UNDERGRADUATE THESIS

STUDY OF COPPER EXTRACTION FROM OXIDE ORE USING SULFURIC ACID SOLVENT

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MINING ENGINEERING STUDY PROGRAM
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APPROVAL PAGE

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Telah dipertahankan di hadapan Panitia Ujian yang dibentuk dalam rangka Penyelesaian Studi Program Sarjana Program Studi Teknik Pertambangan Fakultas Teknik Universitas Hasanuddin
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PREFACE

The author would like to express her gratitude to Allah Subhanahu Wa Ta'ala because by His grace the author was able to complete the Thesis entitled "Study of Copper Extraction from Oxide Ore Using Sulfuric Acid Solvent". The author does not forget to give greetings to the role model of Nabiullah Muhammad SAW who has sown the seeds of virtue as it is today. The preparation of this thesis is intended as a basic provision for completing studies at the Department of Mining Engineering, Faculty of Engineering, Hasanuddin University.

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ABSTRACT

ZALSA VIONATHA. *Study of Copper Extraction from Oxide Ore Using Sulfuric Acid Solvent* (supervised by Sufriadin)

Leaching of copper from Tonra oxide ore, South Sulawesi, has been conducted using sulfuric acid solvent. The aims of this study were to determine the mineralogical and chemical characteristics of copper oxide ore, to analyze the effect of sulfuric acid concentration and leaching time variables on copper extraction rate, and to analyze the effect of sulfuric acid concentration and leaching time variables on the dissolution of minerals. The analytical methods used in this research were the optical microscopic and X-Ray Diffraction (XRD) methods for mineralogical analysis and the Atomic Absorption Spectrophotometry (AAS) method for copper content determination. The leaching experiment was conducted using acid concentration and leaching time as research variables. The results of mineralogical analysis of copper oxide show that the mineral composition consists of pseudomalachite, hematite, and quartz. AAS sample analysis results on the oxide ore from Tonra showed that it contained 0.32% Cu. The maximum Cu extraction rate is 58.23%, which was obtained at a sulfuric acid concentration of 4 M and a leaching time of 60 minutes. The results of the XRD residue analysis showed that quartz and maghemite were not dissolved, while pseudomalachite, langite, and kaolinite were dissolved.

Keywords: Oxide Ore, Atmospheric Leaching, Sulfuric Acid, Extraction rate

ABSTRAK

ZALSA VIONATHA. *Studi Ekstraksi Tembaga dari Bijih Oksida Dengan Menggunakan Pelarut Asam Sulfat* (dibimbing oleh Sufriadin)

Pelindian tembaga dari bijih oksida Tonra, Sulawesi Selatan, telah dilakukan dengan menggunakan pelarut asam sulfat. Penelitian ini bertujuan untuk mengetahui karakteristik mineralogi dan kimia bijih tembaga oksida, untuk menganalisis pengaruh variabel konsentrasi asam sulfat dan waktu pelindian terhadap laju ekstraksi tembaga, dan untuk menganalisis pengaruh variabel konsentrasi asam sulfat dan waktu pelindian terhadap disolusi mineral. Metode analisis yang digunakan dalam penelitian ini adalah metode mikroskopis dan X-Ray Diffraction (XRD) untuk analisis mineralogi serta metode Atomic Absorption Spectrophotometry (AAS) untuk penentuan kadar tembaga. Percobaan pelindian menggunakan konsentrasi asam sulfat dan waktu pelindian sebagai variabel penelitian. Hasil analisis mineralogi bijih tembaga oksida menunjukkan komposisi mineral terdiri dari quartz, langite, maghemite, pseudomalachite, *dan* kaolinite. *Hasil analisis AAS sampel awal menunjukkan bijih tembaga oksida mengandung Cu sebesar 0,32% dengan tingkat pelindian maksimum Cu sebesar 58,23% yang diperoleh pada konsentrasi sulfuric acid 4 M dan waktu pelindian 60 menit. Hasil analisis XRD residu menunjukkan bahwa* quartz *dan* maghemite *tidak terdesolusi, sementara* pseudomalachite, langite, *dan* kaolinite *terdisolusi.*

Kata Kunci: *Bijih tembaga oksida*, *Atmospheric Leaching*, Asam Sulfat, laju pelindian

