The SART process experience in the Gedabek plant

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ABSTRACT

The Gedabek mine is a recent gold copper operation located 55 km from Azerbaijan's second largest city, Ganja. The gold extraction plant operates since 2009 and uses heap leaching cyanidation and resin adsorption processes. The high copper content in the ore forced the inclusion of a SART (sulphidisation, acidification, recycling and thickening) plant in the design of the cyanidation process to treat part of the pregnant leach solution (PLS). The commissioning of the SART plant was performed in the first quarter of 2010, which allowed the recovery of free cyanide and the production of a copper-silver precipitate. The SART plant in Gedabek is one of the five SART processes currently operating in the world and its implementation involved important challenges. The Gedabek SART plant has been in continuous optimisation by the operators, who are focusing their efforts on increasing copper recovery in the process. This optimisation work was based on a critical analysis of operational data followed by a rigorous implementation of changes. The present work describes how the Gebabek plant has been able to increase the copper recovery by around 30-60% to above 90%, reducing the main reagents consumption between 15% and 85%.

INTRODUCTION

The processing of gold ores with high cyanide-soluble copper content is limited by cyanide consumption and cyanide-copper complexes present in the solution circuit, reducing the project profitability and gold recovery in the adsorption processes (Bustos, Estay & Arriagada, 2008; Sceresini, 2005). In this context, a new technology named SART (sulphidisation, acidification, recycling and thickening) process, developed by Lakefield Research in Canada (MacPhail, Fleming & Sarbutt, 1998), was designed to regenerate cyanide and recover copper from cyanide solutions produced by gold leaching operations (Barter et al., 2001; MacPhail, Fleming & Sarbutt, 1998). The SART process has demonstrated to be an efficient technology to recover cyanide and produce copper, capturing the attention of the gold-mining industry due to the reduction of operational costs and to the addition of a new by-product of the mine operation. This process makes possible the treatment of gold ores with high copper contents, increasing the reserves of a deposit.

The process involves both acidification and sulphidisation stages which are performed by adding sulphuric acid (H_2SO_4) and sulphide (in the form of NaHS or Na_2S), producing precipitation of copper sulphide (Cu_2S) and silver sulphide (Ag_2S), among others cations present in the solution. Furthermore, hydrogen cyanide (HCN) is generated in the process, which remains dissolved in solution (MacPhail, Fleming & Sarbutt, 1998) according to Equations 1, 2 and 3:

$$2\mathrm{NaCN} + \mathrm{H_2SO_4} \rightarrow 2\mathrm{HCN_{(aq)}} + \mathrm{Na_2SO_4} \tag{1}$$

$$2\mathrm{Na_2Cu(CN)_3} + \mathrm{Na_2S} + 3\mathrm{H_2SO_4} \rightarrow \mathrm{Cu_2S_{(s)}} + 6\mathrm{HCN_{(aq)}} + 3\mathrm{Na_2SO_4} \tag{2}$$

$$2\mathrm{NaAg(CN)_2} + \mathrm{Na_2S} + 2\mathrm{H_2SO_4} \rightarrow \mathrm{Ag_2S_{(s)}} + 4\mathrm{HCN_{(aq)}} + 2\mathrm{Na_2SO_4} \tag{3}$$

The solids formed by precipitation are removed using stages of thickening and filtration, while the treated solution is conducted to the neutralisation stage where milk of lime ($Ca(OH)_2$) is added until reaching pH 11 (Estay, Arriagada & Bustos, 2010). The $Ca(OH)_2$ addition produces the conversion of dissolved HCN into calcium cyanide ($Ca(CN)_2$) (Equation 4) and precipitation of gypsum ($CaSO_4{\cdot}2H_20$) (Barter et al., 2001).

$$2\mathrm{HCN_{aq}} + \mathrm{Ca(OH)_2} \rightarrow \mathrm{Ca(CN)_2} + 2\mathrm{H_2O} \tag{4}$$

The final solution produced by the SART process is returned into the leaching circuit, having all of its cyanide content as soluble $Ca(CN)_2$, which is equivalent to free cyanide for the purposes of gold dissolution in the cyanidation process (MacPhail, Fleming & Sarbutt, 1998).

