

Mineralogical Examination and Acidic Ferric Leaching of Kayabaşı (Trabzon) Massive Sulphide Ore

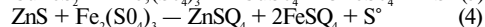
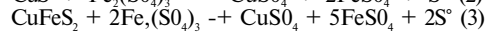
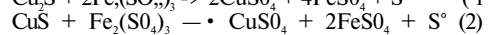
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ABSTRACT: In this study, the mineralogical characteristics and the acidic ferric leaching of Trabzon-Yomra-Kayabaşı Massive Sulphide ore were investigated. Mineralogical analysis of the ore samples has shown that the ore contains a variety of copper sulphides (12.5% Cu) including covellite, chalcocite, enargite, bornite, chalcopyrite, sphalerite (4.9% Zn), pyrite (29.9% Fe) and galena (0.7% Pb). Copper bearing minerals were found to occur as closely associated with pyrite and sphalerite. In the leaching tests, the effect of ferric iron concentration (0.0625-0.5 M), leaching temperature (25-80°C) and particle size (<106 µm) on the extraction of copper and zinc were examined at 0.5% w/v pulp density. The results indicated that the temperature exerts a strong effect on the rate and extent of extraction of copper and zinc that tended to increase exponentially with increasing temperature and over 90% Cu and 54% Zn recoveries were obtained at 80°C. The decrease in the particle size and the increase in the ferric iron concentration under the test conditions did not produce the desired effect on the metal extraction.

1. INTRODUCTION

High grade copper sulphide ores are mostly treated suitably within pyrometallurgical processes involving the production of flotation concentrates followed by smelting and refining. Mainly due to the ever increasing environmental concern and high energy costs associated with smelting and refining operations, hydrometallurgical process have gained importance for the treatment of sulphide ores (Davenport et al, 2002). Due to the low solubility of most base metal sulphides in acidic environments, the presence of an oxidizing reagent such as ferric iron and oxygen is required to engender their dissolution (Dutrizac and McDonald, 1974). Ferric salts with a standard electrode potential of 770 mV can effectively oxidise sulphide minerals including copper sulphides (Arslan et al, 2003, Burkin, 2001). The dissolution of some copper minerals and sphalerite in acidic ferric sulphate medium can be presented by the following reactions



As can be seen from the reactions above, ferric leaching of sulphides results in the formation and accumulation of elemental sulphur on the mineral surface, which can adversely affect the progress of the dissolution process (Dutrizac and McDonald, 1974).

Carranza et al (2004) reported that the concentrates containing mainly secondary copper sulphides could be leached successfully using acidic ferric sulphate media with a copper extraction of 92% at 8 h and 70°C. The authors also observed that the extended leaching periods and addition of catalyst were required to achieve high copper extractions from the concentrates with high chalcopyrite content. Smalley and Davis (2000) demonstrated the technical viability of atmospheric ferric leaching of a secondary copper ore at pilot scale.

Yomra-Kayabaşı copper ore deposit is located in Trabzon, Black Sea Region of Turkey (Figure 1). Yılmaz (2004) reported that Yomra-Kayabaşı ore did not respond well to the flotation concentration with very poor separation efficiency for copper minerals. The presence of penalty elements such as As and Hg in the ore would also make the flotation and smelting less attractive process route. Hydrometallurgical treatment of Yomra-Kayabaşı ore should therefore be examined.

In this study, the mineralogical properties and the acidic ferric sulphate leaching of Yomra-Kayabaşı ore for the extraction of copper and zinc were investigated. The effect of ferric iron concentration, particle size and temperature on the metal extraction was studied.

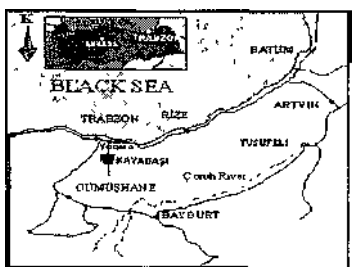


Figure 1. Location of Kayabaşı copper ore deposit.

2. EXPERIMENTAL

2.1. Material

Massive sulphide ore samples were obtained from Trabzon-Yomra-Kayabaşı (Turkey) ore deposit. For the ferric leaching studies samples were prepared as follows: Sub-samples of 1000 g were obtained from the bulk sample and these were then ground in a laboratory rod mill operating at a mill speed of 75 rpm corresponding to 73% of the critical speed. Hand-picked pieces and ground ore samples were used for mineralogical analysis. Chemical composition of the massive ore (Table 1) was determined using standard wet chemical analysis methods and an AAS (Atomic Adsorption Spectrometer).

2.2. Method

For the detailed mineralogical analysis of the ore, thin-sections and resin mounts were prepared, polished and examined under the microscope (Yılmaz, 2004; Alp et al., 2003). A total of 650-700 mineral particles were, on average, studied from each polished section. The mineral proportions were also determined.