LIST OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

LIST OF SYMBOL AND ABBREVIATION

Symbol/Abbreviation	Explanation
Cu	Copper
M	Molar
FCC	Face Center Cubic
VMS	Volcanogenic Massive Sulfide
Zn	Zinc
Pb	*Plumbum*
PGE	Platinum-Group Elements
SEDEX	Sedimentary Exhalative Deposits
Ag	*Argentum*
Au	*Aurum*
XRD	X-Ray Diffraction
AAS	Atomic Absorption Spectrophotometry
gr	Gram
mL	Mili liter
rpm	Revolution per minute
V	Volume
PLS	Pregnant Leach Solution
μ	Micron
Qz	Quartz
Mgh	Maghemite
Pmlc	Pseudomalachite
Gth	Geothite
Å	Angstrom
Ppm	Part per million
η	Extraction rate
C_i	Metal consentration in PLS
m	Mass
W_i	Metal content
S/L	Solid/Liquid

LIST OF APPENDICES

CHAPTER I
INTRODUCTION

1.1 Backgrounds

Copper (Cu) originates from the Latin cuprum, a reddish brown solid metal with an atomic number of 29 and a mass number of 63.54 (Putra et al., 2014). Copper has good electrical and heat conductor properties, is malleable, and is easily formed into plates or wire. Judging from its chemical properties, copper is included in the group of metals that are difficult to oxidize. The most important copper minerals are sulfide and hydroxide compounds. Copper is found in ore form in nature and is an important metal in industry (Sukamto et al., 2015).

To meet industrial demand for copper and the sale of copper, which is not permitted in the form of ore without processing, it is necessary to develop copper ore processing technology. The process of extracting copper minerals with hydroxide compounds is usually carried out using hydrometallurgical methods (Sukamto et al., 2015). Hydrometallurgy is a metal extraction process using dilute solvents and reagents below 1 gramol at temperatures of less than 100 °C (Pratama, et al., 2018).

Research on the extraction of copper from oxide ore was carried out with variations of 0.05–0.5 M sulfuric acid and produced recoveries of 76.70% to 94.26% (Kang et al., 2021). Another study regarding copper extraction using sulfuric acid with a concentration of 0.5 M, ore size distribution of -150 mesh, and an ore weight/leach solution volume ratio of 3 g/l resulted in an extraction rate of 97.98% (Setyawan & Mubarok, 2015). Research on the copper leaching process using the organic solvent citric acid was carried out with an acid concentration of 0.1 M to 1 M and an extraction time of 30 minutes to 240 minutes, which can extract 30% to 92% copper from malachite ore (Shabani et al, 2012).

In industry, to extract copper from oxide ore, a leaching process in sulfuric acid is used (Setyawan and Mubarok, 2015). The copper extraction process from using sulfuric acid solvent has a higher extraction rate compared to the xtraction process using organic acids such as citric acid. Therefore, this will discuss the processing of copper oxide ore using sulfuric acid, which is one of the reagents that can be used and has a high extraction rate for extracting copper ore.

1.2 Problem of Research

The formulation of the problem of the research are:

1. What are the mineralogical and chemical compositions of the copper oxide ore sample?
2. What is the effect of sulfuric acid concentration and time variables on the copper extraction rates?
3. What is the effect of sulfuric acid concentration and time variables on the dissolution of minerals?

1.3 Purposes of Research

The purposes of the research are:

1. To determine the mineralogical and chemical compositions of copper oxide ore sample.
2. To analyze the effect of sulfuric acid concentration and time variables on the copper extraction rates.
3. To analyze the effect of sulfuric acid concentration and time variables on the dissolution of minerals.

1.4 Benefit of Research

This research can be useful for increasing insight and providing information regarding other alternatives to processing and extracting copper from oxide ore so that it can be processed and extracted effectively.

1.5 The Scope of Research

This research was conducted at the Laboratory-Based Education (LBE) Analysis [illegible]ıeral Processing, Mining Engineering Study Program, Hasanuddin [illegible]y. This research was carried out to extract copper oxide ore originating [illegible]de Ore Deposits, Tonra District, Bone Regency, South Sulawesi Province, [illegible] leaching method. The research carried out was limited by the analysis of extraction rates only covering copper, so that the presence of other elements was not taken into account or ignored. The conditions for the concentration of sulfuric acid used in the leaching process were 1 M, 2 M, 3 M, and 4 M, and the time used in the leaching process are 30 minutes, 60 minutes, 90 minutes, and 120 minutes.

CHAPTER II
LITERATURE REVIEW

2.1 Copper

Copper is a metal with the chemical formula Cu. It has a grayish brown color and a Face Center Cubic (FCC) crystal structure. Copper can be classified into three groups, namely sulfide ores, oxide ores, and pure ores (native) (Sukamto et al., 2015). Copper is a heavy metal element with an oxidation level of 0 to 2+, which is the highest oxidant of copper in compound form (Hasria et al., 2015).

