce and plays a vital role in the mining industry. The mineral processing industry uses water in all its operations, with flotation being the most commercial mineral processing method and it consumes a substantial amount of water [1]. In mineral processing, water streams such as pulp in flotation plants represent 80-85% of water on the plant [2]. The high consumption of water in mineral processing has encouraged many mineral processing plants to investigate more on alternative sources of water [3]. Most mineral processing operations have already started assessing and implementing different ways to conserve and manage water resources, bringing about sustainability benefits as well as cost effectiveness [1]. To improve water efficiency, there are two significant strategies that are being implemented. The first one being the recycling of water and the second one, assessing alternatives to freshwater, specifically for flotation. The recycling of water plays a very important role in preserving freshwater supplies and establishing zero-emission mineral processing operations. This is also why a significant number of plants have dewatering systems used to recover water for reuse [4]. These include recycling process water from tailings dams, thickener overflows, dewatering, and filtration units which uses flocculant to settle the slurry. The recycling of process water can have a negative effect on flotation performance resulting in poor recovery of minerals. However, it has an advantage of reducing the cost of flotation reagents by lowering their consumption [5]

The recycled water contains residual flocculant, collectors, depressant, frothers as well as inorganic constituents such as base metals, suspended matters, calcium, magnesium, sulphate, sulphite etc which have several effects on flotation performance [6]. These include uncontrolled chemical variables such as pH, total dissolved solids (TDS), conductivity and turbidity. Mg^{2+} and Ca^{2+} are commonly cited cations in many studies as their precipitated species have negative effect on recovery of valuable minerals [7]. The recycled water gets saturated with salts as a result of oxidation and dissolution during the process of comminution and flotation especially when sulphate, carbonate and sulphide minerals are present. Literature have shown that sodium alone doesn't depress sphalerite but with potassium permanganate, it depresses sphalerite with little effect on chalcopyrite and galena [8].

The residual flocculant might also contribute to the decrease in recovery of PGMs by reacting with other reagents and increasing content of unwanted species in the process water. Flocculant is used in the thickeners, tailings dams etc to settle the slurry and recover back water back in the processing plant. The actions of dispersants and flocculants added at different points in the circuit can determine water quality and the surface chemistry of the different mineral phases. Residual levels of dispersants can induce additional precipitation (e.g., hexametaphosphate or Calgon), or competitive adsorption with other reagents [9].

There are limited studies on the residual flocculant in the recycling process water and its effect on the PGMs performance. Optimized action of flocculants in clarification of recycles from thickeners etc, is often unrecognized and uncontrolled. This work focused on the impact of residual flocculant on PGMs recovery during froth flotation.

2. Materials and methods

2.1. Materials

The PGMs ore and water streams samples used in this research work were supplied by one of the PGMs plant concentrators situated in the Limpopo province, South Africa. The flotation reagents were supplied by Senmin, South Africa. The water samples were collected from the plant and the sampling points are shown in Figure 1. The first sample was collected when the water was routed to the chrome plant and recycled back to the 2nd PGMs rougher flotation plant. The second sample was collected when the tailings from the primary rougher plant were fed into the 2nd PGMs rougher plant without treatment in the chromite removal plant.

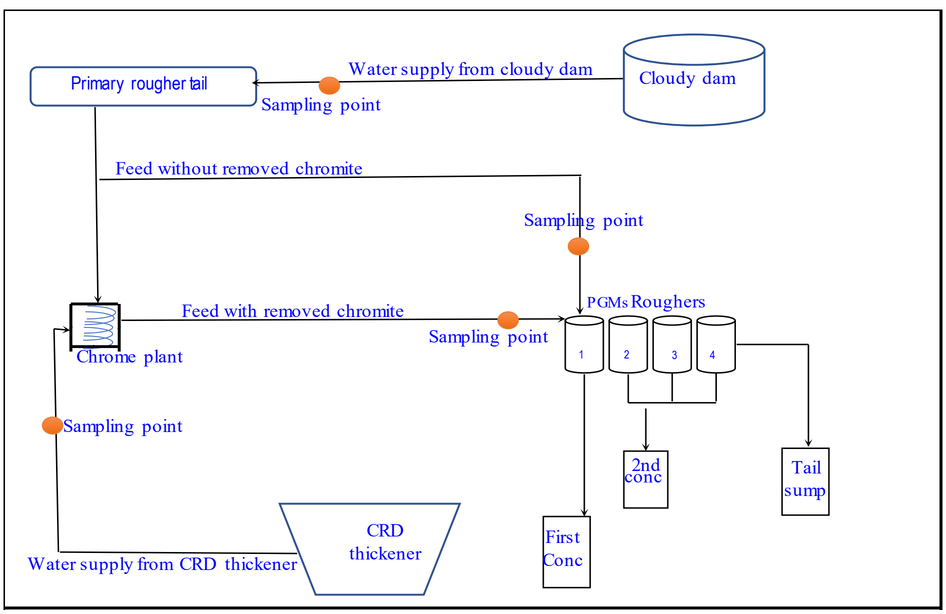

Fig.1: Flowsheet of sampling points on the Chromite removal plant and PGMs flotation circuit

