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PILOT PLANT TESTS FOR ACID LEACHING OF LOW GRADE COPPER OXIDE ORES FROM KALMAKYR COPPER MINE

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Abstract

This paper investigates the feasibility of copper recovery from oxide ores at the Kalmakyr mine (Almalyk, Uzbekistan) using heap leaching, solvent extraction, and electrowinning (HL-SX-EW) technologies. Mineralogical analysis via XRF and XRD confirmed that the ore primarily consists of malachite with a copper content of 1.53%, alongside silicate gangue minerals. A pilot plant with a 10,000-ton annual capacity was utilized to evaluate key operational parameters, including permeability, water evaporation, and acid consumption. Due to the soil-like fine particle size of the ore, the heap exhibited a low permeability of sec and a relatively high water consumption of 1.8 ton. However, the study demonstrated an efficient acid consumption rate of 6.9 kg per 1 kg of recovered copper, which is significantly lower than previous benchmarks due to the higher copper grade of the Kalmakyr ore. The results confirm the technical viability of processing these piled-up oxide ores for commercial copper production.

Keywords

Copper oxide ore, Kalmakyr mine, heap leaching, malachite, solvent extraction, electrowinning, permeability, acid consumption.

Introduction. In recent years, heap leaching technology has become increasingly important in the mining industry as it offers the possibility to process copper oxide ore [3, 5]. From a metallurgical point of view, the main parameters controlling the heap leaching operation are the crushed rock size distribution, permeability, heap height, acid concentration, irrigation rate, total ore and soluble copper content [1, 2, 6].

Kalmakyr copper mines are located in the southeast of Almalyk. It has been developed over the past few decades, focusing on the pyrometallurgical process for copper sulphide ore. For this reason, a considerable scale of copper oxide ore is in a stateof being piled up around it. The average copper content is 0,5 wt%, and a small amount of rare or precious metals are included. Two years of investigation and preparation were conducted to investigate the possibility of heap leaching of this copper oxide ore, and a pilot experiment was conducted for one year. Sulfuric acid was used for the heap leaching-solvent extraction-electrowinning process. To investigate the feasibility of a commercial plant in mind, a pilot plant with a processing capacity of 10,000 tons per year was installed in 2020, and permeability, copper leaching rate, sulfuric acid and water consumption was investigated.

Experimental

Mineral characteristics and preparation. As a result of investigating the constituent elements and content of the ore using XRF, the composition of several ore samples from the same mine is shown in table.

Mass percentage (%) of elements in the copper pre sample

Element	C	O	Si	Al	Fe	K	Cu	Mg	Ca	Na	P	S
Mass %	1,64	50,19	24,88	9,03	5,02	4,77	1,53	1,16	0,22	0,19	0,17	0,21

Oxygen (O) accounts for the largest share with about 50% and silicon (Si) accounting for about 25% of the major elements of the ore, and aluminum (Al), iron (Fe), potassium (K), and carbon (C), followed by copper

(Cu) and magnesium (Mg). It was confirmed that 1,53% of copper and 5,02% of iron were contained. The results of XRD analysis performed to investigate the mineralogical properties of copper ore are shown in fig. 1. Copper was confirmed to exist as a carbonate mineral, malachite ($Cu_2CO_3(OH)_2$). Themain minerals that make up the ore along with malachite were quartz, orthoclase, hematite, and chlorite. Looking at the chemical composition of these minerals,all of them correspond to silicate minerals, and minerals containing elements such as

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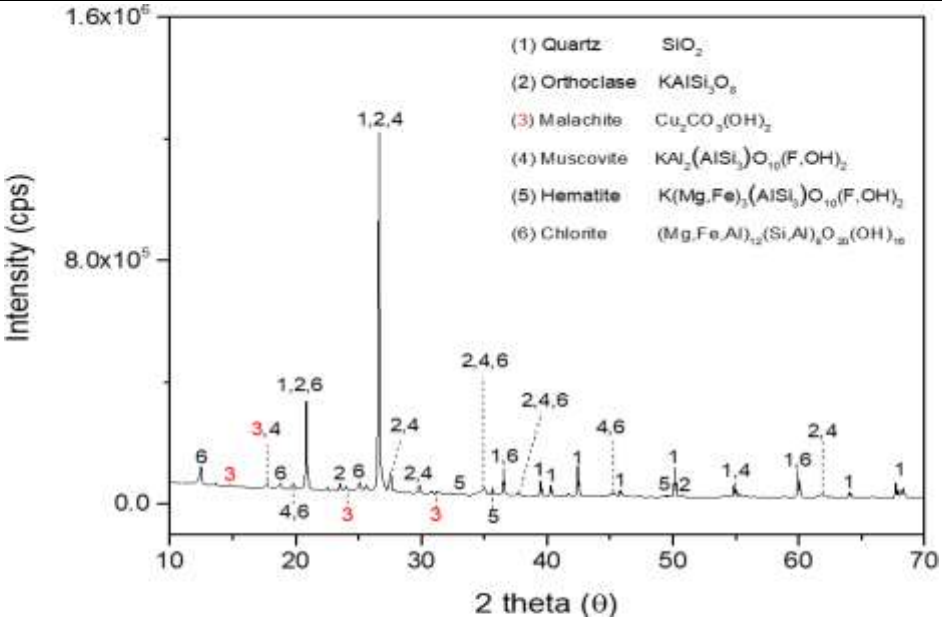

Fig. 1. XRD analysis of sample

Fig. 2. Transport oxidized copper ore.