Copper is one of the most important non-ferrous metals and is widely used from simple industry to high-tech industry. It is used either pure or alloyed with other metals. Physically, copper is reddish brown in color, soft, so it is easy to hammer, can be shaped, and is a good conductor of heat and electricity. Copper has a density of 8,920 kg/m3, a thermal expansion of 16.5 x 10-6 K-1, and a thermal conductivity of 400 mK (Natanael, 2012). The physical characteristics of copper can be seen in Table 1.

Table 1 The physical characteristics of copper

Physical Characteristics	Description	Symbol
Atomic number	29	
Atomic weight	63.54	
Density	8,960	Kg/m^3
Melting point	1,080	^OC
Boiling point	2,567	^OC
Spesific heat capacity	386	J/kg
Electrical conductivity	5.98×10^2	$Ohm^{-1}m^{-1}$
Electrical resistivity	1.67×10^{-8}	Ohm.m

Source: Lusty & Hannis (2009)

Copper ore is a raw material that plays an important role in the mining and metallurgical industries. Copper ore consists of minerals such as bornite, rite, and chrysocolla, which contain various copper contents. The most copper ores are sulfides, chalcocite (Cu_2S), chalcopyrite ($CuFeS_2$), (CuS), and bornite (Cu_5FeS_4). The Cu concentrations of these minerals is low in an ore compared to the copper oxide. Generally, copper ore contains from 0.5% (open pit mines) to 1 or 2% Cu (underground mines). Copper is also obtained from oxidized minerals, cuprite (Cu^2O): carbonate, malachite, and azurite: silica and chrysocholla. Ore in this form is mostly processed using hydrometallurgical methods. Each copper mineral has a different Cu percentage because the chemical structure of each copper mineral is different (Abdul, 2014).

Broadly speaking, copper ore is divided into two groups, namely the sulfide and oxide groups. The main ore minerals of copper oxide are malachite and azurite, which have a bluish green color and are included in hydrated copper carbonate. Several compounds formed by copper can be seen in Table 2.

Table 2 Classification of copper ore minerals.

Mineral Type	**Chemical Formula**	**Max. Cu Content**
Native Copper	Cu	100%
Sulfide Copper Ore		
Chalcopyrite	$CuFeS_2$	34.6%
Bornite	Cu_5FeS_4	63.3%
Chalcosite	Cu_2S	79.9%
Covellite	CuS	66.4%
Antlerite	$Cu_3SO_4(OH)_4$	53.7%
Enargite	Cu_3AsS_4	49.0%
Oxide Copper Ore		
Cuprite	Cu_2O	88.8%
Malachite	$CuCO_3Cu(OH)_4$	57.5%
Azurite	$2CuCO_3Cu(OH)_4$	55.3%
hrysocolla	$CuSiO_32H_2O$	36.2%

sty & Hannis (2009)

2.2 Copper Deposits

Copper deposits are distributed across diverse geological settings globally. While hydrothermal deposits hold the greatest global significance, local importance is attributed to magmatic and supergene deposits. Although various types of mineral deposits contain varying amounts of copper, their economic significance is generally limited. The following are copper mineral deposits (Lusty & Hannis, 2009).

2.2.1 Porphyry deposits

Porphyry copper deposits, comprising 50–60% of global copper production, are vital sources of copper, molybdenum (constituting 99% of world production), and rhenium. These deposits, rich in gold, silver, and tin, are associated with subduction-related felsic igneous intrusions, primarily found in plate boundary collision zones like the Canadian Cordillera, the Andes Mountains, and the western margin of the Pacific Basin in regions such as the Philippines, Indonesia, and Papua New Guinea. In Indonesia, phoriphiry deposits found in PT Freeport Indonesia. These deposits exhibit a stockwork of quartz veins and breccias containing copper sulfides, gold, and/or molybdenum. The mineralization spans intrusive and host rocks, featuring a core of intense alteration extending outward into distinct zones with secondary alteration minerals. Ranging from tens of millions to billions of tons, these deposits typically contain hundreds of millions of tons of ore, with copper grades varying from 0.2% to over 1% (Lusty & Hannis, 2009).

2.2.2 Sediment-hosted Deposits

Sediment-hosted deposits, constituting approximately 20% of global copper production and serving as significant sources of lead, zinc, silver, and the primary global source of cobalt, notably in the Central African Copperbelt, are the second most important copper source. These deposits manifest as disseminations of fine-grained sulfides within various continental sedimentary rocks, including black ndstone, and limestone, often associated with red-bed sandstones and s. Tonnages vary, averaging 22 million tons with grades of 2.1% Cu and ;, but can reach several hundred million tons. Notably, the Lubin orebody in southwest Poland contains a staggering 2600 million tons with >2.0% Cu and 30–80 g/t Ag. The Central African Copperbelt, spanning Zambia and the Democratic Republic of Congo, constitutes the world's largest province with stratiform sediment-hosted copper mineralization. Boundary distinctions between different base-metal deposit types in sedimentary and volcanic sequences can be ambiguous and reliant on specific selection criteria (Lusty & Hannis, 2009).

