

Mineral Processing

**A LABORATORY PROTOCOL TO EVALUATE POTENTIAL CHEMICAL INTERFERENCES
IN FLOTATION CIRCUIT APPLICATIONS**

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ABSTRACT

Some non-flotation chemicals are added to flotation circuits directly and indirectly to control issues such as scaling and dust in other areas of the operations. Since dosage levels are generally not high, a standard laboratory float test may not be able to determine the effect of a specific chemical on the productivity of the flotation circuit. This paper presents a laboratory testing protocol that uses kinetic float studies to test the effect of normal to extreme doses of antiscalant and dust chemistries (5–100 g/t). Laboratory results indicate that this protocol helps to predict potential interference by a particular chemistry on the flotation circuit.

KEYWORDS

Chemicals, Flotation, Interferences, Kinetics

INTRODUCTION

From a chemical perspective, flotation is a very complex system involving more than the reagents used for flotation. Along with collectors, frothers, modifiers, suppressants, and activators, there can be antiscalants for water treatment, dust suppressants used in the mining process upstream of the flotation circuit, residual flocculants from recycled thickener overflows, grinding aids, and many other types of chemicals that are added upstream of a flotation circuit. Although these other chemicals are usually used at very low doses, it is important to know if they affect the flotation process detrimentally in the event of a spill or a build up from recycled water.

Laboratory flotation testing of these chemicals characterizes their effects, but testing at expected doses in the float can mask the effects of the chemicals in the plant. Also, simple tests that do not measure the kinetics of flotation do not reveal the effects the other chemicals have on the flotation circuit. Thus, a new flotation protocol was needed to expose the full effects of chemical additives and to assist in choosing the chemical with the lowest potential for a negative effect.

FLOTATION KINETICS

Measuring recovery kinetics in a laboratory flotation cell is a well-established procedure: analyzing concentrates taken in a timed sequence to determine the recovery rate of individual cells in a flotation circuit. The recovery from the early flotation cells are a true measurement of how well a flotation chemical is performing. The principles of kinetics can be mathematically determined by the following functions (Houston, 2006):



$$R = C e^{k[A][B]} \quad (2)$$

where A is the positively charged chemical ion, B is the negatively charged chemical ion, AB is the reaction product of the two ions, R is a measure of the speed of the reaction, C and k are rate constants, and [A] and [B] are concentration values of the respective chemical ions. In flotation, the kinetics equation shows that

kinetics are driven by the concentration of the sulphide particle (A^+) and the interacting chemical (B^-), which is the collector, activator, or suppressant in an isothermal system. Since the sulphide particle concentration (sulphide grade and percent solids) is a constant, flotation kinetics are determined solely on the concentration of the interacting chemical.

The kinetics equation is the basis for establishing selectivity. The reaction with the fastest kinetics will dominate over all other reactions. The bigger the difference in kinetics, the more selectivity is possible. An example is copper/zinc separation. Finding a collector that has a strong kinetic reaction with copper minerals while showing a weak kinetic reaction with zinc minerals is the best for copper/zinc separation in a flotation circuit. However, if you increase the concentration of the collector sufficiently, the copper flotation kinetics will level off (all the copper minerals have been reacted with the collector) while the zinc kinetics will continually increase. Therefore, finding the optimal collector and collector concentration is the key to gaining the best copper/zinc separation.

A significant change in the physics of flotation can also affect recovery. A non-flotation chemical might not interact with the particle or the collector chemistry at all, but could change the bubble characteristics, which would affect the mechanics of getting a recovered particle separated from the slurry. Chemicals with surfactant characteristics fall into this category. The kinetics equation can quantify these effects as well.

CHEMICAL INTERFERENCE

Three basic types of chemical species exist in a flotation circuit: positively charged, negatively charged, and neutrally (zero) charged. Generally, sulphide particle surfaces hold a positive charge, so any other chemical holding a negative charge (such as collectors) will react with them according to their reaction kinetics. Other negatively charged chemicals can only interfere with the collectors if they react with reasonably close kinetics to the collectors. This is the basis for selectivity in “what reacts with what”.

