

Leaching behaviour of base and precious metals during cyanide leaching of a pyrite concentrate

Oktay Celep ¹, Ersin Yener Yazıcı ¹, Hacı Deveci ¹, Murat Mercimek ², Alper Gönen ², Cumhuri Demirel ², Melih Baki Cingöz ², Hüseyin Kömürcü ², Serkan Çakmak ¹

¹ Hydromet B&PM Research Group, Mineral&Coal Processing Division, Mining Eng. Dept., Karadeniz Technical University, 61080, Trabzon, Türkiye

² Yıldız Bakır Mining Inc. 29100, Gümüşhane, TÜRKİYE

Corresponding author: hdeveci@ktu.edu.tr (Hacı Deveci)

Abstract: This study investigated the influence of cyanide concentration (1.5-7 g/L NaCN), particle size (d_{80} = 28-55 μ m), and solid-to-liquid ratio (40-60% w/w) on the leaching behaviour of gold, silver, copper, zinc, and iron from a concentrate containing predominantly sphalerite, pyrite, and chalcopyrite, as determined by XRD analysis. The concentrate, containing 10.6 g/ton Au, 42 g/ton Ag, 0.21% Cu, 3.57% Zn, and 31% Fe, exhibited refractory characteristics with a low gold extraction (37%) at 1.5 g/L NaCN over a 24-hour leaching period. Increasing the cyanide concentration to 7 g/L enhanced gold extraction to 73%, albeit with a 3.64-fold increase in cyanide consumption. Copper leaching varied moderately (25-32%), likely attributed to its predominant occurrence as chalcopyrite. Negligible zinc leaching was observed, suggesting the relative inertness of sphalerite in the cyanide leaching environment. While particle size variations (d_{80} = 28-55 μ m) had minimal impact on gold extraction, a lower solid-to-liquid ratio (40% w/w) demonstrated improved gold extraction (51%) compared to 60% w/w. The optimal leaching conditions for achieving the highest gold and silver extractions were found to be 7 g/L NaCN, a pulp density of 40%, and a particle size of 55 μ m (d_{80}). These findings indicate that the concentrate exhibits refractory behavior under conventional cyanide leaching conditions. Elevated cyanide concentrations and lower solid-to-liquid ratios are required to enhance gold extraction, albeit with increased cyanide consumption.

Keywords: refractory gold concentrate, cyanide leaching, pyrite, cyanicides

1. Introduction

Cyanide leaching is a widely used hydrometallurgical technique employed primarily in extracting gold and silver from ores. The process involves the dissolution of these precious metals in an aqueous cyanide solution, forming metal-cyanide complexes that can be easily recovered from pregnant leach solutions by activated carbon adsorption or zinc cementation (Marsden & House, 2006). Due to its numerous advantages, efficiency and cost-effectiveness, cyanide leaching has become the dominant industrial practice for gold extraction from ores (Adams, 2016). However, the occurrence of gold is of practical importance, particularly when the gold is present as submicroscopic gold locked within sulphides such as arsenopyrite and pyrite. These ores are classified as refractory, responding poorly to conventional cyanide leaching, often resulting in low gold extractions (<80%). The refractoriness of such ores is primarily attributed to the encapsulation of gold within sulphide matrices, which prevents direct contact between the gold and the leaching agent (La Brooy et al., 1994). In addition to sulphide encapsulation, the presence of carbonaceous matter can further exacerbate the refractory behaviour of these ores. Carbonaceous materials have the tendency to adsorb solubilised gold from the leaching solution, a phenomenon commonly referred to as pregrobbing (Celep et al., 2010). This preg-robbing effect significantly reduces the amount of gold available for recovery, thereby diminishing overall extraction efficiency. Additionally, the presence of other metals and minerals that are soluble in cyanide

leaching conditions can interfere with leaching. These competing dissolutions can profoundly influence the overall process efficiency and cost (Wang et al., 2017).

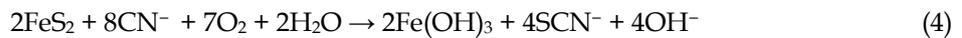
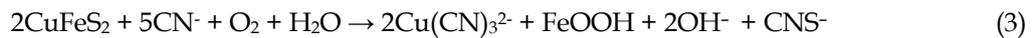
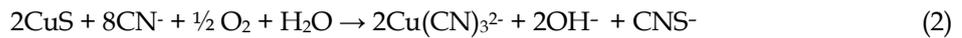
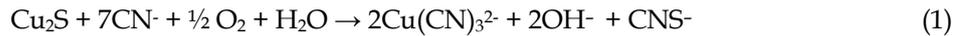
Cyanide leaching is not inherently selective and can dissolve various metals (known as cyanicides) besides gold, forming metal cyanide complexes (e.g., $\text{Cu}(\text{CN})_2$, $\text{Zn}(\text{CN})_4^{2-}$, $\text{Ni}(\text{CN})_4^{2-}$, $\text{Fe}(\text{CN})_6^{4-}$ etc) (Habashi, 1967; Wang et al., 2017). While most copper minerals are readily soluble in cyanide solutions, notable exceptions include chalcopyrite, chrysocolla, and tetrahedrite (Table 1). The detrimental impact of copper on gold extraction has become increasingly significant with the growing production of gold from copper-bearing ores (Fleming, 2011; Hedjazi and Monhemius, 2013; Bas et al., 2015). Gold extraction by cyanidation can become economically unviable when the ore contains more than 0.5-1% cyanide-soluble copper due to excessive cyanide consumption (Muir, 2011). In such cases, pretreatment methods, such as copper flotation, or alternative leaching and recovery approaches, such as intensive cyanidation, may be necessary to mitigate the adverse effects of copper (La Brooy et al., 1994; Bas et al., 2012; Bas et al., 2015; Msumange et al., 2023). Zinc sulphides and oxides generally demonstrate low to moderate solubility (Table 1). Common iron minerals, with the exception of pyrrhotite, are only sparingly soluble or insoluble (Table 1).

