

Investigation into Lime Optimisation and Control in Gold Recovery

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Abstract

In most gold recovery processes; the pH is controlled by regulating the flow of calcium hydroxide into the processes. In this study, the quality of hydrated lime ($\text{Ca}(\text{OH})_2$) was investigated by determining how it is affected by the slaking process and hydration parameters, like the lime-to-water ratio, the slaking temperature and the agitation rate. The investigation was conducted by preparing samples and determining the available lime, the reactivity of lime with Rand Water and process water, lime addition test and rate of increasing alkalinity and, lastly, by investigating flocculants in the respective samples using an experimental design. It was concluded that a proper slaking process will result in an increase in particle surface area and create uniform particle distribution, resulting in higher reactivity. As the pH of the system ranges from 0 to 14, the choice of flocculants ranges from non-ionic to highly anionic.

Keywords:

Process optimisation, quality, industrial engineering

1. Introduction and Background

Plant XYZ is a surface operation located in the Free State, South Africa. The plant recovers gold using conventional methods and gets its ore feed from reclamation sands and old tailings dumps. The plant treats on average 350 000 tons of ore received from various mine tailings facilities, namely, Gun20, Gun38 and Tura. The plant toll treats material from sun tailings although the tonnage contribution is usually less than 10% of the total tonnage treated. The volumes processed by Plant XYZ requires that two to three road tankers of powdered lime be delivered per day at a cost of R2/kg, which amounts to a cost ranging between R100 000 and R150 000. This is essentially 10% of the total operating cost. Consequently, lime addition requires optimisation and tight control. The rate of formation of stabilized compounds, which increases with the curing period, resulted in the reduction of the LL ratio, defined as the ratio of lime leached to the total lime added (Moghal et al. 2020). Losses can be seen in excess pH and high variations of the pH in the streams. An increase in cost is also a function of high lime demand from the reclamation sites. The decrease in the pH that was experienced in production year 2019 was influenced by several factors, of which some are being studied separately and are not the subject of this article. A gradual decrease in the pH of the feed material has affected cyanidation and thickening processes owing to the inconsistent control of lime addition and, consequently, the pH in the process.

The cost of lime was high over the period May 2019 to September 2019 owing to a high demand for lime in the feed and high variations of the pH. The lime consumption was above target over the period May 2019 to September 2019, which was a result of the high lime demand and the pH variations. At Plant XYZ, lime is used to regulate the pH of the ore in the thickener launder feed pipe to help the flocculants quickly facilitate settling in the thickeners. Lime is also added to control and maintain the slurry pH of 10.5 to assist in preventing the loss of cyanide owing to hydrolysis

during the leaching process. Lime is added prior to thickening, and the thickener feeds both the leach and the carbon-in-leach (CIL) circuits. In order to control the pH in the leach and the CIL circuits, a consistent control of pH is needed prior to thickening. The inconsistent control of lime addition results in unjustified lime consumption. Therefore, a study was undertaken to investigate lime optimisation and control in gold recovery.

2. Literature Review

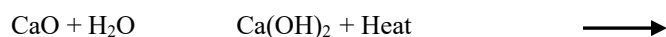
Reaction kinetics of lime

Lime is used in various industries, including hydrometallurgical industries, for pH control during the process of flotation, the neutralisation of acid solutions and the control of pH within the cyanide leach process (Ritchie 1988). Lime is produced by limestone calcination, which is an endothermic chemical reaction that releases CO₂ (Smadi et al. 2023). Usually, lime is slaked prior to usage. Slaked lime is the most preferred form of lime (Zanin et al. 2019). Ritchie (1988) state that “even when quicklime is added to a solution, it seems very likely that partial slaking of lime will occur first”. They further state that the rate at which quicklime is hydrated increases with an increase in lime surface area and the temperature at which the lime is slaked. The reaction of lime with water is diffusion controlled and depends on the degree of supersaturation of the liquid phase with the Ca (OH)₂.

Ritchie (1988) conducted their research using a relatively high purity lime (CaO) in the form of rotary discs and powdered lime samples. The discs of CaO were prepared by passing the powder in a pallet press. Thereafter, the discs were heated. The effect of the pressure used in the making of the discs and the heating temperature and time were investigated. It was found that the optimum pressure was about 40 Mpa for a disc with a diameter of 12.8 mm and that pressures greater or smaller than this will result in a disc that is loose or probably fragile. It was also found that when a disc was heated for 40 hrs at 1 100 °C, its mechanical strength improved, and the disc did not break when rotated in solution. The discs were mounted in a stainless-steel holder such that only one face of each disc was exposed. The holder was exposed to one shaft, coaxially with the discs, which could be rotated in the reactant solution at a controlled speed and 1 500 rpm. The amount of lime present in the solution was determined through pH testing. The slaking of the lime powder samples was followed by a process of measuring the temperature rise of the reacting system in a guild calorimeter, which was calibrated. A reactant liquid of 200 mL was placed in a dewar, and an accurately weighed amount of lime, namely, 0.2g was added. The mixture was stirred by means of a paddle stirrer rotating at 147 rpm. The sample was chosen so that the temperature rise was large enough to be measured accurately, but not so large that heat losses from the system were significant.

