Optimisation of Collector Reagents for Enhancing Efficiency in Low-Grade Upper Group 2 Ore and Base Metal (Copper) ore Processing

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Abstract

Froth flotation is recognized as one of the top ten technological inventions of the 20th century, as it was commercially applied in 1906. Initially developed for the mining industry to recover valuable minerals from high-grade tailings produced by gravity separation plants, froth flotation has since gained importance due to its effectiveness in the beneficiation of low-grade and sulphide ores. It is primarily used to separate minerals of interest from complex ores. This is achieved by optimizing flotation parameters such as particle size, pulp density, water quality, pH, and reagent dosage. However, flotation faces numerous challenges, such as the ever-changing grade and mineralogy of the ore during mining operations. Optimizing collector reagent usage is crucial for maximizing the recovery of valuable minerals from complex ores. For instance, the exploitation of Merensky ore is approaching its peak, necessitating the exploration of alternative platinum group metals (PGMs), such as Upper Group 2 (UG2) ore. PGMs are one of the primary sources of mineral revenue for South Africa. According to literature, PGMs found in the UG2 Reef, Merensky Reef, and Platreef are associated with sulphides, base metals, and gangue minerals. The recovery and grade of PGMs are critical for improving flotation plant performance. However, careful consideration must be given to flotation plant optimization to reduce operational and reagent costs. One key method to control these factors is through the careful selection and dosage of flotation reagents, particularly collectors. Collectors play a significant role in the flotation of valuable minerals, as noted in the literature, and are known for their selectivity and effectiveness in the flotation of sulphide minerals.

Collectors can be utilized either as a single reagent or in a mixed system, depending on their specific interactions with different minerals and their versatility in tailoring flotation performance. A single collector system is considered effective when the mineral system is simple, selectivity is well understood, and flotation can be easily achieved. In contrast, a mixed reagent system is used for more complex mineral systems where multiple minerals need to be targeted, or where selectivity and recovery require improvement. Moreover, mixed systems offer additional benefits, such as synergistic effects, where the primary collector enhances the hydrophobicity of the mineral surface, while a secondary collector improves attachment efficiency to air bubbles. As the range of ores treated by froth flotation has expanded, the process has become increasingly complex, necessitating continuous evaluation and optimization. One approach involves co-blending various thiol collectors to improve ore selectivity, which can lead to higher recovery rates compared to using a single collector. Mintek's Measurement and Control Division (MCD) aimed to identify the most effective collector blend for optimizing flotation performance for PGMs and base metal (copper) ores. The study initially evaluated various individual collectors, including sodium isobutyl xanthate (SIBX), dithiocarbamate (DTC), and dithiophosphate (DTP), before investigating co-blending at fixed proportions (50:50, 70:30, and 90:10) for xanthate-DTP/DTC blends. The research involved flotation test work conducted in two phases. Phase 1 focused on evaluating individual collector reagents on two types of ores—Platreef PGM and base metal ores. Phase 2 examined the co-blending of collectors to enhance the recovery of UG2 PGM ore at different proportions. Optimal conditions for single collectors were determined, resulting in a cumulative copper recovery rate of at least 95%. Additionally, improved recovery rate was determined at the SIBX: DTC 90:10 proportion.

The experimental setup was designed to conduct batch rougher froth flotation tests by transferring a milled slurry into a mechanical batch flotation cell (Denver D12). The slurry volume was adjusted using distilled water to achieve a solids concentration of 34% (wt./wt.). The impeller speed was maintained at 1200 rpm, with a conditioning time of 2 minutes. Airflow was consistently set at 10.5 L/min, which is 50% of the maximum capacity of 21 L/min, across all tests. SIBX, DTP, and DTC reagents were freshly prepared each day to minimize the potential for decomposition, with an initial concentration of 1 g/100 mL for subsequent dilution. The frother, depressant, and activator dosages were kept constant throughout the experiments. Xanthate was used at varying dosages of 40, 60, 80, 100, and 120 g/ton in combination with SIBX: DTP/DTC blends at ratios of 50:50, 70:30, and 90:10. In overall, three concentrates (RC-1, RC-2, and RC-3) were collected at flotation times of 3, 7, and 20 minutes, respectively, by scraping the froth every 15 seconds into a collection pan (as shown in Figure 1). The slurry level was maintained by adding distilled water to the flotation cell. Concentrates (RC-1, RC-2, and RC-33) and rougher tailings (RT) were filtered, dried, and weighed before being analyzed using ICP-OES for the solid products. This procedure was consistently followed for all experiments.