In the last ten years, five SART plants have been constructed and operated around the world (Estay et al., 2012). One of them is the Gedabek plant located in Azerbaijan, their first operating gold mine in recent times, owned by Azerbaijan International Mining Company (AIMC). This plant treats part of the PLS flow produced by the heap leaching operation of the plant. The Gedabek mine produces about 4500-5000 oz of gold per month, based on the treatment of one million tonnes of ore per year. The copper grades in the ore, higher than 3700 g/t, forced the inclusion of a SART process in the cyanidation plant. Thus, the commissioning of the SART plant was performed in the first quarter of 2010, which allowed the recovery of free cyanide and the production of a copper-silver precipitate.

The current operation of SART plants around the world involves important operational challenges, especially for Gedabek's operators who have recently addressed mining knowledge for the optimisation of conventional mining operations.

Description of the Gedabek SART plant

Gedabek mine is located in Gedabey, 55 km from the Azerbaijan's second largest city, Ganja. The gold extraction plant uses heap leaching cyanidation and resins adsorption processes. This plant began its operation on May 2009, but a SART plant with capacity of 140 m^3/h designed to process 50% of the total PLS was commissioned in April 2010.

The PLS treated by the SART plant is pumped into the process, where concentrated H_2SO_4 and Na_2S solution are added into the PLS pipeline by using an in-line mixer until reaching pH 5.5. The PLS-reagent mix is conducted into a nucleation reactor, where Cu_2S and Ag_2S are precipitated and dissolved HCN is generated. The slurry generated in the nucleation reactor discharges into a Cu_2S thickener (8 m diameter) to increase the solids concentration. Part of the thickener underflow is recycled into the nucleation reactor to serve as seed for the precipitate, while the remaining underflow fraction is sent to the filtration stage. The filtration of precipitate is carried out by two filter presses, obtaining a precipitate cake having 55% final moisture. The Cu_2S-thickener overflow is conducted into the neutralisation reactor, where $Ca(OH)_2$ is added until reaching pH 10.5-11 to induce the conversion of dissolved HCN to $Ca(CN)_2$ and consequently gypsum precipitation. The gypsum slurry is fed into the gypsum thickener (8 m diameter) to separate the solids from the treated solution. Similarly to the precipitate thickener, the gypsum thickener operates by recycling part of the underflow into the neutralisation reactor and by sending the remaining underflow fraction to the filtration stage. The gypsum filtration is performed by a rotary filter, obtaining a gypsum cake having 80% final moisture. The process also includes a scrubber system connected to the main equipment of the plant in order to capture and treat the eventual emissions of HCN and/or H_2S gases. The SART plant in Gedabek mine mainly operates by using manual controls. Figure 1 shows a schematic block diagram of the SART process in the Gedabek plant.

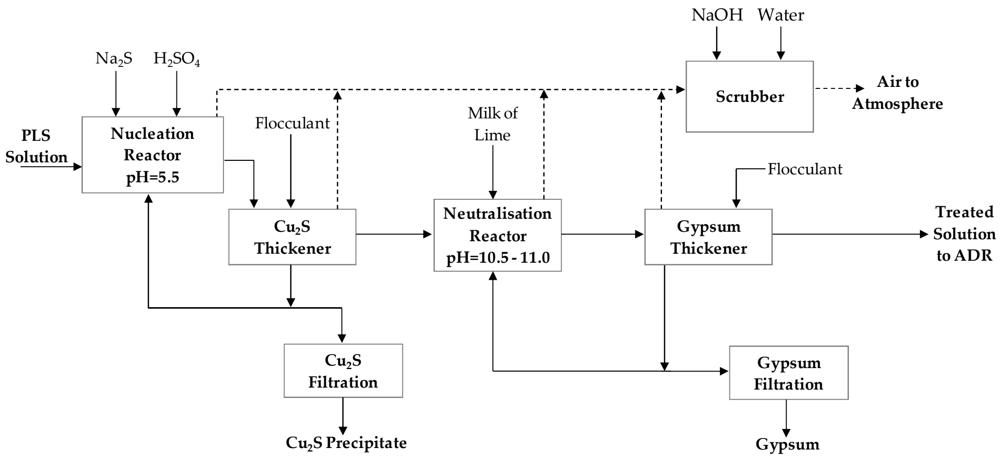

Figure 1 Schematic block diagram of the SART process in the Gedabek mine (Azerbaijan)