Tablo 1. Solubility of some minerals in cyanide solutions (Habashi, 1967)

Mineral			Dissolution in 24 h (%)	
Gold Minerals	Calaverite	AuTe_2	Readily soluble	
Silver Minerals	Argentite	Ag_2S	Readily soluble	
	Cerargyrite	AgCl	Readily soluble	
	Proustite	Ag_3AsS_3	Sparingly soluble	
	Pyrrargyrite	Ag_3SbS_3	Sparingly soluble	
	Copper Minerals	Azurite	$2 \text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$	94.5
Malachite		$\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$	90.2	
Chalcocite		Cu_2S	90.2	
Cuprite		Cu_2O	85.5	
Bornite		$\text{FeS} \cdot 2 \text{Cu}_2\text{S} \cdot \text{CuS}$	70	
Enargite		$3 \text{CuS} \cdot \text{As}_2\text{S}_3$	65.8	
Tetrahedrite		$4 \text{Cu}_2\text{S} \cdot \text{Sb}_2\text{S}_3$	21.9	
Chrysocolla		CuSiO_3	11.8	
Chalcopyrite		CuFeS_2	5.6	
Zinc Minerals		Simitsonite	ZnCO_3	40.2
		Zincite	ZnO	35.2
	Hydrozincite	$3 \text{ZnCO}_3 \cdot 2 \text{H}_2\text{O}$	35.1	
	Franklinite	$(\text{Fe}, \text{Mn}, \text{Zn}) \text{O} \cdot (\text{Fe}, \text{Mn})_2 \text{O}_3$	20.2	
	Sphalerite	ZnS	18.4	
	Galemine	$\text{H}_2 \cdot \text{Zn}_2\text{SiO}_4$	13.4	
	Willemite	Zn_2SiO_4	13.1	
	Iron Minerals	Pyrrhotite	FeS	Readily soluble
Pyrite		FeS_2	Sparingly soluble	
Hematite		Fe_2O_3	Practically insoluble	
Magnetite		Fe_3O_4	Practically insoluble	
Siderite		FeCO_3	Practically insoluble	
Arsenic Minerals		Orpiment	As_2S_3	73
	Realgar	As_2S_2	9.4	
	Arsenopyrite	FeAsS	0.9	
Antimony Minerals	Stibnite	Sb_2S_3	21.1	
Lead Minerals	Galena	PbS	Soluble at high alkalinity	

When sulphide minerals dissolve in aerated cyanide solutions, a variety of species are released into the solution, including metal ions, metal oxides, metal-cyanide complexes, and various sulfur-bearing compounds such as thiocyanate, sulfide, and thiosulfate ions (Marsden and House, 2006). The dissolution of common sulphide minerals in cyanide solutions may be typically expressed in Equations (1)-(8). Consequently, sulphide minerals are significant cyanicides that lead to increased reagent

consumption, affecting both cyanide and oxygen demand. According to the theoretical stoichiometry (Equation (5)), oxidation of just 1% of FeS₂ would consume approximately 16.35 kg/ton of cyanide (NaCN) and 9.67 kg/ton of oxygen. The presence of sulphide minerals further complicates the cyanide leaching process. These minerals contribute to gold surface passivation by forming a sulfide film and depleting cyanide and oxygen resources (Deschênes et al., 2002; Deschênes, 2016). In situations where free cyanide levels are insufficient, sulphide minerals may also facilitate preg-robbing, where gold and silver are adsorbed onto sulphide surfaces instead of remaining in solution (Celep et al., 2010). Cyanicides significantly increase operational costs and present challenges in downstream processes, including activated carbon adsorption, gold recovery (via cementation and electrolysis), tailings management, and compliance with environmental regulations (La Brooy et al., 1994; Marsden and House, 2006; Sceresini, 2005; Gong et al., 2015; Msumange et al., 2023).