2.2.3 Red-bed Copper Deposits

There are two forms of red-bed mineralization: volcanic and sedimentary. Volcanic-hosted deposits are found in mafic terrestrial lava flows and associated volcaniclastic sedimentary rocks, where sulfides are disseminated throughout permeable host rocks or fill cavities. On the other hand, sedimentary-hosted deposits develop in red continental sediments deposited in oxidizing environments, with disseminated sulfides in permeable layers of the host rock. The precipitation of copper in these deposits is proposed to occur when oxygen-rich fluids rise through permeable zones and encounter reduced materials like organic matter and pyrite. Sedimentary-hosted deposits are typically economically unviable due to their small size, although some, like those in Dzhezkazaga, Kazakhstan, and Paoli, USA, have been exploited. In contrast, volcanic-hosted deposits are significant copper producers, with tonnages ranging from hundreds of thousands to hundreds of millions of tons and copper grades typically around one to four percent (Lusty & Hannis, 2009).

2.2.4 Volcanogenic Massive Sulfide (VMS) Deposits

Volcanogenic Massive Sulfide (VMS) deposits play a crucial role as sources of copper and various other metals due to their widespread occurrence, significant tonnages ranging from 0.1 to 500 million tons, and relatively high grades. These deposits commonly yield precious metals like silver and gold as by-products. The ore bodies, characterized by large, stratiform lenses and sheets, are formed on the through the discharge of metal-rich hydrothermal fluids. This geological non occurs in extensional tectonic settings, with modern instances developing at spreading centers and in oceanic arc terranes. Typically, a aped, strata-bound massive sulfide body is underlain by a stockwork feeder zone. VMS deposits are typically constrained to specific stratigraphic intervals within a geological province and tend to occur in clusters. They can be categorized into three main types based on their mineralogy: Kuroko, Besshi, and Cyprus. While VMS deposits vary widely in size, they generally exhibit high grades and low tonnage. Notable examples include the Rio Tinto deposit in Spain, which contains around 250 million tons of 1% Cu, 2% Zn, and 1% Pb (Lusty & Hannis, 2009).

2.2.5 Magmatic Sulfide Deposits

Magmatic sulfide deposits are a diverse group that contains copper along with nickel and Platinum-Group Elements (PGE), existing as concentrations within mafic and ultramafic rocks. As magma ascends through the Earth's crust and cools, a distinct liquid sulfide phase may form if the magma has sufficient sulfur content, resulting in droplets of sulfide liquid within a silicate liquid. Nickel, copper, PGE, and iron are prone to transferring into this sulfide phase from the surrounding magma. Due to its higher density, the metal-rich sulfide liquid tends to sink, creating sulfide concentrations on the floor of the magma chamber. Globally, these deposits typically exhibit copper grades ranging from 0.2% to 2%, with ore tonnages varying from a few hundred thousand to tens of millions of tons. The largest magmatic sulfide nickel-copper deposits, dating back to the Archean (4000–2500 million years) and Proterozoic (2500–540 million years) eras, are notably found in Sudbury, Ontario, and Noril'sk-Talnakh, Russia (Lusty & Hannis, 2009).

2.2.6 Sedimentary Exhalative Deposits (SEDEX)

SEDEX deposits, vital sources of lead, zinc, and silver, with copper as a potential significant by-product, are formed through the exhalation of brine into seawater, leading to the chemical precipitation of minerals upon brine cooling. While sharing similarities with VMS deposits, SEDEX deposits differ by lacking a close volcanic association and are believed to form farther from the exhalative source. Typically ed by sheet or tabular lenses comprising bands of fine-grained sulfide sed with shale, silt, and carbonate host rocks, these sulfide bodies are a few meters thick but can extend laterally for over a kilometer. Global deposits have a median tonnage of 15 million tons with grades of 5.6% Zn, 2.8% Pb, and 30 g/t Ag. Although copper content may reach up to one percent, deposits like Broken Hill, McArthur River, and Mount Isa in Australia, Meggen and Rammelsberg in Germany, and Tynagh in Ireland are noteworthy SEDEX deposits where copper serves as a significant by-product (Lusty & Hannis, 2009).