Leaching experiments were carried out in a glass vessel placed in a water bath controlled within $\pm 1^\circ\text{C}$ at the predetermined temperature. Acidified ferric sulphate solution (300 ml, 0.0625-0.5 M Fe^{+3} + 0.25 M H_2SO_4) at the desired strength was poured into

the reaction vessel prior to the addition of the ore sample. In all the leaching tests, pulp density was kept constant at 0.5% w/v (-106 μm). Stirring of the reactor contents was performed using an IKA-RW20 overhead stirrer equipped with a pitched blade turbine impeller operating at a constant speed of 600 rpm. One ml samples were removed from the vessel at the predetermined time intervals and then used for the analysis of Cu, Fe and Zn in solution by an AAS. Evaporation losses were compensated for by the addition of de-ionised water. pH and Eh were also monitored during the leaching tests.

The effects of Fe^{+3} iron concentration in the range of 0.0625-0.5 M, leaching temperature in the range of 25-80°C and particle size in the range of -106+90 μm to -38 μm on the dissolution of Cu and Zn were examined.

Table 1. The chemical composition of the massive copper ore sample used

Element	%	Element	ppm
Cu	12.5	Au	2.7
Pb	0.7	Ni	27.1
Zn	4.9	Ag	117.7
Fe	29.94	Hg	26.48
As	0.9		
SiO_2	22.08		

3. RESULTS AND DISCUSSION

3.1. Mineralogical characteristics of the ore

Detailed microscopic examination of the ore samples showed the presence of a wide variety of copper sulphide minerals; covellite, chalcocite, digenite, enargite bornite and chalcopyrite (Table 2). Chalcocite was found to be the most abundant copper sulphide mineral in the ore. Sphalerite, pyrite, and galena were identified as the other sulphide phases while quartz and silicate minerals were present as the important non-sulphide phases in the ore samples examined. Copper bearing minerals were found to occur as finely disseminated and closely associated with pyrite and sphalerite (Figures 2-3).

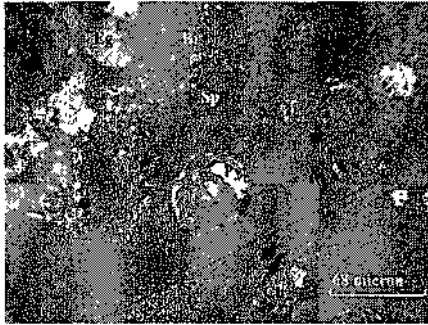


Figure 2. View of massive ore by ore microscope. (Sp: sphalerite, Py: pyrite, Ch: chalcocite, Eg: enargite, Br: bornite) (25x16).

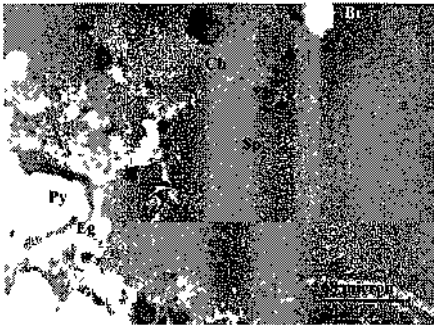


Figure 3. View of massive ore by ore microscope. (Sp: sphalerite, Py: pyrite, Ch: chalcocite, Eg: enargite, Br: bornite) (25x16).

Table 2. Copper sulphide minerals present and their relative abundance in the ore samples examined

Mineral	Amount (%)
Chalcocite (Cu ₂ S)	40
Digenite (Cu ₉ S ₅)	20
Bornite Cu ₅ FeS ₄	20
Covellite (CuS)	10
Enargite (Cu ₃ (As, Sb) ₂ S ₄)	6
Chalcopyrite (CuFeS ₂)	4
Total	100

3.2. Acidified ferric leaching of the ore

3.2.1. Effect of Fe³⁺ iron concentration on the dissolution of Cu and Zn

Figures 4-5 show the effect of Fe³⁺ iron concentration on the dissolution of Cu and Zn respectively from the ore at 0.5% w/v and 70°C. There appeared no significant influence of ferric iron concentration in the tested range on the metal extraction (Figure 6). The dissolution of copper was rapid during the initial leaching periods of 0.5 h; thereafter the dissolution rate slowed down (Figure 4). This could be due to the formation and accumulation of a diffusion barrier such as elemental sulphur on the mineral surface (Dutrizac and McDonald, 1974) and to the depletion of more reactive mineral phases leaving behind the recalcitrant phases such as enargite and chalcopyrite. A similar leaching trend was also observed for zinc (Figure 5).