Since commissioning, the operation of the SART plant has presented some difficulties, particularly related to stabilise the copper recovery and reagent consumption. In this context, the Gedabek`s operators supported by Arcadis Chile have put many efforts for optimising the performance of the SART plant. A general description of the actions taken by AIMC to optimise the operational parameters of the SART plant is presented below.

Table 1 Gedabek's plant PLS characterization

Description	Before Diagnosis	October, 2011
Flow (m^3/h)	60 – 120	110 – 120
Cu concentration (mg/L)	1200 – 1800	600 - 900
Ag concentration (mg/L)	5 – 25	4 – 5

METHODOLOGY

To optimise the SART plant operation, the following steps were done:

1-Analysis of operational data (October, 2010-October, 2011) taken by the operation

2-Preliminary diagnosis of the SART plant operation

3-Implementation of preliminary recommendations

4-Site visit, collection of new operational data and in situ inspection of the SART plant performance

5-Final diagnosis and recommendations

6-Implementation of new recommendations

7-Continuous optimisation of the SART plant

RESULTS AND DISCUSSION

Processing capacity

From October 2010 to March 2011, the SART plant operated at 110-120 m³/h, below its design capacity of 140 m³/h since the Cu_2S-thickener performance increases the solid concentration in the overflow. Under these operational conditions, the copper recovery in the SART process decreased. From March 2011, operational actions were taken by operators to minimise the solids carry-over in the Cu_2S-thickener overflow. In principle, a strong reduction of the PLS fed into the SART plant to 60 m³/h was considered, but other operational adjustments (see the next sections) improved also the thickener performance. As a consequence, a decrease in the solids carry-over in the overflow allowed to increase gradually the PLS fed into the SART plant up to 110-120 m³/h, without presenting the operational difficulties previously described. To date, the SART plant remains operating at 110-120 m³/h. However, even when the present study established that the SART plant is able operate at 86% of its maximum capacity, the dissolved gypsum and flocculant contained in the treated PLS causes scaling of gypsum and coating on the resins, limiting the PLS fed into the SART plant below its design flow.