Factors affecting the efficiency of the slaking process and the quality of hydrated lime

Most minerals develop a positive surface charge under acidic conditions and a negative charge under alkaline conditions (Singh and Hassibi 2007). Given that minerals could change from negative to positive charges at a particular pH, the attractions can be manipulated by adjusting the pH (Hassibi 1999). Ca(OH)₂ is a strong alkali and when it dissolves, it contributes ions that adsorb onto the mineral surfaces (Hassibi 1999). Lime slaking occurs when lime is reacted with water to form hydrated lime. The following is a chemical formula for slaked lime:



The atomic weight for the above formula is Ca = 40, O = 16, H = 1. Therefore, 56 units of lime plus 18 units of water produces 74 units of hydrated lime. The ratio of hydroxide to calcium is therefore $74 \div 56 = 1.32$, which means that 1 kg of CaO and 0.32 kg of water will produce 1.32 kg of hydrated lime Ca (OH)₂. The minimum amount of water required to produce hydrated lime is 0.32 kg, according to the above equation. The composition of hydrated lime therefore contains 75.7% CaO and 24.3% H₂O [3]. The hydration of lime is an exothermic process that releases a great amount of heat.

The following factors affect the efficiency of the slaking process and the quality of hydrated lime:

- Slaking temperature
- Lime-to-water ratio
- Quality of the slaking water
- Water temperature

2.3 Slaking temperature

According to the writings of Hassibi (2007), temperature is one of the most significant factors that affects the slaking process and the quality of the final hydrated lime. Theoretically, the fineness of the hydrate particles is proportional to the temperature of the slaking process. Consequently, the larger the surface area available for the reaction to occur, the higher the rate of reaction, which results in less consumption of lime (Hassibi 1999). However, if the particles of the hydrated lime are too fine as a result of the temperature, they tend to develop hotspots within the lime slurry. When the hotspots form, they cause the hydrate particles to crystallise and agglomerate, forming larger particles with a reduced surface area. In practice, when the temperature is maintained below 80 °C during the slaking process, the agglomeration and crystallisation of the hydrate particles is prevented (Hassibi 1999).

2.4 Lime-to-water ratio

The lime-to-water ratio affects the slaking time by affecting the slaking temperature. This means that the greater the quantity of water, the less the slaking time. However, controlling the lime-to-water ratio does not guarantee a constant temperature. The temperature of the slaking process varies with varying water temperature, the quality of the water and the quality of the lime that is used (Hassibi 2007). Slaking tests with different lime-to-water ratios (theoretical water 0.32 kg and 10 x theoretical amount of water) show a significant difference in the settling rate of lime, which proves that using excess water will result in finer particles while the theoretical amount of water will result in a much faster settling rate (Hassibi 2007).

2.5 Quality of the slaking water

According to the writings of Hassibi (2007), the type of water that is used during the slaking process has a significant effect on the final quality of the slaked lime. There are different chemicals in water that affect the slaking process either negatively or positively. It was found that the rate of hydration of lime is faster in the presence of high concentrations of chloride ions and slower in the presence of high concentrations of sulphide ions (Gheevvarhese 2002). The chemicals found in water are as follows:

2.5.1 Chlorides

The slaking process is affected by the chloride content of water. Chloride has a positive effect on the slaking process in that it accelerates slaking. Water that contains up to 10 000 ppm chloride can be used in the slaking process (Hassibi 2007). According to Ojeda et al. (2023), the chlorides contained in the water by hydration increased the solubility of lime, in contrast to the sulfates and magnesium carbonates, which acted as inhibitors of reactivity

2.5.2 Sulphites and sulphates

These chemicals have a substantial impact on the slaking process. Sulphites and sulphates result in the formation of a coating over the particles of lime, which prevents the hydration of the lime, and this affects the slaking process (Gheevvarhese 2002). According to research, the content of these chemicals in water should not be higher than 500 ppm (mg/l). Table 1 compares the effect of the water chemistry on the slaking time/temperature in respect of deionised water, tap water and industrial water, respectively.

Table 1. Effect of the chemistry of water

Slaking time (min)	Deionised water	Tap water	Industrial water with 5 000 ppm sulphates and sulphides
1	68.5 °C	64.9 °C	56.4 °C
2	70.1 °C	68.3 °C	61.1 °C
3	70.0 °C	70.1 °C	63.6 °C
5	70.1 °C	70.1 °C	65.1 °C
6	70.1 °C	70.1 °C	66.4 °C

2.6 Factors that affect the proper functioning of a pH control system

Singh and Hassibi (2007), list the major factors that affect the proper functioning of a pH control system. These factors include the reactivity or the neutralisation capacity of hydrated lime, the density of hydrated lime slurry, the availability of the system to supply hydrated lime and a reliable pH measurement. They further state that the reactivity and the density of hydrated lime are the two major issues that affect the day-to-day operation of a pH control system; the other factors are system design issues. According to Sarfraz et al. (2022) the effect of culture pH on cell growth, CO₂ fixation ability and C-PC production can be controlled by CO₂ feeding.

Quality of the lime

Singh and Hassibi (2007) state that there are three primary factors that determine the quality of lime, namely, the percentage of lime available versus the lime content, the type of calcination method (that is, soft-burnt or hard-burnt lime) and the quantity of air-slaked lime. They further state that the efficiency of lime used per ton is affected by impurities and changes in the lime content. The different types of lime produced from the calcination process are classified as high reactive lime, medium reactive lime and low reactive lime (Singh and Hassibi 2007). According to Singh and Hassibi (2007), the water temperature affects the slaking temperature. When the slaking temperature requirement of a system is 76 °C, the water temperature should be 1.7 °C for high reactive lime, 10 °C for medium reactive lime and 21.1 °C for low reactive lime.