A common example of selective reactions is the large differential in the kinetics of hydroxide ions at pH 9 compared to a sulphide collector for chalcopyrite and pyrite. At pH 5, the collector dominates over the hydroxide ion for both the chalcopyrite and the pyrite minerals. But at pH 9, the hydroxide ion concentration has increased by 10,000 times. The kinetics of the hydroxide/pyrite interaction becomes much stronger while the hydroxide/chalcopyrite kinetics remains weak. The result is the collector remains dominant on the chalcopyrite, while the hydroxide dominates on the pyrite. The chalcopyrite continues to float while the pyrite is now suppressed.

Too much of one chemical relative to another can affect selectivity as well. If the collector concentration is increased enough, the collector/pyrite kinetics will begin to dominate over the hydroxide/pyrite kinetics and selectivity between chalcopyrite and pyrite will be reduced. If the pH is raised over 12—increasing the hydroxide concentration by another 10,000 times—the hydroxide/chalcopyrite kinetics becomes strong enough to outperform the collector/chalcopyrite kinetics, suppressing the flotation of the chalcopyrite. The conclusion is balance gives the best selectivity and more is not always better.

Neutrally charged chemicals do not directly affect collector/particle interaction, but their characteristics can affect the flotation process in different ways. The mechanics of flotation involve selectively moving valuable particles out of the slurry into the froth on the surface of the slurry. Any chemical that can interfere with, or even enhance, these mechanics can be detrimental. A chemical that has frother absorption characteristics could significantly reduce the froth and thereby prevent good separation. However, a chemical that enhances the froth could increase entrainment of gangue minerals. The dosage at which these effects become problematic can be determined using the same kinetic study testing procedure used for collector interference chemicals.

The types of chemicals that exist in a flotation circuit are not limited or designed to improve the flotation process. These include negatively charged such as antiscalants for water treatment, dust

suppressants from the mine, and residual flocculants in recycled water from thickener overflows. They all have the ability to interfere with the flotation process. Laboratory tests can attempt to determine the extent of their interference. However, a bulk float test at expected doses may show no effect. To accurately measure the potential risk of having these chemicals in a flotation circuit, it is best to evaluate flotation kinetics in the early stages of flotation and to force the reaction kinetics by running high dosage tests. This methodology will show if there is an effect and if so, how severe the effect is. High-dose will tests also identify the effects of a spill of the chemical into the flotation system.

LABORATORY PROTOCOL

To find the true effects of non-flotation chemistries on a flotation circuit, a laboratory protocol should consider flotation kinetics under extreme conditions. First, a standard kinetics flotation protocol with timed concentrate collection is used (Jowett & Safvi, 1961). Second, a series of flotation tests are carried out, testing ever increasing dosages of the non-flotation chemical. Doses should range from as low as 5 grams per tonne (g/t) (representing a typical concentration in a flotation circuit) to as high as 500 g/t to force the kinetics to indicate any possible interference with flotation.

The standard kinetics flotation protocol used at Hudbay's Flin Flon Concentrator for copper recovery testing collects three concentrates at the 1, 2.5, and 4.5 minute marks that are analyzed separately. Some collector is added between concentrates. These concentrates represent the roughers of the copper flotation circuit. The chemicals being tested are added to the grind to represent their presence in the slurry upstream of flotation. Table 1 outlines the laboratory procedure.