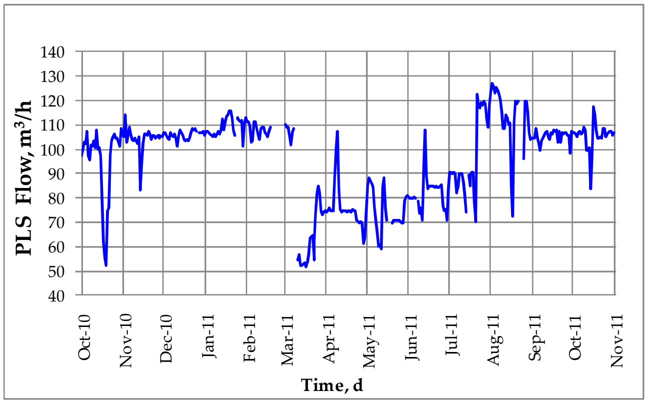

Figure 2 Operational data of the PLS flow treated by the SART plant

Copper and silver recovery

The ideal performance of the SART process and thickening operation should produce a clean overflow, separating the solids from the treated solution in the thickener. Hence, the solids carry-over in the Cu_2S-thickener overflow causes losses of recovered copper due to the re-dissolution of precipitate in the neutralisation stage produced by the increase in pH (based on the thermodynamics stability of Cu_2S). In the particular case of the Gedabek's SART plant, the difference in copper concentration between the neutralisation reactor and nucleation reactor ranged from 400 to 600 mg/L (Figure 3) during October 2010 to March 2011. This fact was explained by re-dissolution of precipitated copper, as mentioned above. Thus, to determine the amount of solids carry-over in the overflow of the Cu_2S thickener, a detailed mass balance of the SART plant was performed supported by operational data. From these mass balances, it was possible to establish that the solids carry-over in the overflow fluctuated between 700 and 2000 mg/L. Besides, it was found that silver behaves different than the copper (Figure 3), which presented a lower re-dissolution degree than copper as a consequence of the wider band of Ag_2S stability in the operational conditions of the neutralisation reactor.

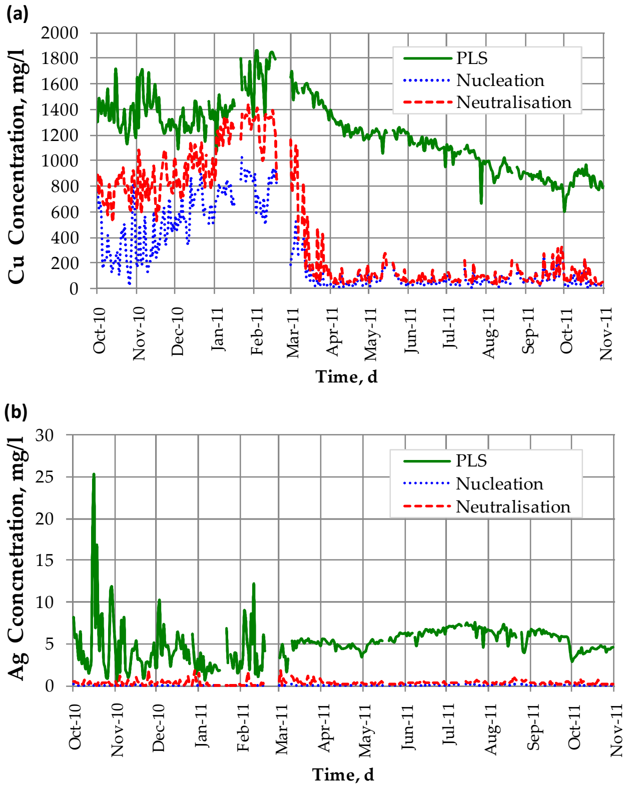

Figure 3 Profiles of copper (a) and silver (b) concentration in the Gedabek's SART plant

In order to diagnose and take actions to improve the performance of the Cu_2S thickener, operational data and design parameters of the SART plant were analysed. The main actions implemented by Gedabek's operators were:

1-reduce the concentration of the flocculant solution added into the thickeners from 2.5 to less than 0.5 g/L

2-change the type of flocculant (according to the results of settling tests)

3-increase instrumentation and automation

4-control the recirculated underflow to keep the solids contents in the feed of the thickener less than 1%

5-rapid implementation of points 1-4

6-a rigorous sampling in each point of the process.

All these actions, in conjunction with the reduction and subsequent gradual increase in the feed PLS solution, resulted in a decrease of copper re-dissolution in the neutralisation reactor at 10-40 mg/L (Figure 3) from March 2011 to October 2011. Likewise, the solids carry-over in the overflow of the Cu_2S thickener was reduced to 20-100 mg/L.

From October 2010 to March 2011, the difference in the copper recovery between the nucleation and the whole SART process was ~40 points (Figure 4), as result of copper re-dissolution occurring in the neutralisation reactor. After applying the above-mentioned actions, this difference in copper recovery decreased to three points from March 2011 and thereafter. The high values of copper recovery from March 2011 (above 90%) are also a consequence of the sulphide dosage, as it will be explained in the next section.

Finally, the low values of copper recovery attained during the period October 2010-March 2011 increased the equilibrium copper concentration in the PLS from 1400 to 1800 mg/L, as illustrated in Figure 3. Thus the actions implemented in the plant reduced the equilibrium copper concentration in the PLS to about 800 mg/L (October 2011).