2.2.7 Epithermal Deposits

Epithermal deposits, known primarily for their gold production, may also contain significant quantities of silver, copper, and other metals. Associated with subduction-related environments at plate boundaries, these deposits take the form of veins, stockworks, or breccias and are generally Tertiary to Quaternary in age, spanning 63 million to the present. Typically forming at shallow crustal levels (300–600 m), they result from the circulation of magmatic fluids through volcanic rocks and often have spatial relationships with porphyry deposits. Principal ore minerals in these deposits include chalcocite, covellite, bornite, and native gold, with the occasional presence of chalcopyrite. While there's notable variation in grade and tonnage, some deposits, such as El Indio in Chile, exhibit extremely high grades, reaching up to 178 g/t Au, 109 g/t Ag, and 3.87% Cu (Lusty & Hannis, 2009).

2.2.8 Skarn Deposits

A skarn is a metamorphic rock that forms as a result of chemical alteration by hydrothermal and other fluids. Copper skarns most frequently develop where granite intrusions are emplaced into continental margin carbonate sequences, such as limestone or dolomite, causing intense alteration and mineral replacement. Deposits are highly varied in form, ranging from tabular lenses to vertical pipes with irregular ore zones controlled by the intrusive contact. The largest copper skarns are associated with porphyry copper deposits. Copper mineralization is present as stockwork veining and dissemination in both the intrusive and the surrounding host rock. Chalcopyrite tends to be the dominant copper mineral, with bornite and tennanite. Globally, copper skarns average one to two opper, generally ranging from one to hundred million tons, although some al deposits exceed 300 million tons. In Indonesia, phoriphiry deposits PT Freeport Indonesia. Major copper skarn mineralization is associated with the Ok Tedi porphyry intrusive system in Papua New Guinea (Lusty & Hannis, 2009).

2.2.9 Vein Deposits

Vein deposits are intimately associated with many of the deposit classes discussed above. Veins are mineralized structures typically developed along fractures and varying in thickness from centimeters to tens of meters or more. Sulfides are commonly irregularly distributed as patches and disseminations within quartz, carbonate, and other gangue minerals. The importance of vein deposits has steadily diminished as changing economics and improved extraction techniques have allowed large, low-grade deposits to be mined. Copper commonly occurs in veins associated with quartz, silver, gold, and occasionally uranium, antimony, and phosphorus. These polymetallic veins may be related to porphyry copper, copper skarn, epithermal gold-silver copper, and sediment-hosted copper deposits. At the El Indio mine in Chile, massive sulfide veins can be over 10 m thick with average grades of 2.4% Cu (Evans, 1993).

2.2.10 Supergene Deposits

Secondary enrichment can affect most classes of mineral deposits. Supergene alteration is the in-situ secondary enrichment of a deposit whereby the primary ore minerals are oxidized, dissolved, and reprecipitated by reduction, commonly at the water table. Supergene enrichment takes place above the primary hypogene ore and can be laterally and vertically extensive (reaching tens of meters downward). This is an important process as it can affect the economics of mining, especially of low-grade porphyry and VMS deposits. Enrichment blankets containing high-grade copper minerals, such as chalcocite, covellite, and bornite, may enhance the average grade of the ore to one to three percent copper. Supergene enrichment favors rocks that are permeable to meteoric water and contain abundant pyrite to allow the formation of oxidizing acids. The presence of acid-soluble metal-bearing minerals
lox barrier (such as the water table) at depth may also contribute to the
of supergene deposits. Supergene enrichment has been a major factor in
opment of several porphyry copper deposits. At La Escondida, in Chile,
gene blanket constitutes around 65% of the copper resource of the deposit.

Grades of up to 3.5% Cu are recorded in this zone (Lusty & Hannis, 2009).

2.3 Copper Extraction Technology

Copper in smaller amounts is also found in the form of oxide, native, silicate, carbonate and sulfate minerals (Schlesinger et al., 2011). Currently, mining companies are already mining ore with a Cu content of 0.5%, and this level has dropped significantly compared to several years ago at a copper content of 1-2%. For copper sulfide ore, the dominant extraction process used is through the flotation route to produce copper concentrate, which is then melted and purified by pyrorefining and electrolytic refining. This process pathway contributes to ±80% of total world copper production (Schlesinger et al., 2011). Meanwhile, for copper oxide ore and some secondary sulfide ores, the copper extraction process in industry is also carried out using the hydrometallurgical route. This hydrometallurgical route consists of a leaching process in sulfuric or hydrochloric acid, followed by solvent extraction and electrowinning. In contrast to oxide-type ore, a certain oxidizer is needed to dissolve copper from sulfide-type ore at atmospheric or high pressure.