Table 1. Laboratory procedure for chemical interference testing protocol

Grinding conditions		Flotation conditions	
Ore	1,000 g	Ore	1,000 g
Water	480 mL	Float cell	3.5 L
Grind time	20 min		
Expected K_{80}	68 μm		
Reagent addition	1 drop 3418A		

Copper float	Time (min)	Slurry conditions			Reagent addition		
		pH	Eh (mv)	Temp ($^{\circ}\text{C}$)	Frother MIBC (drops)	Collector 3418A (drops)	Collector TNC312M (drops)
Initial Conditions		7.50	170.9	29.5		1	
Aerate	5.0						
Lime	2.0	10.51					
Condition	2.0					1	1
Concentrate 1	1.0				1		
Condition	2.0	9.47	107.8	30.1			1
Concentrate 2	1.5				1		
Condition	2.0					1	1
Concentrate 3	2.0	8.80	44.8	28.7	1		

Table 1. Laboratory procedure for chemical interference testing protocol

Additions of a non-flotation chemical were carried out in sequence tests from a low dose (5 g/t) to a high dose (100 g/t) with recoveries plotted against time and copper grade. Grade is important too, because the chemical might actually enhance recovery but detrimentally affect grade. As the process involves a copper/zinc separation, copper recovery is also plotted against zinc recovery.

A dust suppressant was tested using this protocol to determine its effects on the copper flotation. The dust suppressant is a wetting agent that can be used at drop points along conveyor belts to control dust. As a wetting agent, it reduces the surface tension between the water and the particle, allowing the particle to stay wet for extended periods. This also allows for significantly less water needed for dust control, important where water is scarce. An average concentration of the dust suppressant relative to the ore tonnage is about 7 g/t. Tests were conducted in duplicate to estimate the range of variance in the testing procedure due to inconsistencies in the mechanics of the test.

In flotation, it is thought that such chemicals can create changes in the flotation mechanics of the bubbles, but the critical dose that will cause the change is unknown. The act of grinding treated ore could very well nullify the wetting capabilities of the dust suppressant and needs to be incorporated into the standard test conditions. Conducting kinetic tests using dosages of up to 100 g/t will demonstrate the true effects of the dust suppressant in a flotation circuit.

Due to time constraints a full range of test doses was not used. Test dosages were only set at 0, 5, 25, and 100 g/t. Each test was conducted in duplicate to make note of the test variances.

LABORATORY RESULTS

Visual remarks about the flotation tests indicate that the dust suppressant does have a frothing capability. Frothing bubbles begin to be noticeable in the 25 g/t tests during the pre-aeration stage of the test. At 100 g/t, the bubbles became fairly stable and caused concentrate to overflow from the cell during the aeration stage. This is a significant effect of the dust suppressant.

All the data used for the graphs is averaged over the duplicate tests. Figure 1 plots the copper recovery over time. The variation between the two 0 g/t tests bracket the duplicate tests for 5 and 25 g/t, so that recovery is not overly affected up to 25 g/t. The frothing effect visually observed at 25 g/t is not severe enough to create measurable problems in the flotation test.