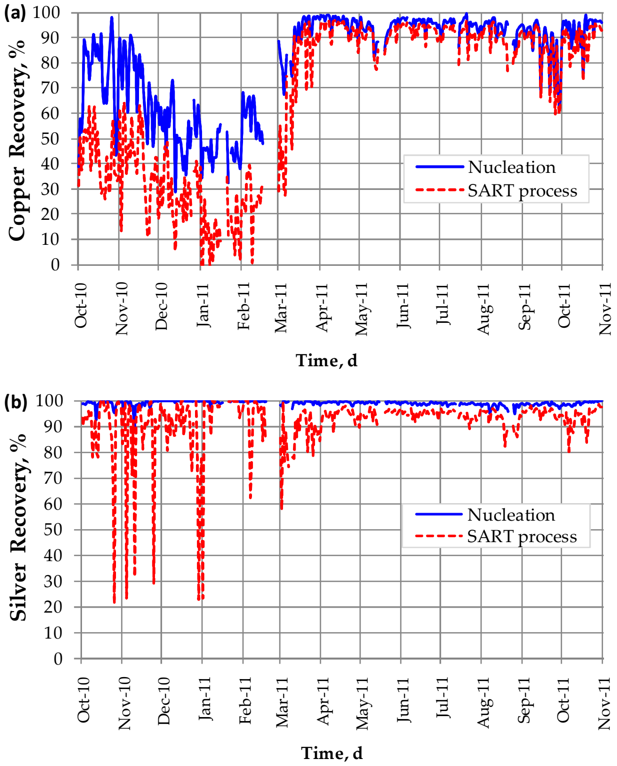

Figure 4 Copper (a) and silver (b) recovery in the nucleation reactor and SART process

Reagent consumption

Sulphuric acid addition and pH control

From April 2011 the nucleation reactor operates at pH 5.5 (Figure 5), due to there were no significant differences in the copper recovery at lower pH values according to the operational data. The result was a reduction in 15% in acid consumption respect to pH 4.5, obtaining a value of 2.5-3.5 kg/m³.

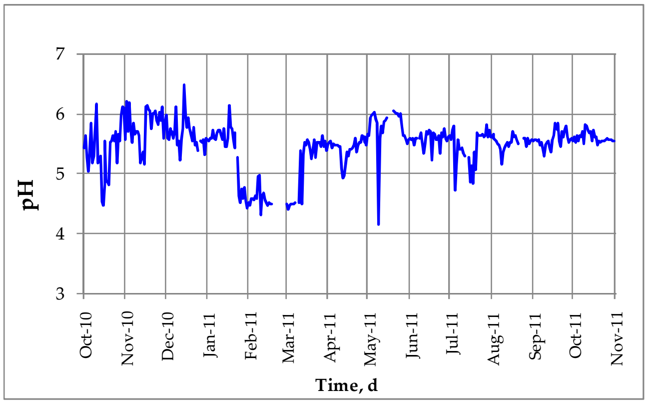

Figure 5 Variation of pH in the nucleation reactor

Sodium sulphide addition and metals recovery

The Na_2S is dissolved in a dilution-distribution reagent plant to obtain a Na_2S concentration of 11.1% by weight. This reagent is then injected into the PLS under manual control, according to the copper concentration in the PLS by addition of the fixed stoichiometric Na_2S quantity. As shown in Equations 1-3, the copper and silver recovery depends on the sulphide addition. In this context, a curve of copper recovery as a function of the addition of Na_2S was developed (Figure 6) by using operational data and statistical methods. As it can be seen in Figure 6, the copper recovery could be above 90% if the amount of added Na_2S is higher than 100% stoichiometric. To avoid reagent losses, the injection of Na_2S has been restricted to values ranging from 110 to 120% the stoichiometric requirement. For these conditions, the silver recovery is higher than 94% (Figure 4).