Singh and Hassibi (2007) conducted two slaking tests using the same lime and water. On test “A”, the slaking water was heated to 24.9 °C; there was a temperature rise of 48 °C, which indicates a highly reactive lime. Test “B” was done with an initial temperature of 35.2 °C; there was a temperature rise to 52.9 °C. The findings are indicated in Figure 6. The findings suggest that the impact on the particle size was noticeable during the tests even though the temperature rise was not great.

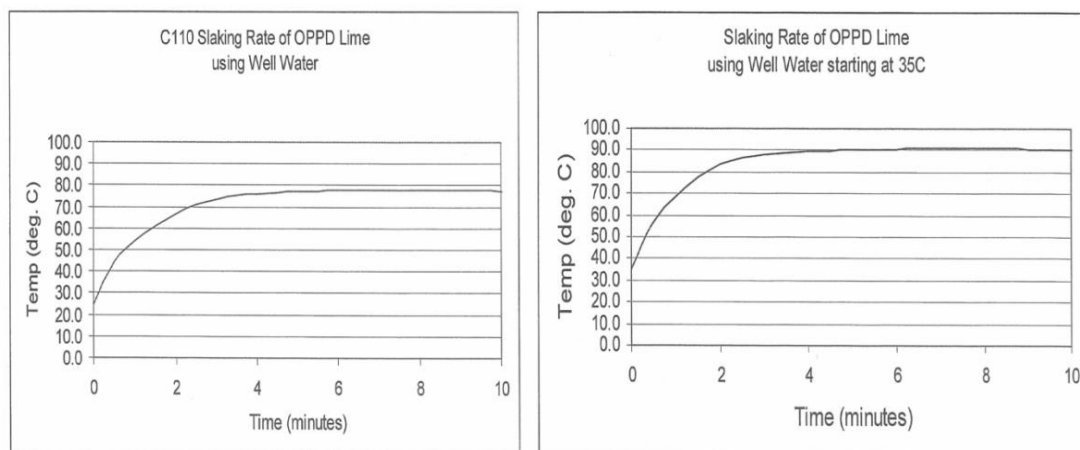


Figure 1. Slaking rate of OPPD Lime

2.5 Factors affecting flocculation

The main purpose of flocculants is to facilitate the settling of particles, ensuring that the coagulated material is brought together into larger aggregates. There are different types of flocculants and, owing to their chemistry, flocculants can be non-ionic, anionic or cationic (Pillai 1990). Pillai (1990) states that many operations use neutral (non-ionic) or anionic flocculants. Non-ionic flocculants are long-chain polymers of polyacrylamides that are created from acrylamide monomer. Acrylamide-acrylate copolymers are anionic because they have negatively charged carboxylate groups within their polymer. The antitonicity within the polymer is determined by the proportion of sodium acrylate to acrylamide. A high ratio of sodium acrylate will result in a flocculant with a high charge (Pillai 1990).

Pillai (1990) lists several factors that can affect flocculation. The primary factors are polymer type, ionic strength, water pH, slurry solids, flocculant dilution, shear, molecular weight and process conditions. These factors, individually and collectively, have an influence on the type of flocculant that will provide optimum performance and addition points. The flocculation process is influenced by many factors, including: the pH (Agbovi and Wilson, 2018) and temperature of the system, dissociated salt concentrations, stirring strength and time, particle size, molecular weight (Cobbedick et al. 2014), dose (Borán et al. 2010) and the chain's ionicity (Mpofu et al. 2003).

2.6 Effect of pH, slurry solids, polymer type and flocculant dosage

Pillai states that the “pH of the slurry plays an important role in the choice of flocculant. As the pH of the system ranges from 0 to 14, the choice of flocculant ranges from non-ionic to highly anionic”. Typical pH ranges over which flocculants of varying anionic polymers find general application are represented in Figure 7. As seen from Figure 7, at a pH of 4 and below, non-ionic polymers show the greatest activity. At this pH range, anionic polymers are coiled up just like the non-ionic polymers, but they show very little activity. The reason for this is that in anionic flocculants, the amide groups are replaced by the more inert (at low pH) carboxylate groups, which reduces the number of hydrogen bonding sites available in the flocculants. Thus, non-ionic flocculants perform better at a lower pH range. As the pH increases, the carboxylate groups of the anionic flocculants are ionised, and uncoiling continues until the polymer is fully uncoiled and active. In the same environment, non-ionic flocculants maintain their configuration (Pillai 1990). The activity of anionic flocculants increases with slurry pH, and at a pH range of 6 to 8, moderately anionic flocculants will show better activity than non-ionic flocculants (Dwari et al. 2018). The performance of non-ionic flocculants is the same at this pH as in the lower pH range. At pH levels over 9.5, highly anionic flocculants perform the best since highly anionic flocculants are fully uncoiled and at the peak of activity at high pH levels. During tests, Pillai noticed that the activity of non-ionic flocculants decreased at a higher pH. Pillai notes that at a higher pH, it is known that the polyacrylamide in non-ionic flocculants can hydrolyse, resulting in a drop-in activity.