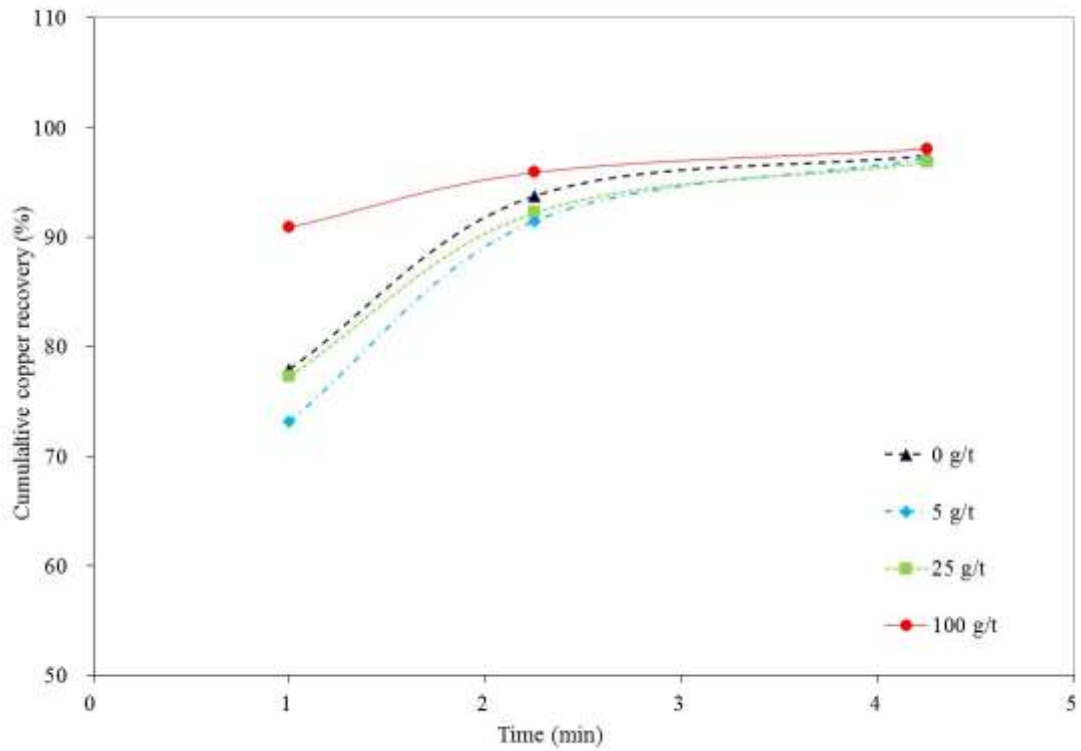


Figure 1. Cumulative copper recovery vs. time curves for dust suppressant doses 0–100 g/t

When the dosage is increased to 100 g/t, the full effect of the frothing capabilities becomes evident. Copper recovery is significantly increased in the first concentrate due to concentrate frothing over the cell during the aeration stage. This is confirmed by Figure 2, which shows a significant increase in mass pull at 100 g/t. The differences between 0 g/t, 5 g/t and 25 g/t for copper and mass recovery are insignificant, while the 100 g/t tests show a very significant shift.