Understanding the behaviour of cyanicides and developing effective strategies to mitigate their impact is crucial for enhancing the efficiency and sustainability of cyanide leaching processes. This study focuses on the leaching behaviour of base and precious metals during the cyanide leaching of a gold-bearing pyrite flotation concentrate. Specifically, the effects of key parameters, including cyanide concentration (1.5-7 g/L NaCN), particle size (d_{80} = 28-55 μm), and solids ratio (40-60%) on the leaching efficiency of gold, silver, and other metals (Cu, Zn, Fe) were systematically examined. The findings provide insights into optimising leaching conditions to maximise metals recovery while minimising cyanide consumption.

2. Materials and methods

2.1. Material

A sample of gold-bearing pyritic concentrate, presented as a pulp with an approximate solids density of 60% (w/w), was kindly provided by Yıldız Bakır Mining Inc. Particle size distribution analysis, conducted using a Malvern Mastersizer Hydro 2000MU, revealed an 80% passing size (d_{80}) of 28 μm . The chemical composition of the concentrate, determined through fire assay and wet chemical analysis, is presented in Table 2. The concentrate, characterised by gold and silver grades of 11 g/ton and 46 g/ton, is classified as a high-grade gold-silver material. X-ray diffraction (XRD) analysis, performed using a PANalytical X-Pert3 Powder diffractometer (Cu K α 1.54 Å, detector Pixel 1D, 5-140°, 45 kV, and 40 mA), identified pyrite, sphalerite and quartz as the dominant mineral phases, with galena, chalcocopyrite, and clay minerals present as minor constituents (Fig. 1).

Table 2. Precious and base metal content of the concentrate sample (Deveci et. al, 2023)

Metal	Au, (g/ton)	Ag, (g/ton)	Zn, (%)	Fe, (%)	Cu, (%)	Pb, (%)
Content	11	46	3.06	31.0	0.18	0.02

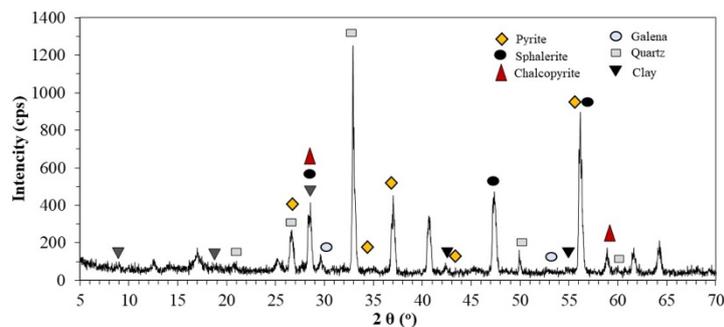


Fig. 1. XRD pattern of the flotation concentrate sample used in this study (Deveci et. al, 2023)

2.2. Method

A multi-port experimental set-up was employed to conduct cyanide leaching tests in 1-L glass reactors, each equipped with pitched-blade turbine impellers operating at 600 rpm. Table 3 summarises the fixed experimental conditions and the variables studied, such as NaCN concentration, solids ratio, and particle size, along with their ranges. During the experiments, the cyanide concentration was kept constant by replenishing any consumed cyanide with a stock solution (5% NaCN). The cyanide consumption was recorded. Similarly, the pH was also monitored and adjusted, if necessary, to control within ~pH 10.5-11 by lime addition.

Table 3. Experimental parameters and conditions in cyanide leaching tests

Parameter	Unit	Value
NaCN concentration	g/L	1.5-3-3.5-5-7
Solid ratio (by weight)	%	40-50-60
Particle size (d_{50})	μm	28-55
Temperature	$^{\circ}\text{C}$	Room temperature
Leach time	hour	24
Stirring speed	rpm	600
Air flow rate	L/min.	1.5
pH	-	10.5-11

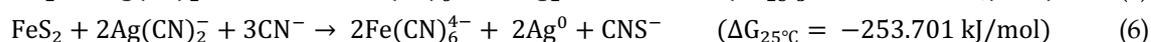
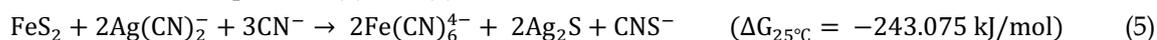
During each test, samples were collected at predetermined intervals and centrifuged at 4100 rpm for 5 minutes to obtain clear aliquots for analysis. These aliquots were used to track metal leaching, measure free CN^- concentration through silver nitrate titration using p-dimethylaminobenzalrhodanine (0.02% (w/w) in acetone) as the indicator, and monitor pH levels.

At the end of the leaching test, the solid residues were separated via vacuum filtration and then analysed for their metal content. The residue analysis was performed through wet chemical analysis methods, which included digestion with a mixture of four acids (HCl, HNO_3 , HClO_4 , and HF), followed by determination of metal concentration using atomic absorption spectroscopy (AAS). The metal content in both solid residue and the pregnant leach solution was used to calculate the mass balance and determine the extent of metal extraction.