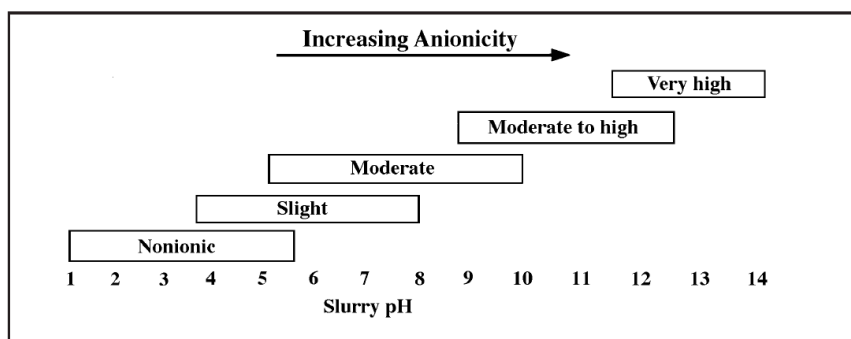


Figure 2. Effect of pH on Flocculant Selection

Arjmand et al. (2019) state that the long chains of hydrocarbon organic polymers are widely used for flocculation which assists with settling of fine particles. These long chains of hydrocarbon organic polymers may be found in various forms, which can be anionic, cationic or non-ionic. Arjmand et al. (2019) further state that the performance of the flocculation process is affected by properties of the flocculants (molecular weight, charge density and functionality) and slurry properties (particle size, surface charge, solution composition, pH and ionic strength).

Arjmand et al. (2019) conducted batch settling tests within a 1 000 mL graduated cylinder. The flocculation tests were conducted by preparing a slurry with the desired solids content and then adding a flocculant solution of known concentration immediately using the graduated cylinder. The slurry and the flocculant were mixed gently by inverting the cylinder four times prior to commencing the settling process.

A homogeneous stock solution of anionic polyacrylamide flocculants was prepared every day and used. The slurry pH was adjusted by means of sulphuric acid (H_2SO_4) or sodium hydroxide (NaOH) solutions prior to the addition of the flocculants. In the laboratory flocculation tests, the effect of flocculant dosage (5–20 g/t solid), slurry solids concentration (3–12%), pH (4–12) and flocculant dilution (0.05–1%) on the performance indicators, including settling rate (cm/s), turbidity of supernatant (NTU) and sediment volume (mL), were evaluated. A higher settling rate and lower supernatant turbidity and sediment volume are desirable (Weir and Moody 2003). A total of 33 experimental runs were conducted according to a randomised block design. The settling rate of particles was determined from the slope of the linear section of the interface position (mud line height) versus a time curve. After 2 minutes of settling, a calibrated turbidity sensor was inserted to 50 mm below the water level to measure the supernatant turbidity. The flocculated suspension was allowed to stand for 10 minutes, and the sediment volume was recorded.

The results from the tests conducted by Arjmand et al. (2019) indicate that slurry pH, flocculant dosage and slurry solids percentage have the greatest influence on the settling rate. The interaction between pH and flocculant dosage is

statistically significant (Arjmand et al. 2019). Thus, the effect of each of these variables on the settling rate depends on the value of each one. Slurry pH and solids content substantially influence the rate of particle settling. Arjmand et al. (2019) note that flocculation performance improves at a higher slurry pH and flocculate dosage and a lower slurry solids content.

Research Methodology

A case study and experiments were used to evaluate the current scenario at the organisation concerned representative sample of delivered lime was taken and divided into four portions. According to Creswell and Creswell (2017), researcher designed and conducted an experiment to examine treatment outcomes but used case study methodology to study how participants in the study experienced the treatment procedures. The experiment and survey are undertaken under a controlled environment (Baker, 2001). The samples were labelled sample A, sample B, sample C and sample D, respectively. Experiments were carried out with the labelled samples to determine the amount of lime in the respective samples. The amount of lime was determined by means of the acid-base titration method using hydrochloric acid (HCL) and sulphuric acid. A 1 g sample of each labelled sample was placed in a 1 000 mL conical flask, after which 100 mL of deionised water was measured and added to the 1 000 mL conical flask. The mixture was stirred for 20 minutes. The amount of excess HCL was titrated using a 0.5 M NaOH solution and 5 drops of the indicator phenol. The percentage of available lime in the sample was equivalent to 1 mL of HCL, that is, 1 mL HCL = 1% available CaO. Reactivity of lime with rand water and process water reactivity indicates the rate at which lime reacts with water. The rate at which the temperature rises is an indicator of how reactive lime is.

The test was conducted using rand water and process water. The following apparatus was used to determine the reactivity of lime with rand water and process water, respectively: a no. 7 mesh sieve (2.83 mm), a conical flask and a thermometer reading to at least 100 °C, a clock or a watch with a second's hand and a scale to weigh 50 g to ± 0.5 g. A measured amount of 170 mL water was placed into a thermos flask at the normal prevailing water temperature. Thereafter, 50.0 g of the no. 7 mesh quicklime was measured and placed into the same thermos flask. The mixture was then stirred for 20 minutes, and a measurement was taken of the temperature at 2-minute intervals. It was important to note the maximum temperature and the time it took to reach the maximum temperature. The results were used to construct a hydration curve of a temperature-versus-time graph. A lime addition test was performed to determine the rate of increasing alkalinity. The aim of this test was to determine how much lime is required to increase the pH of the feed material from acidic to alkaline (9-10.5). The rate of reaction was also measured. The reactivity rate was used to evaluate the lime addition. The test further determined how much lime is required to maintain the target value pH. This was done by determining the lime consumption to maintain the target pH. The test was conducted according to the following procedure:

An amount of 200 mL of the feed sample was placed in a 1 000 mL roller bottle, after which 1 g lime was added to the roller bottle. The sample was then bottle-rolled for 4 hours, after which 1 g lime was continuously added to the roller bottle until the target pH was reached. Once the sample reached the target pH, it was bottle-rolled for a further 8 hours in order to determine the consumption of lime within the 8 hours. A pH-versus-time curve was then constructed to determine the relationship.