2.2. Characterization of water streams samples

The water samples sampled from the chromite processing plant and flotation circuits were analysed for pH, total dissolved solids (TDS), electrical conductivity (EC), and turbidity at an accredited laboratory in South Africa. The chemical composition of water streams was obtained using inductively couple plasma mass spectrometry (ICP). The sample was analysed for residual flocculant using ultraviolet spectrometry (UV).

2.3. Settling test work

Settling test were done using a PGMs concentrate. The samples were taken from process water (feed to flotation circuit), circuit), fresh water and flocculant to compare their settling rate. 3,8 g/t of flocculant were added in each of the three water water samples. The slurry was filled in a 1L cylinder. After shaking the cylinder, the interface level of slurry was recorded recorded at 50 second intervals for 300 seconds.

2.4 Hot float test work

The hot float tests were carried out in a Denver flotation cell of 8 litres capacity. The ore sample used was chrome plant rougher feed collected from chrome rougher flotation circuit using a container of the same capacity with Denver flotation cell. The sample was weighed before discharged to the Denver flotation cell to record the initial mass of the slurry. The sample was agitated in Denver machine to ensure homogenous suspension of the solids. Thereafter, air rotameter on the Denver machine was used to induce an air. The scraper blade was used to collect the concentrate by scraping the froth in 15 seconds intervals into a labelled container.

The remained slurry in the Denver flotation cell was collected as tailings. After hot float, both concentrates and tailings were filtered, dried, weighed and analysed for PGMs using the nickel sulphide collection method. The process was repeated twice: first during the time when running with the return from the chrome plant tr and secondly when running without the return from the chrome plant. The feed samples were collected after every two hours for four times.

3. Results and discussion

3.1 Characterization of the streams water

The two water streams and fresh water were analysed using ICP for chemical composition and the results are shown in Table 1. The results shows that the chrome plant stream has the highest concentration of all the chemical elements analysed followed by the flotation circuit stream and then the fresh water. This means that there are remarkable chemical changes on the chrome plant stream. Thus, water from chrome plant stream introduces a higher percent of impurities and these impurities may react with other reagents and negatively affect flotation performance [4, 7, 6].

Table 1: The chemical composition of the three water stream using ICP mass spectrometry.

Elements	**Fresh water (mg/L)**	**Flotation circuit stream (mg/L)**	**Chrome plant stream (mg/L)**
Calcium	37,57	32,68	108
Magnesium	24	31,73	49,9
Sodium	65,4	83.7	252
Potassium	10,37	14.21	17
Chloride	102.37	122,3	376
Sulphate	82.27	82.9	278
Nitrate	0,796	0,89	30,2

The water samples were then tested for total dissolved solids (TDS), electrical conductivity (EC), pH, turbidity and total hardness and the results are shown on Table 2. The chrome plant stream has high electrical conductivity of 217ms/m followed by the flotation circuit stream with 87.3ms/m and lastly fresh water with the lowest of 73.77ms/m. The high electrical conductivity decreases recovery while increases the grade of the PGMs minerals. This may be attributed to the spiking effect of alkali metals ions particularly Ca^{2+} and Mg^{2+} which may deactivate non sulphide gangue minerals thus decreasing recovery and increasing the grade [7].

The Chrome plant pulp stream shows high total dissolved solid (TDS) of 1331mg/l followed by flotation circuit stream (461mg/l) and fresh water with the lowest of 393.67mg/l. Dissolved solid are present in recycling water as colloidal particles and this may remain dispersed or attached to mineral particles as hydrophilic surface layers. This leads to reduction in recovery since valuable minerals will behave as if they are gangue minerals and report to the tailings. Hence there is need to filter the recycled water from the chrome plant before using it in the flotation plant.

The pH obtained were 7.03, 7,73 and 8.41 for freshwater stream, flotation circuit water stream and chrome plant stream respectively. Increase in pH favours high water recoveries which indicates froth stability. Thus, high pH of the chrome plant stream is an advantage on the flotation circuit.