3. Results and discussion

3.1. Effect of cyanide concentration

Fig. 2 illustrates the effect of cyanide concentration on the leaching of Au, Ag, Cu and Zn. Increasing the cyanide concentration improved both gold and silver extractions. To illustrate, increasing the cyanide concentration from 1.5 g/L to 7 g/L enhanced gold extraction significantly from 37% to 73% (Fig. 2). In addition, the dissolution of gold appears to continue, albeit at a slower rate. A similar trend was observed for silver, although there was a delay in the dissolution of silver at cyanide concentrations of ≤ 3.5 g/L NaCN. This delay could be attributed to insufficient free cyanide for effective silver dissolution during the initial stages. Furthermore, a decrease in the extraction of silver occurred after 8 hours of leaching at 1.5 g/L NaCN, potentially due to inadequate cyanide availability to maintain silver in solution. It is well-established that sulphide minerals, such as pyrite, exhibit adsorptive properties ('preg-robbing') properties in the presence of insufficient cyanide in the leaching medium (Celep et al., 2010). Thermodynamic calculations have confirmed the feasibility of silver precipitation from solution by pyrite, as shown in Equations (1) and (2).



The dissolution of sulphide minerals during cyanide leaching can result in the release of sulphide ions (Equations (7) and (8)), which has a detrimental impact on gold leaching by passivating the gold surface, thereby reducing its activity (Marsden and House, 2006). Guo et al. (2005) reported the adverse effect of pyrite (20%) on the rate and extent of gold leaching. These investigators also observed the accumulation of sulphide on the surface of gold during cyanide leaching in the presence of pyrite. The

release of sulphide ions can also influence silver leaching. Silver sulphide (Ag_2S), which has a very low solubility ($K_{\text{sp}}=6 \times 10^{-51}$), can form when the cyanide concentration is low (Equation (9)). This reaction could have also contributed to the loss of silver from the solution, as observed during the last stages of cyanide leaching at the low cyanide concentration (Fig. 2).

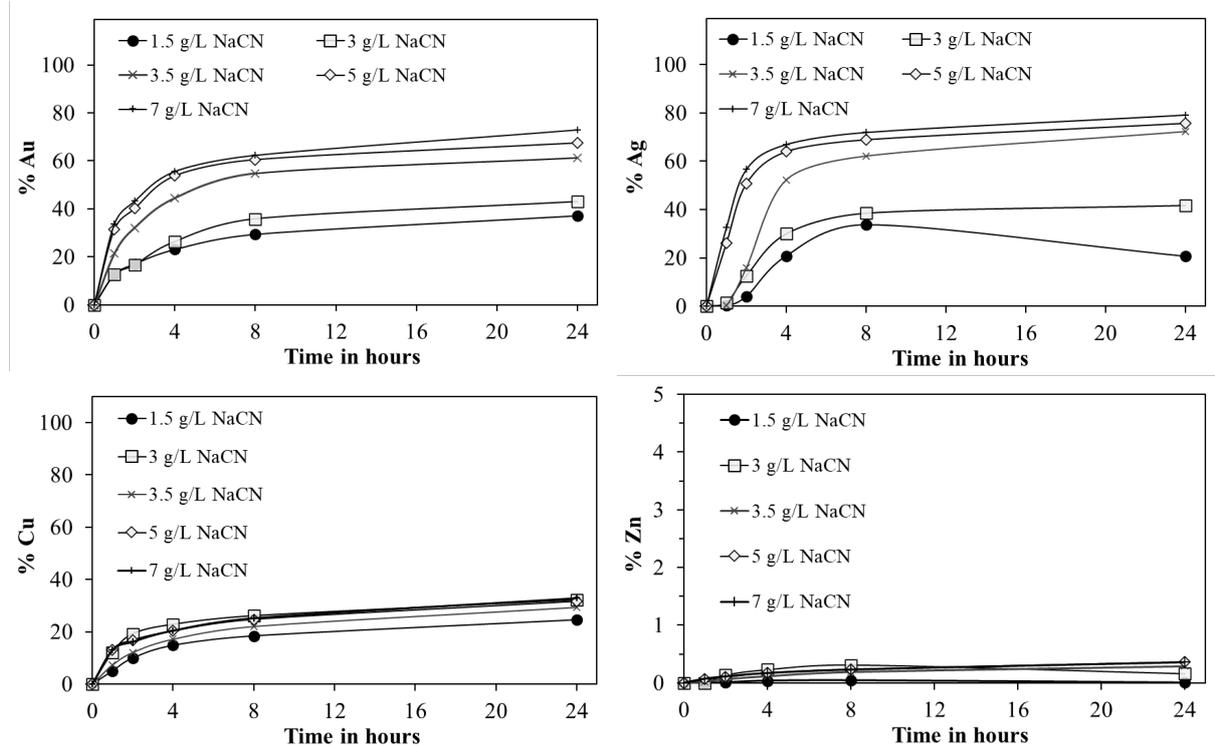
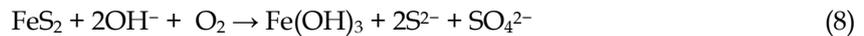


Fig. 2. Effect of concentration of cyanide on the leaching of metals. (Data for 1.5 g/L NaCN were sourced from Deveci et al. (2023))



The dissolution of copper at different cyanide concentrations is also shown in Fig. 2. In general, copper dissolved rapidly at the beginning (first 2-4 hours); thereafter, its rate of dissolution remarkably slowed down. The dissolution of copper, although slow, continues in a time-dependent manner. In other words, it increases as the retention time increases. In the plant case, the long retention times can lead to high copper levels. In this regard, copper concentrations as high as 2000 mg/L have been reported in the plant solutions.