Copper processing and extraction involve a series of physical and chemical processes to obtain copper from its ore. The stages of copper processing and extraction include exploration and discovery of copper ore, copper ore mining methods, processing of copper ore, beneficiation of copper ore, smelting and extraction of copper from copper ore concentrate, and refining copper to produce pure copper. Copper oxide ore is more difficult to extract than sulfide ore because the copper in the oxide ore is bound to oxygen and is not easily released. Therefore, sulfuric acid solvents can be used to extract copper from oxide ore because sulfuric acid can dissolve copper oxide and form copper (II) sulfate ions. The process of extracting copper from sulfide ore and oxide ore is different. For sulfide ores, the sulfide concentrate is usually melted in a furnace, while for oxide ores, the oxide concentrate is usually processed by a hydrometallurgical process using chemical solvents to extract the copper from the ore. After that, the copper produced through n from sulfide ore or oxide ore is still not pure and must be further purified r electrolysis (Putra et al, 2014).

e of the methods for concentrating copper minerals is froth flotation.

Flotation is preceded by crushing and grinding the mined copper ore into small particles (~50 mm) (Schlesinger et al., 2011). Flotation aims to separate copper minerals from impurities by exploiting differences in the physical properties of the mineral surface by floating one of the minerals. Minerals that are floated are minerals that like air (hydrophobic), while minerals that are not floated are minerals that like water (hydrophylic). In the flotation concentration process, one of the most important things is the addition of reagents to the mixture of water and minerals (pulp) so that there is a change in the surface properties of the mineral particles. Because minerals are generally hydrophilic (like water), it is necessary to change the surface properties to become hydrophobic. The properties of a reagent in the flotation concentration process are activators, depressants, and dispersants (Napier-Munn, 2006).

2.3.1 Pyrometallurgy

Pyrometallurgy is a mineral processing method using high temperature. The essence of this process is the processing of copper through a process that aims to convert sulfide impurities into oxides, also called a roasting process. Pyrometallurgy is used by several large companies to produce commercial metals. The stages in the pyrometallurgical process are drying (removing the water content in the ore), calcination (removing crystal water from the ore), smelting, and refining (increasing the content of a metal) (Tarumingkeng et al., 2016). Pyrometallurgy uses a high energy so that operational costs are high and produces SO_2 (sulfur dioxide) gas, which is very dangerous and can damage the environment (Murta & Pintowantoro, 2012).