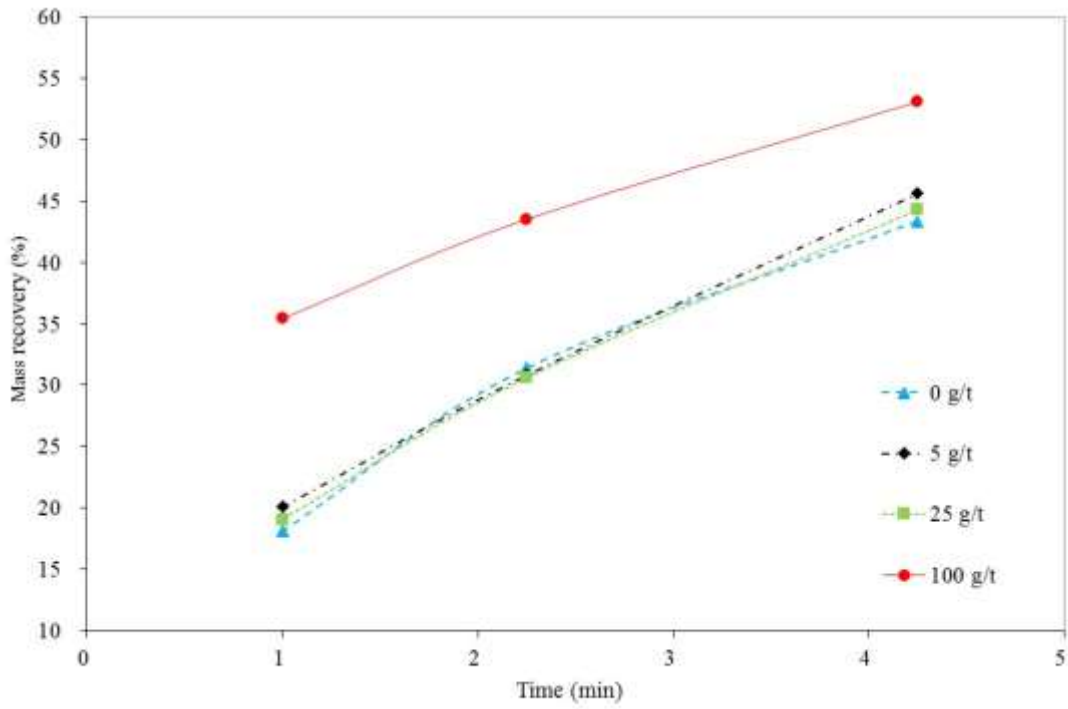


Figure 2. Mass recovery vs. time for dust suppressant doses 0–100 g/t

Increased recovery alone would be considered an improvement. However, as shown Figure 3, copper grade is severely affected. Copper grade is reduced by almost 40% in the first concentrate in the 100 g/t dose tests, indicating the frothing effect of the dust suppressant is very detrimental to the selectivity of the copper minerals.

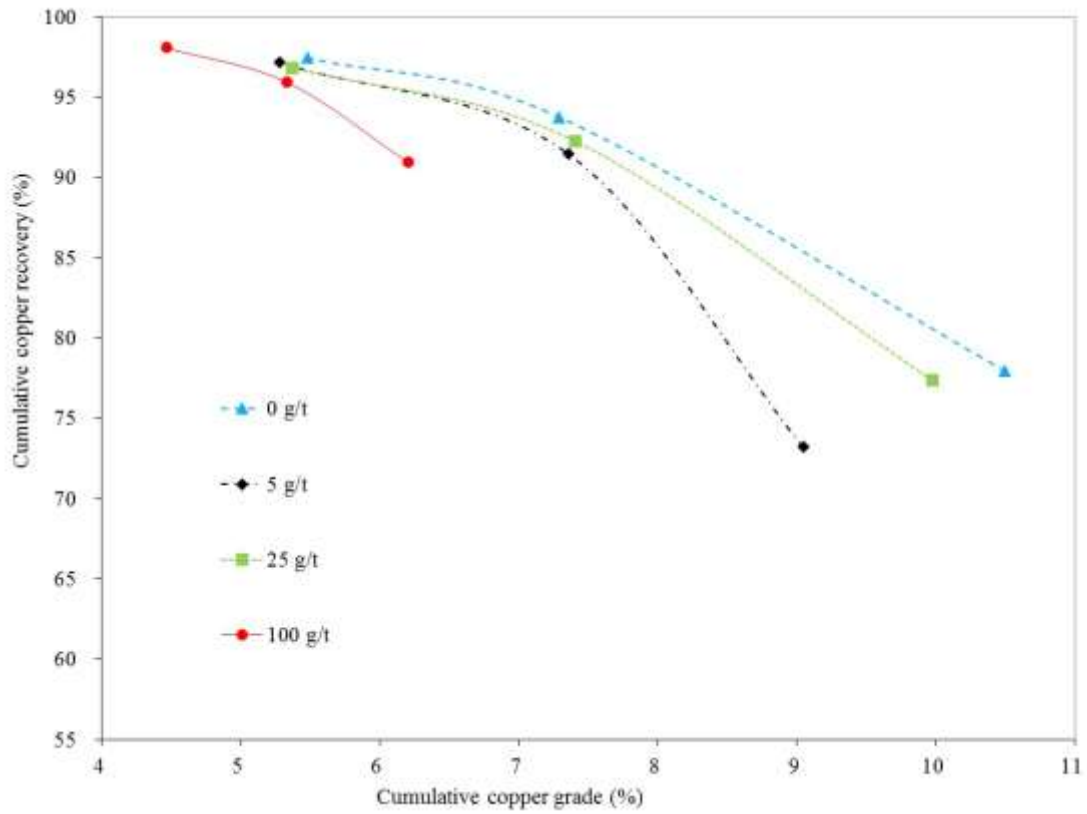


Figure 3. Cumulative copper recovery vs. cumulative copper grade for dust suppressant doses 0–100 g/t

This effect is reinforced in Figure 4 where copper recovery is plotted against zinc recovery. Copper/zinc separation is the key measurement of selectivity in a copper/zinc mill. The 5 g/t and 25 g/t doses do not affect the copper/zinc separation significantly, but the 100 g/t dosage does.