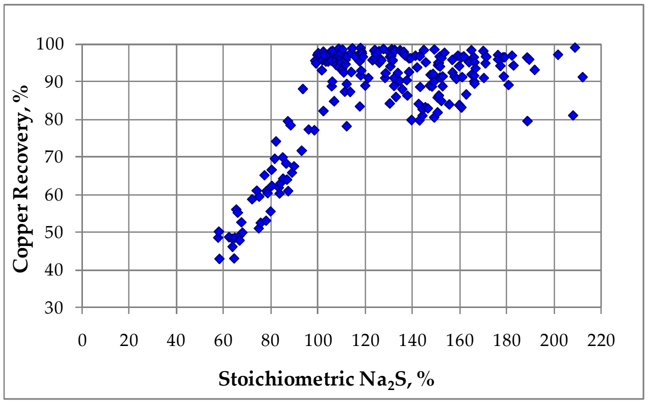

Figure 6 Copper recovery as function of the added stoichiometric Na_2S in the SART plant

Flocculant addition

The observed variability in the profiles of copper concentration and copper recovery (Figures 3 and 4) through the period October 2010-March 2011 are explained by operational instability of the Cu_2S thickener. Under this condition, the solids carry-over in the overflow was, on average, 1300 mg/L, and the added flocculant concentration of 2.5 g/L. In addition, the flocculant dosage was ~7 g/m³, but until April 2011, no formal measurement of this parameter was carried out. In order to improve the performance of the Cu_2S thickener, the following actions were taken:

1-install flocculant flow-meters in both thickeners

2-conduct settling tests to establish the optimum type of flocculant

3-reduce the added flocculant concentration at values lower than 0.5 g/L

4-control the underflow recirculation, keeping the solid concentration in the thickener feed in less than 1%

5-increase the instrumentation and automation in the process

6-routine sampling in the overflow, measuring the solids carry-over

7-continuous reduction of the flocculant dosage according to results from point 6.

All these actions resulted in a reduction of the solids carry-over to 30 mg/L, on the average, increasing copper recovery in at least 30 points. Furthermore, the flocculant consumption was determined to be less than 2 g/m^3 in the nucleation thickener and 1 g/m^3 in the gypsum thickener (Figure 7).

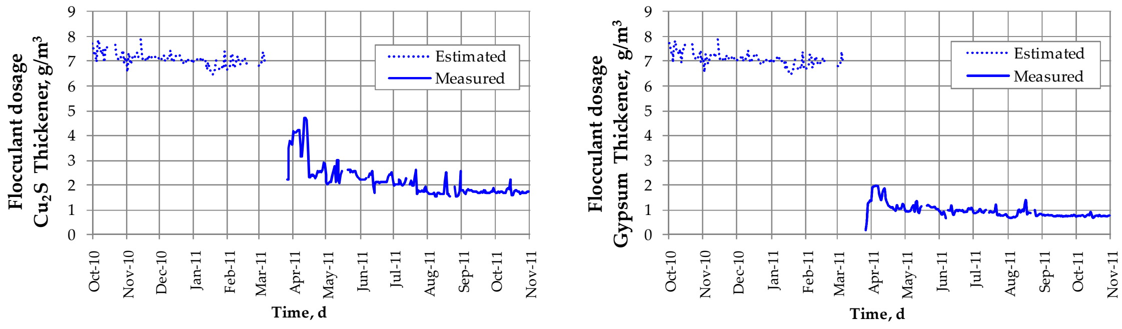

Figure 7 Flocculant addition in the nucleation (left) and gypsum (right) thickeners

CONCLUSION

The SART process in Gedabek plant has made possible the treatment of gold-copper ores present in the deposit, recovering copper, silver and cyanide. The present study has shown how the optimisation of the plant increased the copper and cyanide recovery from 30-60% to above 90%, reducing the acid, Na_2S, and flocculant consumption in 15%, 20-40%, and 70-85%, respectively. These excellent operational advances have been reached by applying a critical analysis of the plant, rapid implementation of recommendations and rigorous sampling in each point of the circuit

ACKNOWLEGMENTS

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