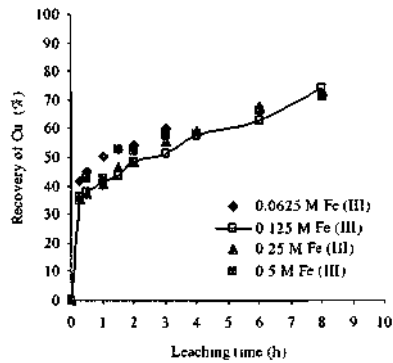


Figure 4. Effect of Fe³⁺ iron concentration on the dissolution of Cu (Temperature 70°C; Stirring speed 600 rpm; Pulp density 0.5% w/v)

At the end of leaching time of 8 h, approximately 74% of copper and 45% of zinc was extracted using 0.125 M Fe³⁺ solution (Figure 6). Copper seems to be solubilised more readily than zinc indicating the presence of more reactive copper phases than sphalerite. This could be consistent with the earlier reports that the rapid release of copper into the media adversely affected the flotation recovery of copper phases leading to the activation pyrite and particularly sphalerite (Yilmaz, 2004).

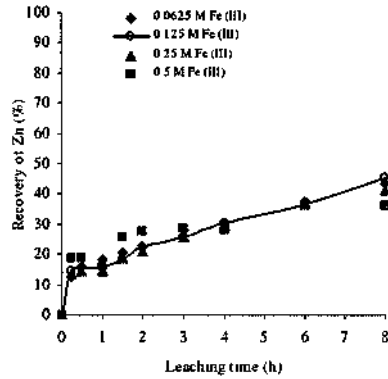


Figure 5 Effect of Fe³⁺ iron concentration on the dissolution of Zn (Temperature 70°C, Stirring speed 600 rpm, Pulp density 0.5% w/v)

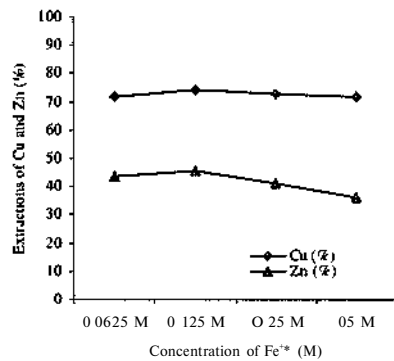


Figure 6 The plot of ferric iron concentration vs final metal extraction after 8 h

3.2.2 Effect of temperature on the dissolution of Cu and Zn

Figures 7-8 illustrate the influence of increasing temperature from 25°C to 80°C on the rate and extraction of copper and zinc respectively from the ore. Figure 9 depicts temperature versus the extraction of copper and zinc at the end of leaching period. Over a leaching period of 8 h approximately 91% of copper was solubilised at 80°C compared with 42% at 25°C (Figure 7). A similar trend of enhancement in the extraction of zinc with increasing temperature was also noted to occur. It was also observed that after 8 h the release of copper severely reduced despite the prolonged leaching period. This could be attributed to the poor accessibility of the leaching reagent to the remaining

portion of copper or the slow dissolution characteristics of refractory copper sulphides.

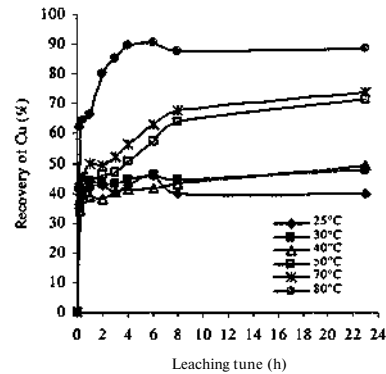


Figure 7 Effect of temperature on the dissolution of Cu (0.125M Fe³⁺, Stirring speed 600 rpm, Pulp density 0.5% w/v)

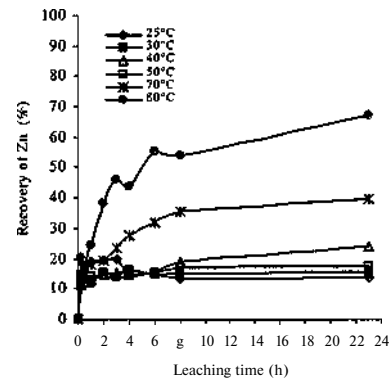


Figure 8 Effect of temperature on the dissolution of Zn (0.125M Fe³⁺, Stirring speed 600 rpm, Pulp density 0.5% w/v)

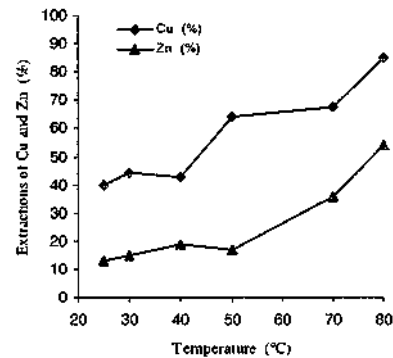


Figure 9 The plot of temperature vs final metal extraction

Carranza et al, (2004), Palencia et al, (2002) also observed the significant improvement in the extraction of copper and zinc from a secondary copper sulphide ore with increasing temperature to 90°C. They also noted the increase in the precipitation of iron as jarosite at high temperatures. In the current study, pH was controlled consistently below 1, which presumably curbed the formation of iron precipitates.