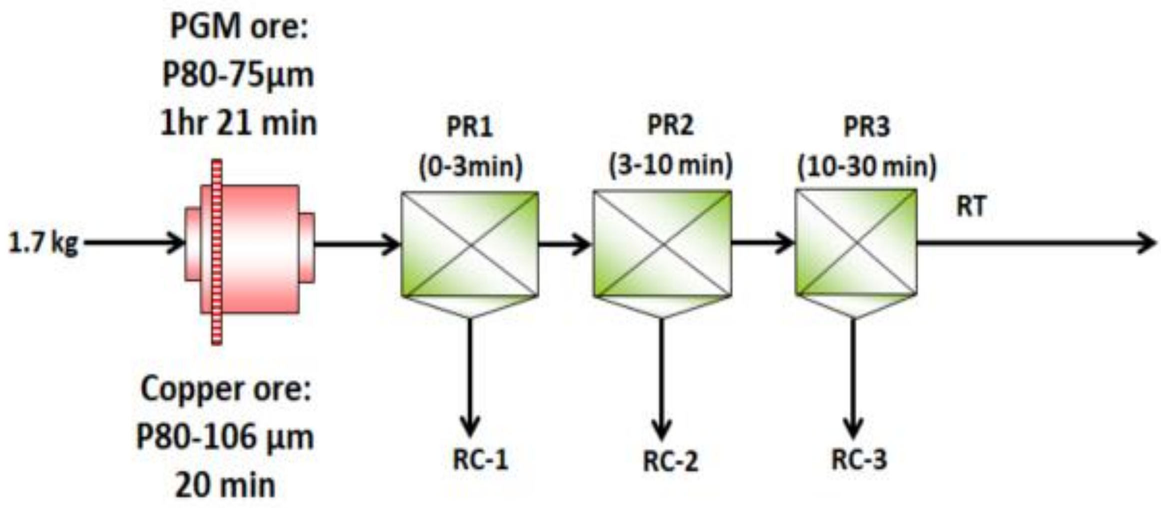

Figure 1: Flotation flowsheet for PGM and base metal ore testing

This study demonstrated the effectiveness of optimizing collector reagent usage in the flotation of PGM and base metal ores. Phase 1 flotation results indicate that the thiol xanthates tested (SIPX, SIBX, PAX, and SEX) were effective for both base metal (BM) and PGM ores, achieving high cumulative recoveries (above 80%) with increased dosages. Among the four xanthates, SIBX consistently outperformed the others. However, Phase 2 flotation results revealed that the UG2 ore tested is of low grade. The highest recovery rate was attained using 120 g/t SIBX at 37%, followed by 120 g/t DTP at 32% and 120 g/t DTC at 31%. These results demonstrated that SIBX exhibited the highest selectivity, attributed to its strong chemisorption onto sulphide mineral surfaces. DTP showed moderate selectivity, ranking below SIBX but above DTC. DTP’s partial selectivity can be explained by its formation of less stable metal complexes compared to SIBX, resulting in slightly lower flotation efficiency. DTC exhibited the lowest selectivity, which, according to literature, is due to its tendency to act as an over-collector, targeting both valuable and gangue minerals, thereby reducing concentrate grades.

Based on the observed trends, selectivity can be ranked as follows: SIBX > DTP > DTC. Among the three blends tested, the SIBX combination improved the recovery rate by at least

3%. Literature suggests that even a 1% improvement can significantly impact the valuation of a mining operation. The tests also indicated that a 70:30 ratio provided the optimal balance for enhancing overall flotation efficiency. This improvement is attributed to the synergistic interaction between SIBX's strong collecting ability and DTP's selective adsorption properties.

Keywords: UG2 ore, Optimisation, Flotation, Collector reagents, Co-blending, Recovery rate

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