A STUDY ON THE POTENTIAL OF TIN RECOVERY FROM IRON ORE TAILING

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LIST OF SYMBOLS

SnO_2	Cassiterite
Al_2O_3	Aluminium Oxide
SiO_2	Silica
P_2O_5	Phosphorus Oxide
Fe_2O_3	Iron(III) Oxide
SO_3	Sulphur Trioxide
CaO	Calcium Oxide
TiO_2	Titanium Oxide
Pb_2SnO_4	Tin (iv) Dilead Oxide
Cr_2O	Chromium Oxide
MnO	Manganese Oxide
CuO	Copper(II) Oxide
ZnO	Zinc Oxide
As_2O_3	Arsenic(III) Oxide
ZrO_2	Zirconium Dioxide
Br	Bromine
BaO	Barium Oxide
WO	Tungsten Trioxide
PbO	Lead(II) Oxide

LIST OF ABBREVIATIONS

PSD	Particle size distribution
SEM	Scanning electron microscope
XRF	X-ray fluorescence
XRD	X-ray diffraction

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KAJIAN MENYENAI KEUPAYAAN PENGUMPULAN TIMAH

DARIPADA ‘TAILING’ BIJIH BESI

ABSTRAK

Sampel ‘tailing’ bijih besi diperoleh daripada kilang pemprosesan besi di lombong bukit kachi, kedah. Matlamat kajian ini adalah untuk mencirikan dan memproses bijih timah dalam ‘tailing’ bijih besi. Kaedah penyelidikan telah dibahagikan kepada dua bahagian: pencirian dan pemprosesan. Mod kejadian, saiz butiran, taburan mineral, dan penilaian analisis pembebasan dikaji menggunakan mikroskop optik, mikroskop polarisasi, dan mikroskop pengimbasan elektron (sem). Sinar-x pendarfluor (xrf) dan pembelauan sinar-x (xrd) digunakan untuk menentukan komposisi kimia sampel. Ujian pendarfluor timah digunakan untuk mengesahkan kehadiran timah dalam sample yang telah diproses menggunakan spektrum warna cahaya. Bagi kaedah pemprosesan, sampel ‘tailing’ bijih besi telah melalui proses pengecilan saiz untuk pembebasan mineral sebelum pengasingan graviti menggunakan ‘mozley table’. Menurut analisis sem, pembebasan mineral mula memberikan tanda terbebas pada pecahan saiz (-1mm +0.5mm). Menurut analisis taburan saiz zarah, 50% daripada sampel mempunyai saiz kurang daripada 1.4mm dan 40% daripada sampel mempunyai saiz lebih daripada 1.4mm. Mengikut penemuan, pemisahan ‘mozley table’ boleh meningkatkan pemulihan timah daripada 0% kepada 4.05% peratus timah asli. Ujian pendarfluor timah mendedahkan kehadiran timah dalam sampel pekat, di mana nyalaan warna biru dapat diperhatikan dengan jelas selepas tabung uji dicelup dengan larutan ion timah. Kesimpulannya, mineral tin telah diklasifikasikan dan ‘mozley table’ tidak sesuai digunakan untuk mendapatkan tin daripada ‘tailing’ bijih besi kerana hasil yang didapatkan terlalu rendah.

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ABSTRACT

The iron ore tailings sample was obtained from an iron processing plant in Bukit Kachi Mine, Kedah. The goal of this study is to characterise and process the tin in iron ore tailings. The method research has been divided into two parts: characterization and processing. The mode of occurrences, grain size, mineral distribution, and liberation analysis assessment were studied using an optical microscope, polarising microscope, and scanning electron microscope (SEM). X-ray fluorescence (XRF) and X-ray diffraction were used to determine the chemical composition of the sample (XRD). The Tin Fluorescence test was used to confirm the presence of tin in the concentrate using light colour spectrum. For the processing method, an iron ore tailings sample undergone comminution process for mineral liberation before gravity separation using the Mozley table. According to SEM analysis, mineral liberation began to give a liberated sign at a size fraction of (-1mm +0.5mm). According to the particle size distribution analysis, 50% of the samples have a size less than 1.1mm and 30% of the samples have a size greater than 1.1mm. According to the findings, the Mozley table separation can improve tin recovery from 0 percent Sn to 4.05% percent Sn. Tin Fluorescence testing revealed the presence of tin in concentrate samples, where the blue colour flame can clearly observe after the test tube dipped with the tin ion solution. In conclusion, tin minerals had been characterized and Mozley table still not suitable for tin recovery in iron ore tailing as the recovery is very low.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Tin's origins are lost to history. Bronzes, which are copper–tin alloys, were used by humans long before pure tin metal was discovered. Bronzes were widely used in ancient Mesopotamia, the Indus Valley, Egypt, Crete, and Peru. Much of the tin used by the early Mediterranean peoples appears to have come from the British Isles' Scilly Isles and Cornwall, where tin mining dates back to at least 300–200 Before the Current Era (BCE) (Britannica, 2021). Before the Spanish conquest, tin mines were active in both the Inca and Aztec domains of South and Central America. Tin is represented by the symbol Sn, which is an abbreviation of the Latin word for tin, Stannum.