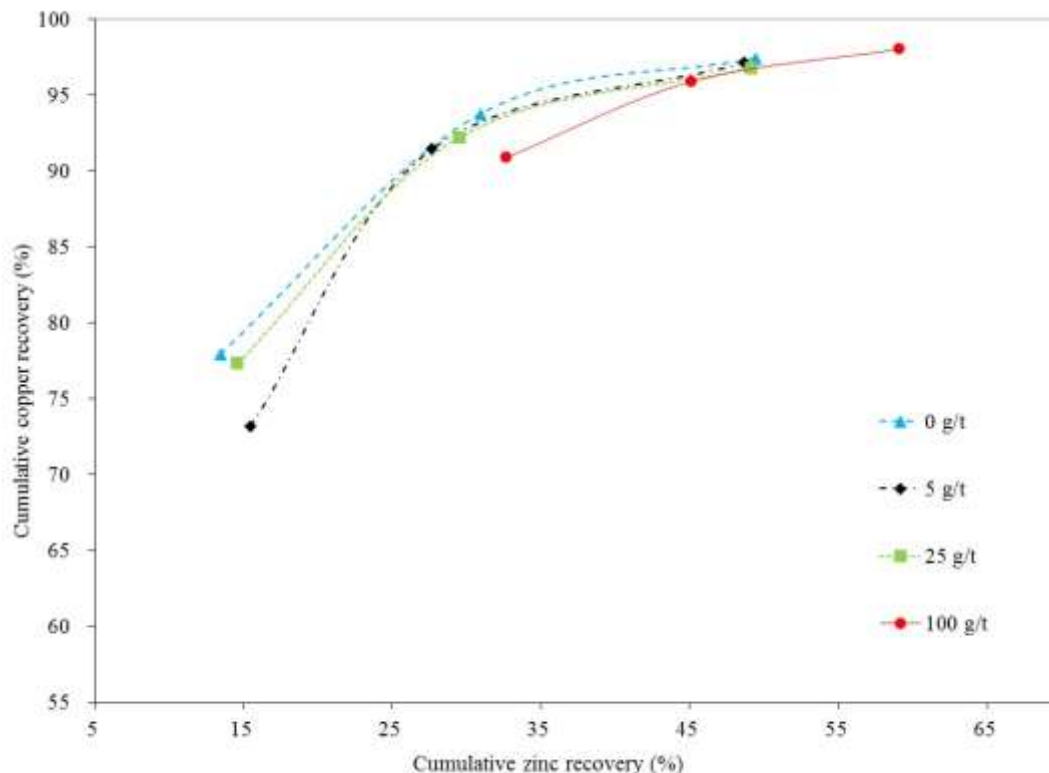


Figure 4. Cumulative copper recovery vs. cumulative zinc recovery for dust suppressant dosages 0–100 g/t

CONCLUSIONS

Based on the testing performed at Hudbay, the use of the wetting agent as a dust suppressant upstream of the flotation circuit is safe up to 25 g/t. At higher dosages, the chemical's frothing characteristics start to detrimentally affect the frothing mechanics of the float. This leads to severe selectivity reduction between the copper and zinc minerals. Control of dust suppressant dose use through process control methods is recommended to reduce risk to the downstream flotation process. For spills that create higher than 25 g/t doses on the ore, balancing the dust suppressant concentration with reductions of frother additions may control over frothing in the flotation cells.

Knowing the chemical make-up in your flotation circuit is critical to optimizing recovery and concentrate grade. By determining the kinetic interferences of non-flotation chemicals, you can reduce the risks, choose the right chemicals and use care in limiting their concentration in the flotation circuit.

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REFERENCES

Houston, P. L. (2006). *Chemical kinetics and reaction dynamics*. Mineola, NY: Dover Books.

Jowett, A., & Safvi, S. M. M. (1961). *Minerals beneficiation - Refinements in methods of determining flotation rates*. Denver, CO: AIME Transactions.