Discussion and Findings

Reactivity of lime using process water and rand water

There is a relationship between the types of water used during the slaking process. The results of the rate of reaction between lime and water are shown in Figure 3

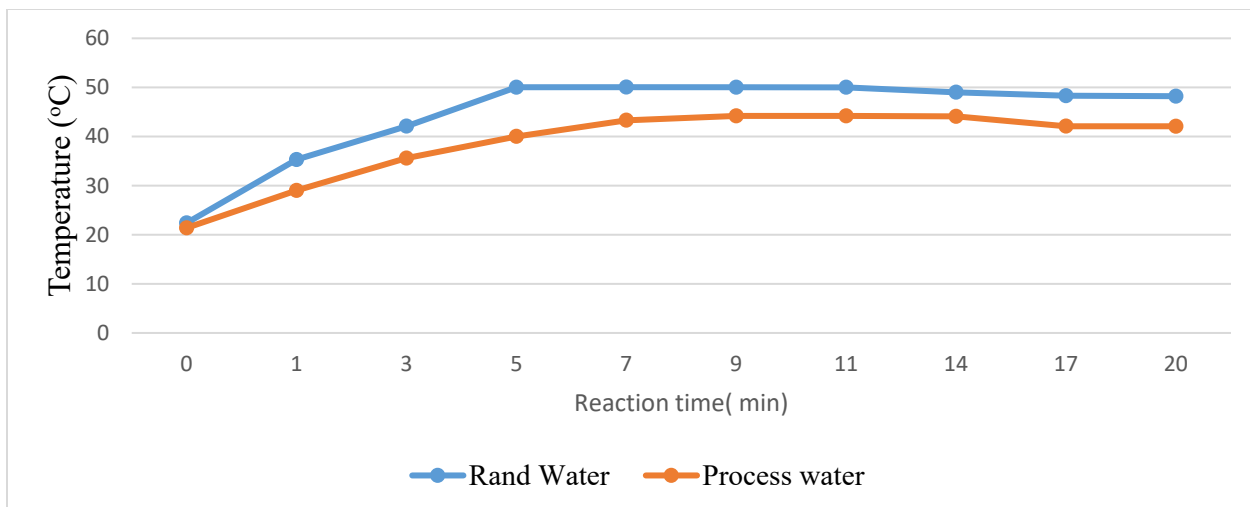


Figure 3. Rand water vs process water

In test 1, using process water, the initial slaking water temperature was 21.4 °C and the temperature rose to 35.6 °C in 3 minutes, indicating a highly reactive lime. The second test (rand water) was done with the same lime and water, with an initial temperature of 22.4 °C, and the temperature rose to was 42.1 °C. The results for rand water showed an increase in temperature of 6.5 °C when compared to Rand Water The test results indicate that the reactivity of lime is influenced by the quality of the water used in the slaking process. Rand water reacts much faster than process water. Normally, the commercial lime slakers in the industry operate using 3 to 4 parts of water for 1 part of lime. In this investigation, the water-to-lime ratio varied between 2:1, 3:1 and 4:1. Figure 8<shows the reaction curves with varying water-to-lime ratios.

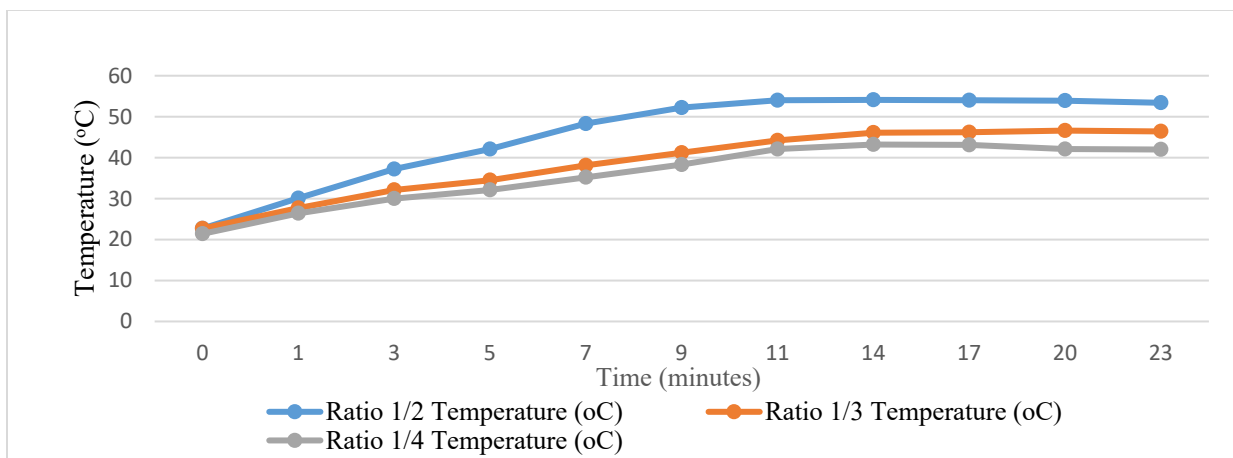


Figure 4. Varying lime-to-water ratio

The data indicate that the reactivity values stay the same within experimental error. There seems to be a tendency to higher reactivity values when smaller amounts than those prescribed by the standard test method are used, although too little work has been done to make conclusive deductions in this regard. However, the limited data are enough to caution that using smaller amounts when limited material is available for testing can produce misleading figures, that is, figures that reflect a higher reactivity of lime than is truly the case.