In addition, the data obtained in the leaching tests carried out within the scope of this study showed that the copper dissolution efficiency increased with the increase in cyanide concentration (1.5-7 g/L). While 25% of copper was dissolved at 1.5 g/L NaCN concentration at the end of 24 hours of leaching time, it reached 32% at 7 g/L NaCN (Fig. 2). In effect, the relatively slow dissolution of copper from the concentrate is consistent with the occurrence of copper, as chalcopyrite is the only copper phase detected in the XRD analysis (Fig. 1), with its inherent resistance to cyanide leaching (Table 1).

Zinc and iron were found to be dissolved to a minimal extent ($\leq 0.45\%$ and $\leq 0.21\%$, respectively) (Fig. 2). This can be attributed to the relatively low solubility of sphalerite and pyrite minerals, which are the primary zinc and iron phases present, in cyanide solutions (Table 1). It is important to note that the extent of zinc dissolution observed in this study was significantly lower than that reported in the previous studies for common zinc minerals, including sphalerite (Table 1) (Habashi, 1967).

Fig. 3 presents the effect of increasing NaCN concentration on its consumption. Cyanide consumption increased from 2.83 kg/tonne to 12.1 kg/tonne (3.3 times) with increasing cyanide concentration from 1.5 g/L to 7 g/L NaCN. The increase is most significant above 3 g/L NaCN.

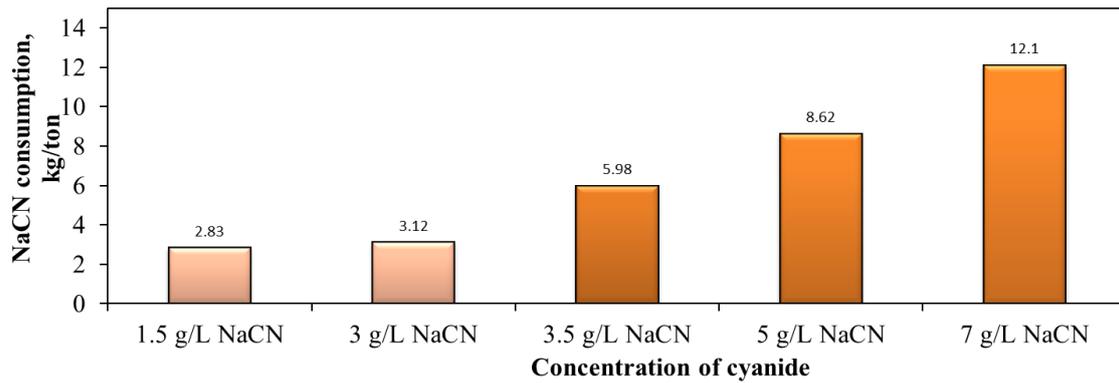
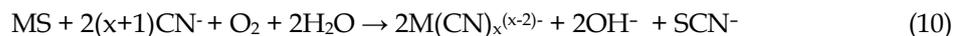


Fig. 3. Cyanide consumption across varying initial cyanide concentrations (pH 10.5-11, 60% w/w solids, 1.5 L/min air, d_{80} : 28 μm) (Data for 1.5 g/L NaCN were sourced from Deveci et al. (2023))

Sulphide minerals act as cyanicides, consuming both cyanide and oxygen during the cyanide leaching process (Equation (10), Deschenes, 2016). Pyrite, the most abundant sulphide phase detected in the concentrate, is particularly susceptible to oxidation in cyanide leaching conditions. Based on Equation (4), the theoretical consumption of cyanide and oxygen is approximately 0.87 kg and 0.93 kg, respectively, per kg of pyrite oxidised. Guo et al. (2005) investigated the effect of pyrite addition on the cyanide leaching of gold coupons, reporting a substantial increase in cyanide consumption, 5.6-fold and 10-fold in the presence of 10% and 20% pyrite, respectively. These findings align with empirical data, as illustrated in Fig. 2, which demonstrates the positive correlation between cyanide concentration and gold and silver leaching. This highlights the critical role of maintaining adequate cyanide levels to ensure efficient leaching performance.



Guo et al. (2005) demonstrated the beneficial effect of pretreatment by adding lead nitrate (100 g/ton $\text{Pb}(\text{NO}_3)_2$), mitigating the adverse effect of pyrite and remarkably enhancing the kinetics of gold leaching. This pretreatment also reduced the accumulation of sulphide on the gold surface. Recent studies (Deveci et al., 2023) further explored the addition of lead nitrate (200–500 g/t $\text{Pb}(\text{NO}_3)_2$), showing an enhancement in silver leaching while concurrently suppressing copper leaching from pyritic gold flotation concentrate at 1.5 g/L NaCN. However, its impact on gold leaching was found to be negligible. Deveci et al. (2023) also investigated the effect of pre-aeration, which enhanced gold and silver leaching while significantly reducing cyanide consumption. They attributed this enhancement to the passivation of sulphides, particularly pyrite, through surface oxidation. This oxidation process leads to the formation of a protective oxyhydroxide layer (Deschênes et al., 2002), which suppresses sulphide-ion release and minimises its interference with cyanide leaching.