Water from the Chrome plant had a high turbidity of 2.42 NTU and total hardness of 476 mg/L. High turbidity may due to high flocculant dosage. There is no separation between suspension and water at high flocculant dosage due to high speed of mixing. So, the speed of mixing and flocculant dosage should correlate. If the flocculant dosage is high, then speed of mixing should be low because if the speed exceeds a certain limit the mixer impellers will begin to tear apart the flocs forming in the water and therefore the particle becomes smaller and difficult to settle which result in increase in the turbidity.

Table 2: Physical properties of the water samples.

Physical Property	Fresh water	Flotation circuit (cloudy water) stream	Chrome plant (CRD water) stream
Electrical conductivity(mS/m)	73,77	87,3	217
Total dissolved solid (TDS) mg/l	393,67	461	1331
Turbidity (NTU)	0,713	1,025	2,42
Total hardness (mg/L)	184	224,7	476
pH	7,03	7,73	8,41

3.2 Residual flotation analysis

The dissolved flocculant, cloudy water and the chrome water plant was analyzed using UV and the results are shown in Figure 2. CRD and cloudy water curves are similar, and they follow the same trend as the flocculant revealing that there is residual flocculant in the two streams. The figure also reveals that the CRD water have same chemical concentration with dissolved flocculant at wavelength of 2,93nm and which is higher than that of cloudy water. This shows there is high residual flocculant in CRD water than cloudy water.

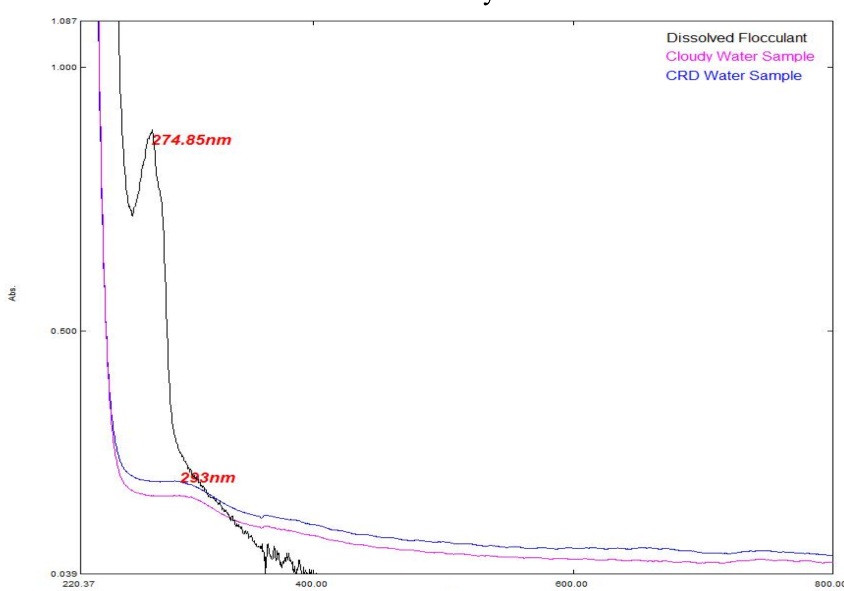

Fig. 2: UV-spectrometry of cloudy water and CRD water against dissolved flocculant at high absorption (concentration)

3.3 Settling tests results

The settling rate of fresh water, process water (combined streams of flotation circuit and chrome plant pulp) and flocculant were investigated by measuring the interface level after every 50 seconds and the results as shown on Figure 2. The aim was to prove that there is residual flocculant in the recycled process water. The flocculant shows lowest interface level always followed by process water and fresh water respectively. Thus, flocculant increases the settling rate of the slurry and since process water settle faster than fresh water this proves residual flocculant in the process water.