The data indicate that the temperature increase is the same when the ratio of lime to water is 1:3 and 1:4. When comparing the ratio 1:3 and the ratio 1:4, the increase in temperature is 2.1 °C. The temperature increase in the same tests when the ratio is 1:2 is between 5.1 °C and 7.2 °C, which indicates that the temperature is affected by the water

amount The density of the lime slurry is much higher (30% solids) when the ratio is 1:2 compared to when the ratio is 1:3 and 1:4 – the density of the lime slurry varies between 15% and 30% solids when the ratio is 1:3 and 1:4.

Process water contents

The quality of the water used during the slaking process influences the reaction kinetics of the slaking process. Figure 8 shows

the concentration of sulphates and chlorides in the water that is used for slaking lime. According to Gheevarthese (2002), the water used for the slaking process should not contain more than 500 ppm sulphates. The sulphates in the water slow down the reactivity of lime, which affects the quality of the slaked lime. On the other hand, the chlorides in the water increase the rate of the slaking process. Water that contains more than 1 000 ppm chlorides has a major influence on the reactivity of lime. It was found that the process water used at Plant XYZ contains more than 2 000 ppm lime and under 65 ppm chlorides.

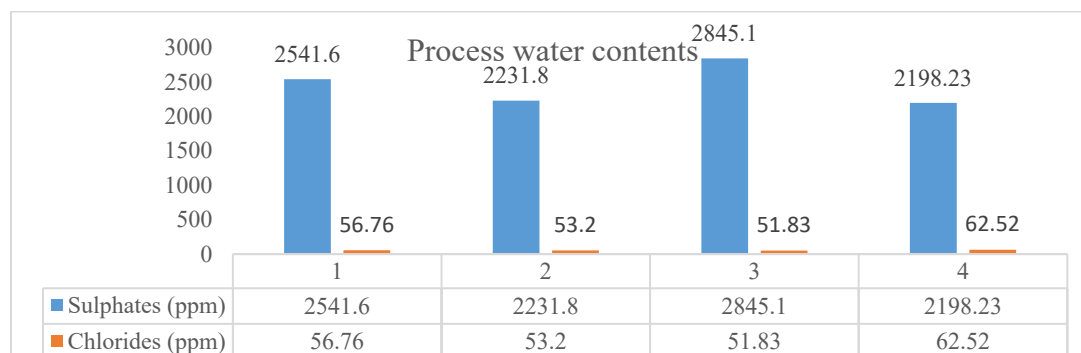


Figure 5. Sulphate and Chloride contents of Processed water samples

Lime transfer

Table 2 shows the amount of lime that is transferred at varying rotations per minute. A rotary feeder is used to regulate the amount of lime that is transferred from the lime silo to the mixing tank. The test was conducted using four different rotary intervals, keeping the time constant. The test pointed to a relationship between the time and the mass of lime transferred into the mixing tank. However, the aim of this test was to evaluate the amount of lime used per hour at varying rotations per minute. Changes in the rotary feeder rotations are influenced by the pH changes in the feed ore. The desired pH is 10.5 for cyanidation. However, there has not been a thorough study of the relationship between lime and the pH. This article does not cover the relationship between lime and the pH. As Table 1 indicates, when the rotary feeder runs at 600 rpm, the consumption increases significantly and, consequently, so does the cost of lime.

Table 2. Rotary variations

Test number	Rotations per minute	Time (sec)	Mass (kg)	T/hr	Consumption (kg/t)	Cost (rand)
1	300	30.0	10.15	1.22	2.92	R1 987 776.00
2	300	30.0	10.00	1.20	2.88	R1 958 400.00
3	300	30.0	10.44	1.25	3.01	R2 044 569.60
1	400	30.0	14.74	1.77	4.25	R2 886 681.60
2	400	30.0	14.7	1.76	4.22	R2 869 056.00
3	400	30.0	14.9	1.79	4.30	R2 921 932.80
1	600	30.0	23.9	2.87	6.88	R4 676 659.20
2	600	30.0	23.6	2.83	6.79	R10 400 000.00
3	600	30.0	24.0	2.88	6.91	R4 696 243.20

Figure 6 shows the relationship between the tons transferred per hour and the rotations. The graph has a positive gradient; therefore, it is assumed that the relationship between the rotations and tons transferred is linear.