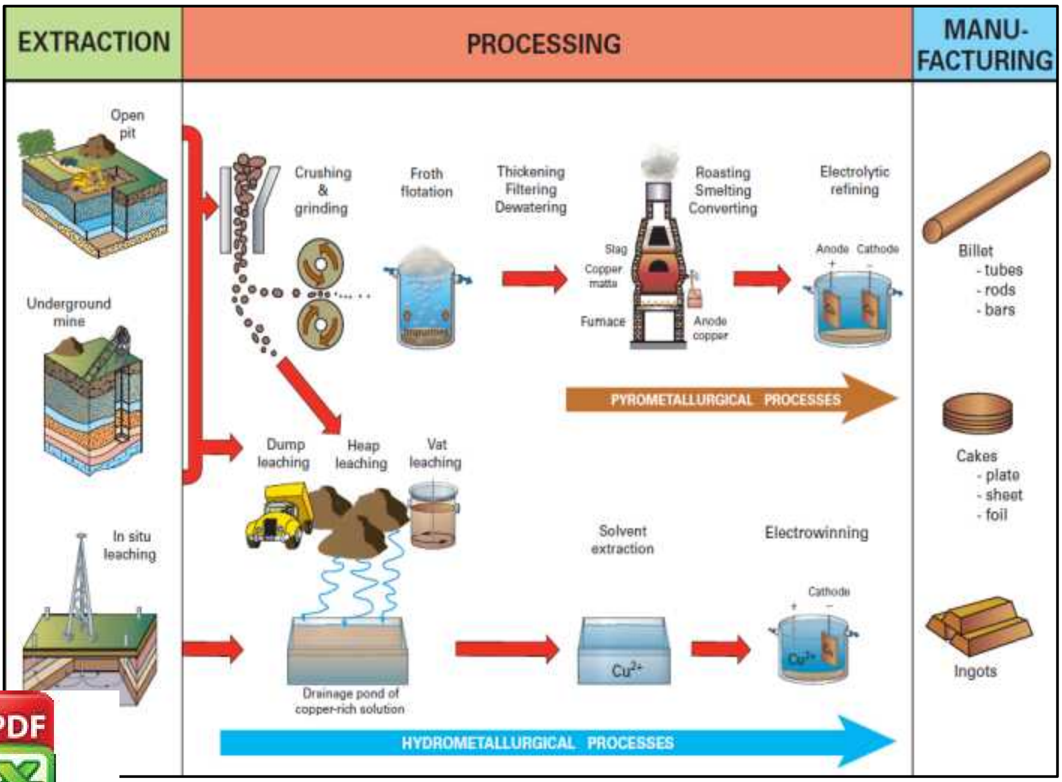
2.3.2 Hydrometallurgy

Hydrometallurgy is the process of metal extraction from rocks or ores using an aqueous solvent (aqueous solution) or the use of a liquid chemical substance that can dissolve certain particles at temperatures below 200°C (Prathama, 2022).
H d tallurgy is a method of processing copper from natural rocks based on
a processing agent, but what water means is not ordinary water but water
een mixed with a certain acid as a reducing agent.

drometallurgy has several advantages, namely low processing costs, a high extraction rate, relatively easy processing, and a relatively shorter processing process. As technology advances, the pyrometallurgical process is no longer applied for copper processing because it is replaced by a more economical process, namely the hydrometallurgical process. The choice of solution for the hydrometallurgical process is based on the type of metal to be extracted. This process generally uses acid as a reducing agent, for example sulfuric acid (Natanael, 2012).

2.3.3 Electrometallurgy

Electrometallurgy is an extraction process that involves the application of electrochemical principles, both at low and high temperatures. The working principle of electrometallurgy is electrolysis, where electrical energy is used to deposit a metal or metals on one of the electrodes (Pagnanelli et al., 2004). This electrolysis work consists of two levels: electrowinning (an electrochemical process used to reduce metal cations to the cathode surface from a water solution originating from a chemical washing process) and electrorefinery (purifying the metal).



gure 1 Pyrometallurgical and hydrometallurgical copper processing
(Lusty and Hannis, 2009)

Currently, hydrometallurgy is mainly used only for oxide ores or low-grade ores. But the hydrometallurgical process has ma ny advantages compared to the pyrometallurgical process, including (Lusty & Hannis, 2009):

1. Low grade ore can be processed
2. Higher energy efficiency due to the lower temperatures required. Higher energy efficiency due to lower temperatures required. Capital and lower operating costs make hydrometallurgy more economical for small-scale operations.
3. Lower environmental impact because liquid waste streams are easier to contain and neutralize than, for example, sulfur dioxide gas released during smelting.

2.4 Leaching of Copper Using Sulfuric Acid

Solid-liquid extraction, or leaching, is the process of separating soluble solid substances (soluble substances) from their mixture with other insoluble solid substances (inert) by dissolving. The extraction process consists of three steps, namely (Oktaviani, 2017):

1. Adding a mass of solvent to contact with the sample, usually through a dilution procces.
2. The solute will be separated from the sample and dissolved by the solvent to form the extract phase.
3. Separation of the extract phase from the sample.

Leaching is the process of extracting minerals or solutes from solids by dissolving them in a liquid or solvent, either in nature or through industrial processes. Dissolution, desorption, or complexation are factors for separating dissolved substances (Kulkarni, 2015). Currently, leaching is one of the most important front-end operations in hydrometallurgy, but in the future, hydrometallurgical processes for the extraction rate of secondary metals, the treatment of low-grade and complex ores, as well as research and development gh-temperature and high-pressure processes, will become increasingly t.

furic acid is a solvent that is often used in the extraction of copper from sulfide ores and oxide ores. Sulfuric acid can dissolve copper minerals and form copper (II) sulfate ions, which can then be precipitated and further purified. Sulfuric acid has the ability to dissolve copper minerals in large quantities, thereby increasing the efficiency of copper extraction. Sulfuric acid can be used to extract copper from oxide ores that are difficult to extract with other solvents (Subagja et al., 2016).

Dissolving or leaching using sulfuric acid is a method commonly used in metal processing, both on an industrial and laboratory scale. Sulfuric acid has the ability to dissolve most metals and metal compounds, including oxides and sulfides, resulting in the formation of sulfate compounds. According to Dey et al. (2017), sulfuric acid is the most commonly used solvent for the extraction of metals such as copper, nickel, and cobalt from mineral ores, electronic waste, and industrial waste.

The use of sulfuric acid in copper extraction is very important because sulfuric acid is used as a leaching solution to dissolve copper from the ore. Sulfuric acid is used as a reducing agent in the copper extraction process. In the leaching process using sulfuric acid solution, atmospheric pressure is used and can be assisted by ozone. The influence of variable sulfuric acid solution concentration and leaching process time on the extraction rate of Cu, Fe, and Zn was also studied. The research results showed that leaching using a sulfuric acid solution with a concentration of 20 g/L produced the highest extraction rate: Cu of 79% (24 hours) (Kusdarini et al., 2023).