3.2. Effect of particle size

In cyanide leaching processes, achieving high gold recovery typically requires grinding the ore to a degree that ensures adequate contact between precious metals (Au, Ag) and cyanide solutions, without necessitating complete liberation of gold particles. However, in the case of refractory gold ores, gold is often present in sub-micron sizes and is associated with carrier minerals such as pyrite or embedded within the mineral lattice of these host minerals (La Brooy et al., 1994; Adams, 2016). For certain pyritic or arsenopyritic refractory gold ores, marginal improvements in gold extraction may be attained through ultra-fine grinding (Marsden and House, 2006). To assess the influence of particle size on gold extraction efficiency, samples collected from the feed and discharge points of a ball mill, where fine grinding was conducted, were subjected to cyanide leaching. Fig. 4 illustrates the effect of fine grinding on the cyanide leaching of metals.

Cyanide leaching is predominantly a surface-controlled reaction, where the particle size of the ore plays a crucial role in determining reaction kinetics (Marsden and House, 2006). A reduction in particle size significantly increases the surface area available for interaction between the cyanide solution and precious metals such as gold and silver. This enhancement facilitates faster reaction rates and improves

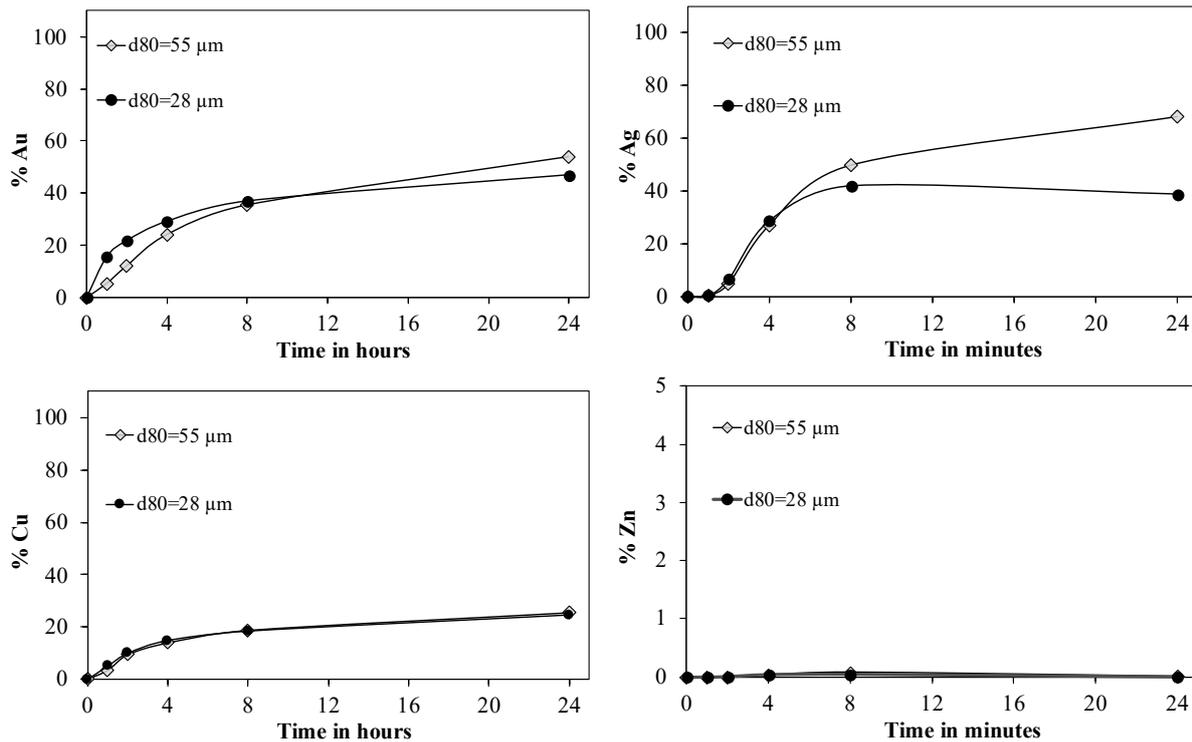


Fig. 4. Effect of fine grinding on the extraction of Au, Ag, Cu and Zn from the pyrite concentrate (pH 10.5-11, 60% w/w solids, 1.5 L/min air, d_{80} : 28 μm)

overall leaching efficiency. However, increasing the surface area through size reduction also intensifies the reactivity of gangue minerals and cyanicides, leading to higher consumption of cyanide and oxygen.