Tin is a metal that has been utilized for thousands of years. Tin's electrically conductive and malleable qualities make it valuable in a variety of fields, including electronics, medicine, building, and aerospace. Tin was highly esteemed by many civilizations prior to the twentieth century due to its ease of handling and the usage of more complex materials. Tin is mined in nearly equal numbers from ores (mainly traditionally mined but also through some artisanal mining) and secondary sources (recycled materials), yielding about 300,000 tonnes per year. China and Indonesia produce over 70% of the world's tin and are home to the majority of the world's tin smelters (López et al., 2018). During the 20th century, tin prices significantly fell due to its abundance. In the early 1900s, a lot of tin was consumed by manufacturing industries in Europe and US. Usage rates in these areas fell significantly after having a constant increase during previous decades.

There are often varying amounts of impurities in different parts of each deposit which results in separate processing for each deposit on a site-by-site basis. Global tin consumption need has increased annually since the third industrial revolution, but tin supplies are quickly depleting and will be depleted in 20 years (Zhang et al., 2019). According to the US Geological Survey's Minerals Commodity Summaries 2017, the world's confirmed tin reserves total 4.7 million tonnes, with the majority of them concentrated in China (110 kt), Indonesia (80 kt), Brazil (70 kt), and Malaysia (70 kt) (25 kt). Between 1999 and 2016, tin reserves fell dramatically, from 9.6 Mt to 4.7 Mt. (Su et al., 2017).

Tin has a low melting point of 232°C, and liquid tin easily alloys with and wets other metals. Tin is malleable, ductile and resistance to corrosion of tin render which make it suitable for use in variety of applications. Tin is required for the building industry, the manufacture of autos and other consumer items, and packaging. One of its most important applications is in the electronics industry, where it is used to make specialized solders. New lithium ion batteries, tin– stainless steel alloys, and energy production technologies all require tin (López et al., 2018). Because metallic tin is chemically stable and harmless, it is commonly utilized in the manufacture of cans, tinfoil, and food packaging (Su et al., 2017). Electronic solder, chemicals, and tinplate accounted for 43.4 percent, 15.5 percent, and 14.7 percent, respectively, of global tin use in 2015.

The International Tin Research Institute (ITRI) has forecasted that the reserve of economically recoverable tin was only 2.2 Mts in 2016, which would merely meet the current global tin demand for approximately eight years (Su et al., 2017). This will make the original tin resources exhausted in a few years. A study from Zijian Su and Yuanbo Zhang,2017, since tin mine production cannot meet the demand for global tin consumption, tin-bearing secondary resources become important alternative sources for tin production. It has been stated that the tin production from renewable resources accounted for nearly 30 wt.% of the global tin consumption. Hence, the attention have been paid on the recovery of tin from secondary resources, such as tailings, slags, Waste from Electrical and Electronic Equipment (WEEE), etc.

1.2 Problem Statement

Tin processing is one of the most time-consuming, tedious and labour-intensive processes in the metal industry (Britannica, 2021). Tin has several different physical forms that are derived from ore washing and grinding, tin refining and the percentage of recovery of tin and other minor impurities in the tailing. The difficulty of the process puts extra importance on both selecting tin source regions with low content as well as selecting an appropriate manufacturing process to start from.

The source of tin for this research is from iron ore tailing. In the mineral ore tailing, there is a high concentration of iron, and a small concentration of tin. The concentration of tin in the ore is not worth extracting, but it can be left in the tailing as an environmental pollutant. Tin is a toxic heavy metal that can cause harm to humans and the environment. It is important to manage and clean up tin-containing tailings to prevent contamination There have been numerous studies into the procedure of extracting tin from other materials. Tin can be separated using physical means or pyrometallurgy in most cases. However, due to the low percentage of tin concentration in the sample, the potential for tin recovery is limited. As a result, appropriate tin extraction from iron ore tailings is critical for increasing the percentage of tin and making it affordable to the mining industry.

1.3 Objectives

The objectives of this research are :-

1. To determine and characterize the tin content in the iron ore tailing samples.
2. To study the potential recovery using Mozley table to process tin in iron ore tailing samples.

1.4 Scope of Works

There are five chapters explained in this thesis regarding a study on the potential of tin recovery from iron ore tailing which includes Chapter 1 an introduction towards the study and research as the first part. In Chapter 1, all background, objectives and problems related to the research briefly discussed.