3.2.3 Effect of particle size on the dissolution of Cu and Zn

Surface area is an important variable in the leaching systems since the dissolution reactions occur on the mineral surface. The rate and extent of leaching generally tend to increase with increasing reactive surface area. Figures 10-11 show the effect of increasing surface area using the different size fractions obtained from the ground ore on the extraction of copper and zinc. The extraction of copper varied in the range of 78-93% with a general tendency of increasing with decreasing the particle size.

4. CONCLUSIONS

The mineralogical properties and the acidic ferric leaching of Trabzon- Yomra-Kayabaşı massive sulphide ore were studied. A wide range of copper sulphides with chalcocite as the most abundant copper phase were identified to be present in the ore. Copper sulphides were found to occur as finely disseminated within pyrite and sphalerite. Leaching tests have shown that the rate and extent of extraction of copper and zinc significantly increase with increasing temperature with over 90% Cu and 54% Zn recoveries at 80°C. The extraction of copper and zinc appeared to be independent of ferric iron concentration in the range of 0.0625-0.5 M at 0.5% w/v. A limited improvement in the rate and extent of dissolution of copper and zinc was found to occur with the increase in the surface area via size reduction.

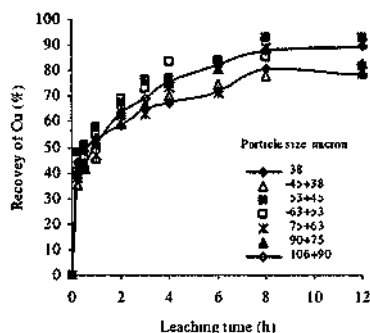


Figure 10 Effect of particle size on the dissolution of Cu (Temperature 70°C, 0.125 M Fe³⁺, Stirring speed 600 rpm, Pulp density 0.5% w/v)

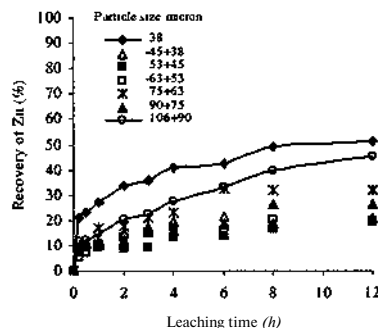


Figure 11 Effect of particle size on the dissolution of Zn (Temperature 70°C, 0.125 M Fe³⁺, Stirring speed 600 rpm, Pulp density 0.5% w/v)

REFERENCES

- Alp I, Yılmaz T, Yazıcı E, Celep O, 2003, Determination of the Degree of Liberation and Optimum Grind Time of Kayabaşı-Trabzon (Turkey) Cu-Pb-Zn Massive Ore, 3rd International Conference "Modern Management of Mine Producing, Geology and Environmental Protection" SGEM, pp 39-44, Bulgaria
- Arslan F, Kangal M O, Bulut G, Gui A, 2004, Leaching of Massive Rich Copper Ore with Acidified Ferric Chloride, *Mineral Processing & Extractive Metall*, 25 143-158
- Carranza F, Iglesias N, 2004, Treatment of Copper Concentrates Containing Chalcopyrite and Non-Ferrous Sulphides by The BRISA Process, *Hydrometallurgy* 71 413-420
- Burkin A R, 2001, Chemical Hydrometallurgy, *Imperial College Press*, London

- Davenport, W G, King, M, Schlesinger, M, Biswas, A K, 2002, Extractive Metallurgy of Copper, Pergamon, UK
- Dutrizac, J E, McDonald R J C , 1974, Ferric ion as a leaching medium, *Mineral Sei Engng* 6 No2 59-95
- Palencia I, Romero R, 2002, Treatment of secondary copper sulphides (chalcocite and covellite) by the BRISA process, *Hydrometallurgy* 66 85-93
- Smalley, N , Davis, G , 2000, Operation of the Las Cruces Ferric Sulphate Leach Pilot Plant, *Minerals Engineering*, 13 599-608
- Yılmaz, T , 2004, Yomra-Kayabaşı Masif Sulfid Cu-Pb-Zn Cevherinin Flotasyon Yöntemi ile Zenginleştirilmesi, Yüksek Lisans tezi, KTU Muh Mim Fakültesi, Trabzon