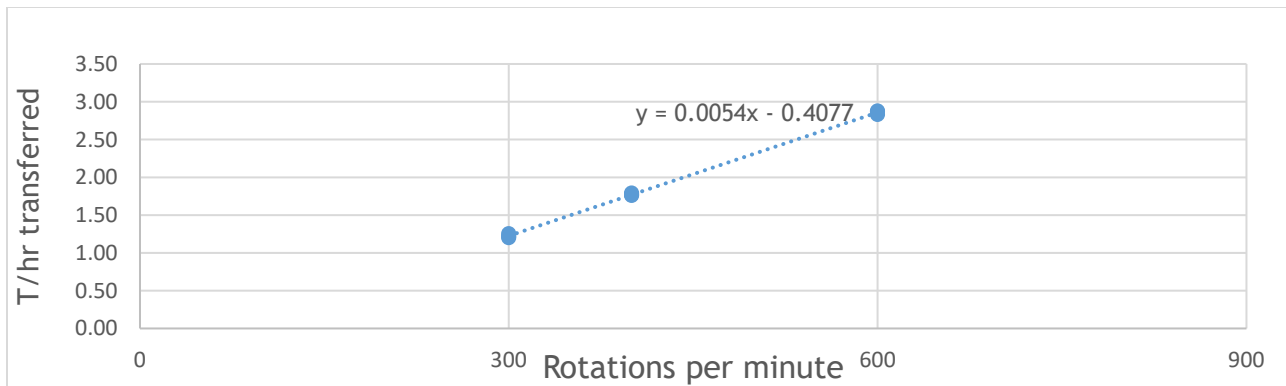


Figure 5. Rotations per minute vs tons transferred

Lime Addition

The results of the lime addition test are shown in Table 3. The relationship between the pH and lime consumption is illustrated in Figure 6. The test was performed using bottle rolls. The sample was bottle-rolled for 4 hours. The test showed that the pH reaches a threshold after 24 hours. Initially, the amount of lime in the material was zero, with a natural pH of 5 for test 1. An amount of 6.5 mL lime with a fixed density of 1.15 was added to the slurry. The final lime amount after 24 hours resulted in 2.8 mL, which amounts to a consumption of 3.70 kg/t. The amount of lime initially added for test 2 was 4.5 mL, and it resulted in a final lime amount of 0.2 mL and an overall consumption of 4.28. The results obtained show that there is a variation of the lime demand in the material, irrespective of the natural pH. Ideally, lime consumption should be below 3.8 kg/t to keep the lime cost within plan. Figure 11 shows that there is a relationship between the pH and the lime demand. When the natural pH is low, more lime is needed to increase the pH to above 10.5; consequently, lime consumption increases.

Table 3. Lime consumption

	1	2	3	4
Initial lime	0.0065	0.0045	0.0050	0.0040
Final lime	0.0028	0.0002	0.0003	0.0003
Consumption (kg/t)	3.70	4.28	4.67	3.72
pH				
Natural pH	5.2	6.9	7.0	7.4
Initial pH	11.4	11.4	11.4	10.6
Final pH	10.9	10.8	11.1	10.7

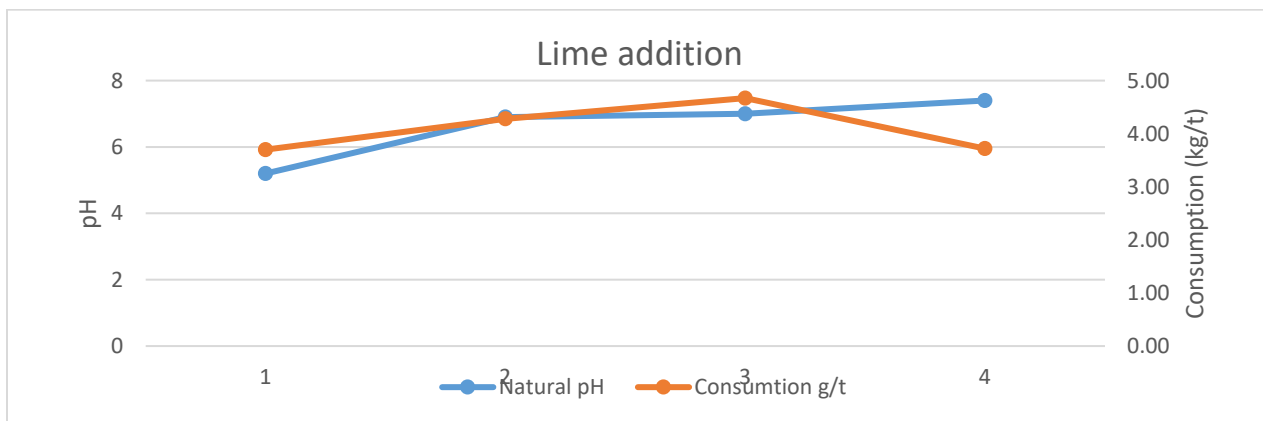


Figure 6. pH versus consumption

Investigating the ability of flocculants to facilitate settling at different pH levels

There is a clear solid-liquid interface during the settling of particles. The results of the settling experiment are shown in Figure 12. It is evident that the pH and the concentration of solids have an influence on the settling ability of the feed material.

Anionic flocculants perform better at a higher pH while non-ionic flocculants perform better at a lower pH range. A sample of the desliming cyclone overflow and the flocculant slurry was used for the settling test. The initial pH was 4.85, with an initial density of 1.28 t/m^3 . The density was manipulated; water was used to dilute the concentration of the solids. The pH was adjusted using lime and increased to 6.33 while keeping the density constant for the first test. The density and the pH were adjusted for the second test – the density was diluted to 1.18 t/m^3 and the pH was increased to 7.92. For the last test, using the same feed material and water for dilution, the pH was adjusted to 11.71 and the density was adjusted to 1.14 t/m^3 . The results indicate that the flocculant used performs better when the solution is alkaline, combined with a solids concentration of 1.14 t/m^3 . It was found that the concentration of slurry solids has a major influence on the settling ability. When a flocculant is added to the slurry, the flocculant must be well distributed throughout the slurry. The concentration of the solids, as well as the particle size, has a strong influence on the distribution of the flocculant in the slurry. A density of 1.12 t/m^3 to 1.14 t/m^3 is ideal for flocculant performance. When the concentration of solids is greater than the desired concentration, it becomes difficult for the flocculant to be uniformly distributed throughout the slurry. As Figure 8 shows, the settling velocity of slurry with a solids concentration of 1.14 is much higher than the settling velocity of slurry with a solid's concentration of 1.28 with the pH kept constant. It is also evident that the settling velocity is affected by an increase in the pH.