Next, Chapter 2 is the literature review on the properties of tin, characterization methods and the physical processing methods used in order to extract tin minerals. Chapter 3 on the other hand explains all the procedures and methodology of experimental work including sampling the samples, characterization of minerals and the physical processes conducted.

After that, the discussion on the result obtained from the characterization and the physical processing will be discussed in Chapter 4. Last but not the least, Chapter 5 contains the conclusions from result obtained and the suggestions of improvement steps that is recommended on this study.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

Tin is a geochemically known as unsuited element that accumulates during magmatic differentiation. According to the study by Hamaguchi et al., 1964 and Hamaguchi & Kuroda, 1969, from the ultramafic to mafic (0.3 ppm) to mafic (0.9 ppm), the intermediate (1.5 ppm), and felsic (3.5 ppm) rocks, the average Sn content increases. The data emphasizes tin's geochemical behaviour is primarily lithophile, with the highest concentrations found in felsic rocks, according to the data. The average upper continental crust and bulk continental crust contain 2.1 ppm and 1.7 ppm, respectively (Fakult et al., 2016).

The inorganic compound tin (IV) oxide, often known as stannic oxide or cassiterite, has the chemical formula SnO_2.It is the only economically important tin mineral that can be easily extracted using proper processes. Cassiterite is a physically and chemically resistant heavy mineral having a specific gravity of 7.15. As a result, cassiterite is found in abundance in heavy-mineral deposits where the velocity of flowing water fluctuates, such as in waterfalls, meanders, and irregular bedrock surfaces (Lehmann, 2020).

Several tin ore areas within bigger granite belts account for roughly 85% of all tin mined in the past (approximately 27 Mts Sn). Because of the density, hardness, and chemical stability of cassiterite, the majority of main tin ore deposits are always associated with late granite stages and are part of magmatic-hydrothermal (pegmatites, tin granites, and tin porphyries) magmatic-hydrothermal (pegmatites, tin granites, and tin porphyries) magmatic-hydrothermal (pegmatites, tin granites, and tin porphyries

Tin mining usually started with alluvial placer deposits, which accounted for at least half of all tin extracted (Lehmann, 2020).

Tin metal has a low hardness of 1.5 on the Mohs scale, which is one of its most important characteristics. Tin metal has a low melting point of 231.93°C and a high boiling temperature of 2602 °C (Lide, 2009). It also forms a synchronously oxidised, non-reactive layer on the surface, preventing further oxidation. In the context of corrosion, this is known as passivation (Fakult et al., 2016).

2.2 Properties of Tin Minerals

The melting point of pure cassiterite (SnO_2) is much higher than pure Sn, according to Paparoni (2010), is around 1625 °C while Sn only 231.93°C. It crystallises in the tetragonal system. Cassiterite is most commonly found as prisms with (110) and (010) or as bipyramids with (111) and (010). (011). Cassiterite is frequently twinned along (011), forming elbow-shaped crystals with a distinct notch. According to Ahlfeld (1958), the different crystal habits of cassiterite indicate different mineralization phases and thus different production circumstances. Specifically, temperature. Pegmatites have bipyramidal crystals, hydrothermal veins and greisen deposits have short prismatic pyramids with twinning, and low temperature, epithermal phases have long prismatic along (321), which is known as "needle tin" (Fakult et al. 2016).

The Mohs hardness of cassiterite is 6 to 7 (VHN200 = 1239 to 1467 kg/mm^2 on Vickers scale; Criddle & Stanley, 1993), indicating that it has a high hardness scale, as well as a high density of 6.8 to 7.1g/cm' (Klein et al., 1993). The cleavage of cassiterite is poor along the 010 plane, and the brittle fracture with a conchoidal form

(Klein et al., 1993). Cassiterite ranges in colour from colourless to yellowish to reddish-brown, with a yellow to largely colourless stripe. Cassiterite exhibits an adamantine lustre on fracture planes and a greasy lustre on crystal planes. Diaphaneity is typically opaque to translucent, with just a few exceptions being transparent (Fakult et al.,2016)

Sn^{2+} (stannous) and Sn^{4+} (stannic) are the tin's major valences in natural compounds with ionic radii of 0.93 A and 0.69 A, respectively (Shannon, 1976; Taylor, 1979), but their native form is extremely rare (Anthony et al., 2001; Dekov er al., 2009). Only a few specific placers have been identified as containing native tin (Krivitskaya et al., 1995). Namibia in south-west coast of Africa (Melver & Mihálik, 1975) and the Lost River skarn deposit in Alaska (Dobson. 1982) reported extremely high concentrations of Sn in garnets, with SnO2 contents as high as 5.8% by weight and 5.9% by weight, respectively. Studies by Wang et al. (2013), detected of tin in biotite (100-200 ppm of SnO_2, average of 125ppm SnO_2) of the Qitianling granite in the Nanling Mountains, China, and late magmatic ilmenite (8-26% by weight of SnO_2, average of 14,8% by weight of SnO_2) (Fakult et al., 2016).