The particle size, expressed as the 80% passing size (d_{80}), of the samples collected from the inlet and outlet of the mill was found to be 55 μm and 28 μm , respectively. Cyanide leaching tests were conducted under standard plant conditions, utilizing a sodium cyanide (NaCN) concentration of 1.5 g/L. The results indicated that gold dissolution occurred more rapidly during the initial phase (within the first 8 hours) when the particle size was reduced from 55 μm to 28 μm . However, a reduction in gold leaching efficiency of approximately 7% was observed for the finely ground ore after 24 hours of leaching (Fig. 4). Similarly, a notable decline in silver leaching efficiency, from 68% to 38.7%, was recorded when the particle size of the concentrate was reduced to 28 μm (Fig. 4). In contrast, copper extraction remained relatively unaffected by the decrease in particle size, with nearly identical leaching profiles and efficiencies ranging between 24% and 25% (Fig. 4). Additionally, zinc dissolution was minimal ($\leq 0.25\%$) for both fine and ultrafine samples (Fig. 4). Particle size reduction was found to have an insignificant impact on cyanide consumption (data not shown). However, at low cyanide concentration (1.5 g/L NaCN) and high pulp density (60% w/w), the negative impact of finer particle size could be attributed to the increased surface area and reactivity of sulphide minerals, particularly pyrite. This, in turn, promotes preg-robbing and sulphide-ion release, both of which were previously identified as detrimental to the leaching process.

These findings indicate that fine grinding does not significantly improve gold and silver recovery under the tested conditions. Since fine grinding is an energy-intensive process, a more comprehensive assessment is needed, especially at finer particle sizes ($< 28 \mu\text{m}$), where the potential for enhanced gold and silver extraction may be higher.

3.3. Effect of pulp density

The solids ratio had a significant impact on metal recovery during cyanide leaching tests, particularly for gold, silver, and copper (Fig. 5). Gold extraction increased from 37% to 51% as the solids ratio was reduced from 60% to 40% w/w, suggesting that lower solids concentrations improve gold leaching from the concentrate. Silver recovery exhibited an even more pronounced increase compared to gold, rising

sharply from 20% to 72% (Fig. 5). Notably, no delay in silver leaching was observed during the initial stages, and no silver losses from the solution were detected at solids concentrations of 40–50% w/w, unlike at 60% w/w solids. Additionally, copper leaching improved as the solids content decreased, while zinc dissolution remained minimal ($\leq 0.15\%$) (Fig. 5). Moreover, higher solids ratios corresponded to lower cyanide consumption (Fig. 6), likely due to reduced metal leaching efficiency under these conditions.

The positive impact of reducing the solids ratio on metal extraction could be ascribed to improved contact between the cyanide solution and the gold particles, better oxygen transfer, and decreased viscosity of the slurry at lower solids content (Fleming et al., 2011). In other words, as the solids ratio increases, reagent and oxygen consumption also rise, and mixing efficiency and oxygen transfer deteriorate due to increased slurry viscosity (Deveci, 2017). Given that the cyanide leaching system operates as a three-phase system comprising solid, liquid, and gas phases, mixing efficiency in this context is defined by the extent to which contact among these phases is maximised to optimise leaching reactions. In other words, the primary objective of mixing is to achieve a high degree of uniformity,