Fig. 3. Photograph of heap.

Fig. 4. Photograph of electrolyte.

Fig. 5. Photograph of a cathode.

Al, Fe, K, and Mg are observed. In many cases, copper ore is present with reactive gangue minerals such as muscovite, chlorite and quartz [3].

Pilot plant test. For this experiment, a 1 м heap with an area of 7 м×10 м was installed. All floors of the pilot plant were installed safely with HDPE film. A 10 м×20 м×1 м pit was installed in the front of the hip to manage the PLS. Pollution was minimized by installing a space for neutralization treatment of heap and neutralization treatment of wastewater within the plant site. All devices for copper recovery were installed in commercial containers and controlled remotely. Fig. 2 shows the copper oxide ore being transported to the pilot plant. Fig. 3 shows the heap view of the pilot plant. Fig. 4 shows the process of solvent extraction and concentration of copper for electro refining. Fig. 5 shows a copper cathode.

Permeability of heaps. Since the copper oxide ore is soil-like, the particle size is very small, and the permeability affecting leaching was poor. The measured value was confirmed to be about 4×10^{-4} cm/sec. This value means that it takes about 3 days for the sulfuric acid solution sprayed on the heap with a height of about 1m to pass through the heap and be discharged.

Water consumption, local climate and evaporation of water. Sulfuric acid sprinkling for heap leaching and circulating sprinkling of PLS solution were carried out from 12 May to 31 August 2021. Experiments for solvent extraction and electrolytic refining were carried out for 30 days from 1 September. The local climate during this period is a high of 42°C and a low of 32°C.

The amount of water used was 200 tons, and the amount of diluted and sprayed sulfuric acid was 1000 Kg. The pH of the diluted sulfuric acid was about 1.

Meanwhile, the amount of PLS left in the pond at the end of the experiment was 20 m^3 and had a copper concentration of 4,3 g/L Cu. Therefore, the total amount of copper left in the PLS is 86 Kg.

Meanwhile, the recovered Electrolyte was 640 L and had a copper concentration of 45 g/L Cu. Therefore, the total amount of copper left in the electrolyte is 28,8 Kg. The copper metal recovered by electrolytic refining during the experiment period was 30 kg. Therefore, the total copper recovery amount is 144,8 Kg The amount of water evaporated during the 142 days of the experiment corresponds to 180 m^3. Based on the ore throughput, water consumption of 1,8 m^3/ton can be confirmed. This corresponds to a significantly higher water consumption compared to other studies showing water loss of 0,1 m^3/ton [4]. In general, water loss in the heap leaching process tends to increase as the size of the ore particles is finer and the sulfuric acid concentration of the leaching agent is high. Since the particle size of the heap used in this experiment corresponds to the size of the soil particle, it is awared that the result was higher than the water loss seen in the existing heap leaching process.

On the other hand, the evaporation rate of water confirmed in this experiment is about 53 L/hr. In this experiment, acid was sprayed using a pump of 14 LPM, so the irrigation rate was 840 L/hr. If the evaporation rate of water is subtracted, it can be seen that the pure irrigation rate is 787 L/hr. Referring to the permeability of the heap discussed above, it can be seen that it takes about 3 days to completely submerge the heap. Since the total irrigation amount for 3 days is 56,7 m^3, it can be said that the heap in this experiment has a high-liquid ratio of at most about 2:1.

Acid consumption. In previous studies, it was found from the literature that there was an acid consumption of 30 Kg per ton of ore [4]. In this experiment, the total amount of copper recovered under specific conditions was analyzed for acid consumption by using 1000 Kg of acid. This corresponds to the consumption of 10 kg of acid per ton of ore. Since the total amount of leached copper is 144,8 kg, it can be seen that 6,9 kg of acid was consumed per 1 kg of copper. Compared to the previous study, 12 kg of acid was consumed per 1 kg of copper, it was found that the acid consumption was almost half. This is due to the fact that the copper quality of the heap used in the experiment was 1,53%, which is higher than the 0,4% used in the comparative data.

Conclusion. Copper oxide ore from Kalmakyr copper mine was mainly composed of malachite-type copper and gangues such as quartz, hematite and muscovite. The copper grade is in the range of 0,6 to 1,5%, which corresponds to a relatively high copper content. Iron is about 5%.

By installing a 100 ton heap, leaching, solvent extraction, and electrolytic refining experiments were performed to confirm water consumption and acid consumption. It was confirmed that the permeation speed was slow as 4×10^{-4} cm/sec and the water consumption was 1,8 m^3/ton due to the influence of the small constituent particles of the heap.As for the acid consumption, it was confirmed that 6,9 kg of acid was consumed per 1 kg of copper based on the recovered copper. This indicates that half of the acid was consumed compared to the 12 kg of acid consumed per 1 kg of copper shown in the previous study. This result is due to the fact that the copper quality of the copper oxide ore used in this study was 1,53%, which is higher than the 0,4% used in the comparative data.

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