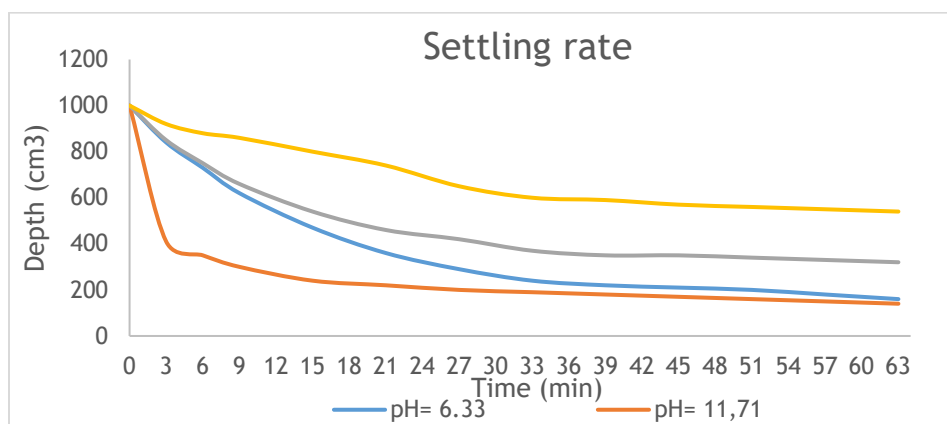


Figure 7 . Settling rate

Figure 9 below shows the density of the thickener feed for the period September 2019 to December 2019. It is evident that maintaining the density below 1.15 t/m^3 posed a challenge. The slurry density was above 1.15 t/m^3 from September 2019 to December 2019. This means that the lime addition and flocculant dosage demand were higher.

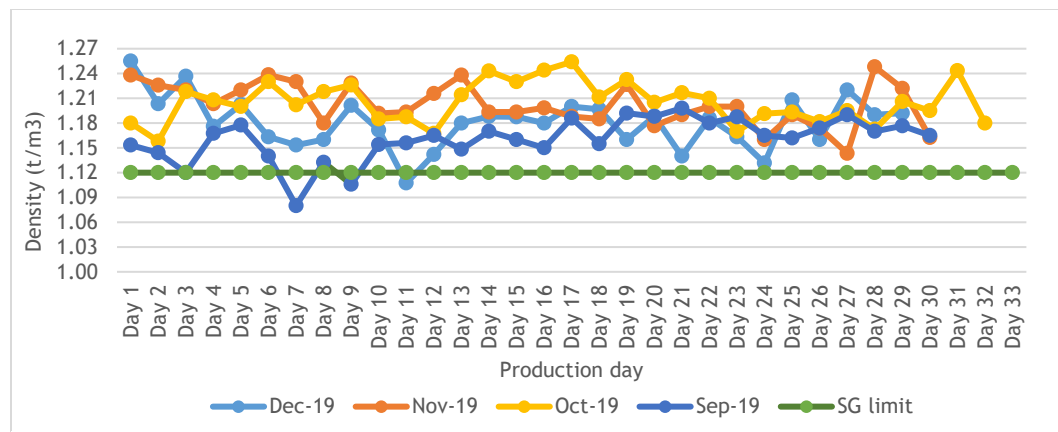


Figure 8. Thickener feed SG

Conclusion and Recommendation

The quality of the water used for the slaking process has an impact on the reaction rate. Although the type of water can improve the slaking rate, this measure is not advisable since it will contribute towards the cost. The amount of available lime is above 88%, which indicates that the lime is highly reactive.

The ratio of lime to water is important for maintaining the quality of the slaked lime, which assists in producing a moderate lime slurry density that is easy to pump, with less choking in the system. Consequently, the addition of lime is sufficient and easily controlled. The slurry solids percentage and the slurry pH have the greatest influence on the settling rate. Flocculation performance increases with slurry pH and lower solids content. The flocculant pH needed for better performance ranges from 9 to 12. The lime supplier's product data sheet indicates that when the solids content is between 0% and 12%, the resultant lime slurry is in dilute suspension.

A solids content that is between 12% and 25% results in a moderately viscous suspension, which can be pumped easily. A solids content that is above 25% results in a thick, viscous suspension, which is quite difficult to pump and causes slurry build-up. It is important to keep the solids content between 12% and 25% to have a moderate slurry density in order to prevent build-up and chokes. The type of water used for the slaking process should contain less than 500 mg/l sulphides and a higher concentration of chlorides. The rotary lime feeder should be maintained at between 300 rpm and 600 rpm in order to maintain the consumption within the budget while maintaining a pH of 11 in the launder and 10.5 in the leach streams. The density of the thickener feed plays a major role in the ability of a flocculant to facilitate settling. Ideally, a density of 1.15 is recommended for better flocculant distribution throughout the slurry, which in turn enhances flocculant performance. A system that is controlled online with less human intervention is required in order to minimise an inconsistent rotary feed rate.

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