Sulphosalts containing Sn, such as stannite (Cu_2FeSnS_4) and teallite, are found in some sulfide-rich hydrothermal deposits with economically significant enrichments ($PbSnS_2$). Tin is also found in a variety of rock-forming minerals, including ilmenite, titanite (sphene), magnetite, monazite, epidote, rutile, apatite, xenotime, garnet (especially andradite), biotite, hornblende, and muscovite. Sn is incorporated under conditions of high oxygen fugacity by replacing Fe^{3+} or Ti^{4+} (Lehmann, 1982). Layne and Spooner (1991) reported significant tin concentrations in epidote (up to 1.56 wt% SnO2), andradite (up to 0.79 wt% SnO_2), and amphibole (up to 0.61 wt% SnO_2) from the Yukon Territory,Canada.

2.3 Application of Tin

At this moment in time, solder is the major application of tin. Solder has low-melting alloy that was employed to connect components onto circuit boards or to connecting metals. The solder's melting point is lower than the melting points of the other components. Soft solder consists of melting points less than 450 °C utilised as a mechanical and electrical link in switching networks for electronic devices. Tin has been in high demand in recent years due to the fact that lead-free solder includes higher tin than standard lead-based solder (Fakult et al., 2016).

In ancient times, the primary application of tin was as tinplate for food and beverage cans. It grew less significant throughout time, and currently lower than 20% of tin output utilised for tinplate (Elsner 2014). Tinplate is made by the electrolytically coating steel plate (with thicknesses ranging from 0.1 to 0.5 mm) with a thin tin film containing between 1 and 6 g Sn per m^2; the coating technique is known as hot dip tinning. Because of tin is non-toxic and non-corrosive. so tin is best suited for using in food and beverage cans (Fakult et al., 2016).

The European Union passed a rule restricting the consumption some hazardous chemicals in electrical and electronic tools in 2006 (European Commission, 2003). Due to environmental and health concerns about lead, this command limited the use of Pb-Sn alloys in the manufacturing of electric and electronic equipment. Furthermore, more than half are used as solder on a global scale; particularly in Asia. Because of Asia's dominance in the electronics industry, there are up to 65% consumed as solder. whereas in Northern America and Europe, tin is used as a solder in far smaller proportions, with 30%, and 25, respectively (Fakult et al., 2016).

According to Elsner (2014), tin is in high demand as 15% of the global use of tin always increases especially in chemicals and pigments to be used in the glass and plastic industries. However, organic compounds containing Sn are also used as biocides and as a stabilizing agent in manufacture of polyvinyl chloride (PVC). Tin is also utilised in other alloys such as bronze and red brass (Elsner, 2014). Since ancient times, humans have used bronze for daily items like tools and swords. Bronze and red brass are the most often used cast alloys in engineering today, with temperatures below 450 °C used as a mechanical and electrical connection in switching networks for electronic devices. Bronze and red brass are the most often utilised cast alloys in engineering today. Bronze is simpler to cast than copper because the inclusion of tin lowers the melting point substantially when compared to elemental copper (Fakult et al., 2016).

Molten tin is used to make float glass, which accounts for 2% of global tin usage (Elsner, 2014). Sir Alastair Pilkington devised the industrially practical method in which molten glass floats on liquid tin and forms a highly flat surface (Pilkington, 1959). Tin is appropriate for this procedure due to its high density, low melting temperature, and low surface tension (Fakult et al., 2016).

2.4 Tin Recovery from *Amang*

Tin mining has been an important industry in Malaysia since 1848. Up till 1980, Malaysia has been contributed 30.7% of tin global production. Currently, Malaysia can only produce less than 1.5% of global production. According to the World Bureau of Metal Statistics, the production volume of tin mines in Malaysia amounted to approximately 3.2 thousand metric tons in 2020. This was a gradual increase from

2010, in which Malaysian mines produced approximately 2.7 thousand metric tons of tin. The entire collapse of the international tin industry in 1985, when the price of tin plummeted by more than 50% become the causes of lower tin production. Due to the decrease of tin production and the rising cost of the global's tin, focus moved to the processing of *Amang* for valuable minerals (Meor, 2016).

Amang is a slang term called by tin mining community to indicate tin tailing, which is a combination of tin ore, sand, and minerals that is originally dumped by tin miners. *Amang*, a by-product of reprocessing tin ore, has been discovered to contain precious minerals. The analysis of mineralogical on *Amang* sample from Kinta Valley is shown in Table 2.1. (Meor, 2016).