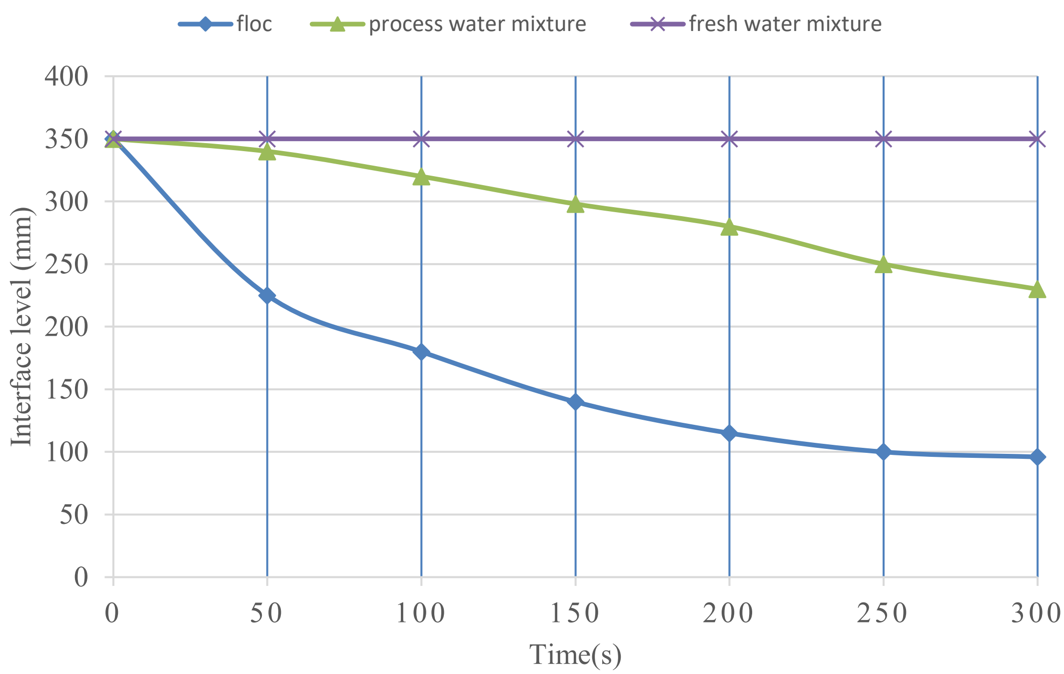

Fig. 2: Settling rate of flocculant, process water and fresh water.

3.4 Hot float results

The PGMs recovery from the two water pulp streams were investigated through the hot float process and the result are shown on Figure 3. The flotation circuit pulp stream always shows higher recoveries of PGMs [70-78%] compared to CRD (54 – 62%) and that proves that chrome plant pulp provides poor flotation conditions. This could be caused by the chrome plant pulp having more residual flocculant than flotation circuit stream. Residual flocculant molecules collide with ultra-fine particles in pulp and form floc aggregates [10]. These aggregates in turn reduces flotation performance by reducing the probability of the fine particles reacting with the collectors and colliding with the bubbles. Apart from that, with high levels of residual flocculant, additional precipitates are formed (e.g., hexametaphosphate or Calgon) that may compete for adsorption with other reagents thereby reducing flotation efficiency. Thus, the flocculant dosage on the chrome plant stream from the thickener should be optimized and reduce the amount of the residual flocculant.

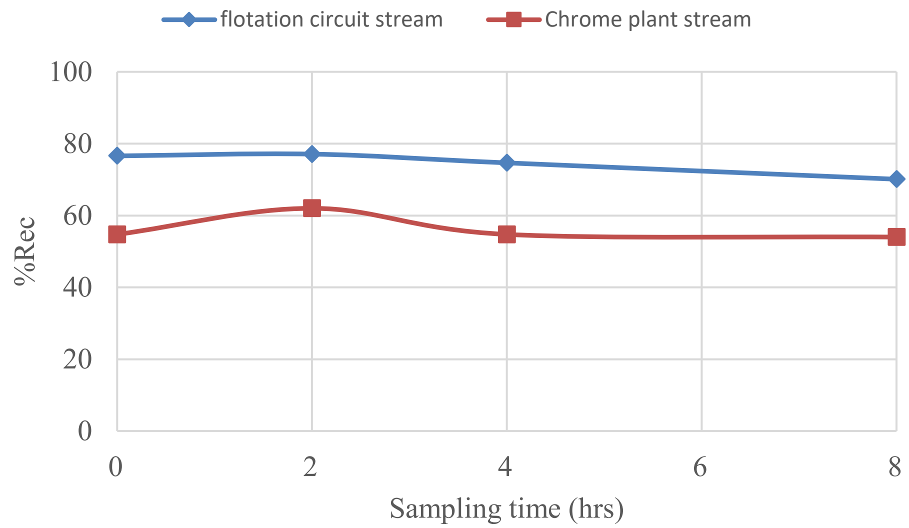

Fig. 3: % PGMs Recovery vs sampling time.

4. Conclusion

Research has shown that water recirculated from Chrome removal plants in PGMs flotation plants contain higher concentrations on inorganic ions and residual flocculants. These ions and flocculants negatively affect the flotation performance of the PGM ores. With the optimisation in use of flocculants in thickeners, the impact of residual flocculants can be reduced. TDS, EC, Turbidity, pH and total hardness are higher for water circulated from chrome removal plants compared to water in the rougher flotation circuits. The faster settling rate of slurry in the process water confirmed the residual flocculant in the process water. The flotation circuit pulp stream always showed higher recoveries of PGMs [70-78%] compared to CRD (54 – 62%).

Acknowledgements

The authors would want to thank the University of Johannesburg and the National Research Foundation of South Africa [Grant number **132291]** for the financial support of this project.

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