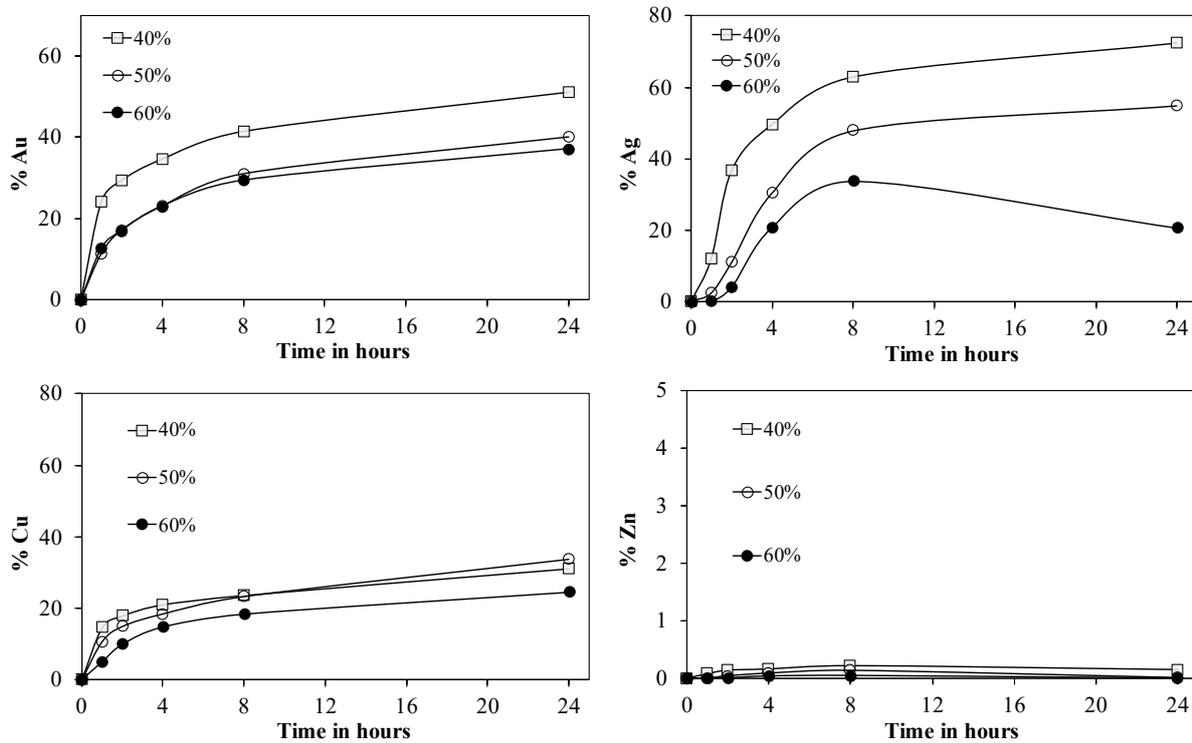


Fig. 5. Effect of pulp density on the extraction of Au, Ag, Cu and Zn from the pyrite concentrate (pH 10.5–11, 1.5 g/L NaCN, 1.5 L/min air, d_{80} : 28 μm). (Data for 1.5 g/L NaCN were sourced from Deveci et al. (2023))

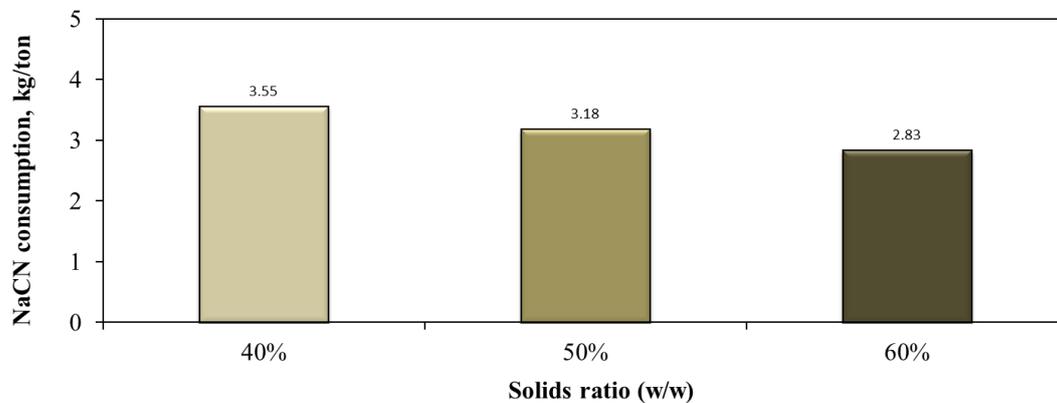


Fig. 6. Effect of pulp density on cyanide consumption (pH 10.5–11, 1.5 g/L NaCN, 1.5 L/min air, d_{80} : 28 μm). (Data for 1.5 g/L NaCN were sourced from Deveci et al. (2023))

ensure the effective suspension of solids, and facilitate efficient oxygen transfer. Typically, cyanide leaching plants operate at solids ratios of 40-50% (Stange, 1999). The current findings suggest that operating at lower solids content (e.g., <50%) could enhance the overall performance of the leaching circuit.

4. Conclusions

This study examined the impact of process conditions on the leaching of precious and base metals from a pyrite concentrate, with a particular focus on understanding the accumulation of cyanides—especially copper—in the leaching and adsorption circuit of the plant. The results indicate that increasing cyanide concentration enhances gold and silver extraction. Gold recovery improves significantly as cyanide concentration increases from 1.5 g/L to 7 g/L, rising from 37% to 73%. Silver extraction follows a similar trend but is more sensitive to cyanide concentration, showing a decline in recovery at lower cyanide levels. While copper dissolution gradually increases with time and cyanide concentration, zinc and iron dissolution remain minimal. However, higher cyanide concentrations lead to substantially greater cyanide consumption, which must be considered when optimizing leaching conditions.

Fine grinding improves the initial rate of gold dissolution but does not yield better overall gold recovery after 24 hours. On the contrary, finer grinding reduces silver recovery by a substantial margin. Copper and zinc extractions remain unaffected by particle size reduction. Given the energy demands of fine grinding, these findings suggest that fine grinding to 28 µm may not be justifiable under the current conditions. However, ultrafine grinding (<28 µm) could be explored for potential improvements in gold extraction.

Reducing the solids ratio from 60% to 40% significantly enhances the extraction of gold and silver. The most substantial improvement was observed for silver extraction, rising from 20% to 72%. The enhanced leaching of metals by lowering the solids ratio could be due to the improved contact between the cyanide solution and the metal or mineral particles, improved oxygen transfer, and reduced slurry viscosity. The results suggest that operating at lower solids ratios (<50%) may improve the performance of the leaching circuit.

Acknowledgements

The authors gratefully acknowledge Yıldız Bakır Mining Inc. for their financial support of this research.

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