The use of sulfuric acid in copper extraction is very effective and efficient because sulfuric acid is easy to obtain and has low processing costs. Sulfuric acid can also be used in the gold and silver extraction processes using thiourea. Apart from that, sulfuric acid can also be used as an oxidizer in leaching copper from chalcopyrite ore originating from the Pacitan area of East Java. A series of leaching experiments were carried out with variations in sulfuric acid concentration, ore particle size distribution, temperature, and ore weight/leach volume ratio, and their
the percent copper extraction were studied.

use of sulfuric acid in copper extraction is also very important because
one of the metals that is needed by industry. Therefore, the Cu extraction

rate in copper ore processing needs to be optimized considering the very large industrial demand for Cu metal. The use of sulfuric acid in copper extraction can find the best concentration of sulfuric acid solution and leaching time so that it can save on the use of sulfuric acid solution and leaching time.

The use of sulfuric acid in copper extraction can also help protect the environment. Sulfur dioxide gas, for example, is captured and converted into sulfuric acid, which can then be used in the extraction process or sold for purposes such as making fertilizer. Copper ore also contains other elements such as Fe and Zn, which can be recovered using sulfuric acid. Therefore, the use of sulfuric acid in copper extraction is very important to protect the environment and maximize the use of natural resources. There are several factors that need to be considered in the copper extraction process using sulfuric acid, including the concentration of sulfuric acid, temperature, and reaction time. The sulfuric acid concentration, temperature, and reaction time need to be determined to extract copper from oxide ore with high efficiency (Setyawan & Mubarok, 2015).

The concentration of sulfuric acid is a very important factor in the dissolution process. The right concentration of sulfuric acid will affect the rate of dissolution and the purity of the extraction results. The optimal sulfuric acid concentration for metal extraction from a particular sample may vary depending on the type of metal and the physical and chemical properties of the sample. Temperature is also an important factor in dissolving sulfuric acid. High temperatures will speed up the dissolution reaction, but they can also increase equipment damage and require an adequate cooling system. Reaction time also affects the effectiveness of dissolution using sulfuric acid (Li et al., 2019).

2.5 Samples Analytical Methods

Several analytical methods that need to be carried out to determine the extraction rate of copper are as follows:

croscopic Analysis

pic analysis is an analytical method used to study the structure and s of objects using a microscope. This method can be used to analyze various types of samples. Microscopic analysis can help to understand the structure and function of objects and can be used to identify the causes of disease and study biological processes. Several types of microscopes used in microscopic analysis include light microscopes, electron microscopes, and fluorescence microscopes.

In microscopic analysis, observations are made using a microscope, which has the ability to enlarge the image of the sample. This method can be used to analyze various types of samples, such as cells, tissues, and organisms. Microscopic analysis can help understand the structure and function of objects and can be used to identify the causes of disease and study biological processes. Several types of microscopes used in microscopic analysis include light microscopes, electron microscopes, and fluorescence microscopes. This method is very important in the fields of natural science and medicine because it can help understand the structure and function of objects in detail.

2.5.2 XRD Analysis

X-Ray Diffraction (XRD) is an effective analytical method for describing rocks and certain chemical compounds in solid form using diffraction or X-ray reflection. X-rays are electromagnetic radiation produced by the sudden deceleration of particles at high speed. The wavelength of X-rays is of the same order as the distance between atoms, so it is used as a source of crystal diffraction. The high voltage in the X-ray tube produces electrons, which are then fired at the target metal (anode), resulting in X-rays radiating in all directions (Moore, 1997). In simple terms, the working principle of XRD is that every compound consists of an arrangement of atoms that form a certain plane. If a plane has a certain shape, then light particles (photons) arriving at a certain angle will only produce a characteristic reflection or refraction pattern (Masruroh, 2013).

2.5.3 AAS Analysis

Atomic Absorption Spectrophotometry (AAS) is an analytical method used to [illegible] metal levels in various types of samples. This method works by [illegible] the amount of light absorbed by the metal atoms in the sample being [illegible]. AAS analysis can be used to analyze metal levels in various types of [illegible] such as water, rocks, and industrial waste. This method can help determine whether a sample is suitable or not for use, especially in terms of health and the environment. Some of the advantages of the AAS method are high sensitivity, good accuracy, and the ability to analyze various types of metals.

The AAS method can be used to analyze various types of metals, such as copper, zinc, iron, and nickel. This method can be used to analyze metal levels in various types of samples, such as water, soil, rocks, and industrial waste. The AAS method has high sensitivity, good accuracy, and the ability to analyze various types of metals