

**SCHOOL OF MATERIALS AND MINERAL RESOURCES ENGINEERING
UNIVERSITI SAINS MALAYSIA**

**EVALUATION OF TIN IN AMANG FROM
RAHMAN HYDRAULIC TIN SDN. BHD.**

By

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DECLARATION

I hereby declare that I have conducted, completed the research work and written the dissertation entitled “Evaluation of Tin in *Amang* from Rahman Hydraulic Tin Sdn. Bhd.”.

I declare that it has not been previously submitted for the award of any degree or diploma or other similar title of this for any other examining body or University.

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LIST OF ABBREVIATIONS

LOI	Loss of Ignition
XRF	X-Ray Fluorescent
XRD	X-Ray Diffraction
PSD	Particle Size Distribution
SEM	Scanning Electron Microscopy
RHT	Rahman Hydraulic Tin

PENILAIAN TIN DI AMANG DARI RAHMAN HYDRAULIC TIN SDN. BHD.

ABSTRAK

Tujuan kajian ini adalah untuk mengenal pasti *amang* dari Rahman Hydraulic Tin Sdn. Bhd dan pra tumpuan timah dalam *amang*. Terdapat dua sampel yang berlainan tempat di dalam kajian ini. Beberapa ujian telah dilaksanakan dalam kajian ini seperti ujian kandungan kelembapan, ujian kehilangan pencucuhan (LOI), analisis pengagihan saiz partikel (PSD), analisis pendarfluor sinar-X (XRF), analisis pembelauan sinar-X (XRD), analisis mikroskopi pengimbasan elektronik (SEM), mikroskopi optik, penentuan ketumpatan dan proses konsep 'pengapungan' yang mudah. Daripada kajian ini, kuarza (SiO_2), pirit (FeS_2), arsenopirit (AsFeS), sulfur triosida (SO_3) didapati kandungan tertinggi di antara mineral lain di *RHT Amang*. Merujuk kepada imej SEM, kasiterit ditemui terperangkap dengan mineral lain. Kuantiti terbesar jisim *amang* dalam julat saiz 75-125 μm . Berdasarkan ujian LOI, kedua-dua sampel boleh dianggap mempunyai nilai LOI yang cukup tinggi yang membuktikan bahawa *RHT Amang* mempunyai bahan-bahan yang tidak menentu seperti mineral sulfida. Memandangkan *RHT Amang* sangat halus untuk proses selanjutnya untuk mengeluarkan tin dalam *amang*, mungkin lebih baik menggunakan kaedah pengapungan.

EVALUATION OF TIN IN AMANG FROM RAHMAN HYDRAULIC TIN SDN.

BHD.

ABSTRACT

The purpose of this research is to characterize *amang* from Rahman Hydraulic Tin Sdn. Bhd and preconcentrate tin in *amang*. There were two different places of samples available in this research several tests were implemented in this research such as moisture content test, Loss of Ignition (LOI) test, Particle Size Distribution (PSD) analysis, X-Ray Fluorescent (XRF) analysis, X-Ray Diffraction (XRD) analysis, Scanning Electron Microscopy (SEM) analysis, Optical Microscopy, determination of density and a simple 'floatation' concept process. From this research, quartz (SiO_2), pyrite (FeS_2), arsenopyrite (AsFeS), sulphur trioxide (SO_3) were found to be the highest content among the other mineral in *RHT Amang*. Referred to the images of SEM, cassiterite were found on interlock with other mineral. The largest quantity of mass of the *amang* in range size 75-125 μm . Based on LOI test, both samples can be considered to have quite high value of LOI which proved that *RHT Amang* have high volatile substances such as sulphide mineral. Since the *RHT Amang* is fine for further process to extract tin in *amang*, might best to use floatation method.

CHAPTER 1

INTRODUCTION

1.1 Tin in *Amang*

Stannum is a chemical element that has symbol Sn. Cassiterite or tin dioxide (SnO_2) is the most important ore for tin. The symbol of tin is Sn (from Latin: stannum). In earlier Latin tin is known as white lead. Tin is a chemical element having atomic number 50 and in periodic table it is known as a post-transition metal of group 14. Allaby (2013) stated that tin has specific gravity in the range of 6.8-7.1 and the hardness is 6-7.

It has the great combinations properties which is low melting point, malleability, resistance to corrosion and fatigue, and the ability to alloy with other metals. Tin has multifarious uses where it can be used to coat other metal in order to prevent corrosion, to produce window glass by using Pilkington process and it can used to form many useful alloys. The majority of the world's economic tin resources at Eastern Asian countries are China, Malaysia, Thailand and Indonesia. However, other countries with large tin resources include Brazil, Bolivia, Peru and Russia.

Tin occurs in primary and secondary deposits. Primary deposits are usually associated with granite intrusive rocks which form when magma bodies are embodied into rock beneath the earth's surface. It occurs in intrusive rocks as veins, disseminations, skarns or carbonate replacements generated by tin bearing fluids derived from the granite magmas. Secondary deposits is a placers deposit where it derive from the weathering and erosion of primary tin deposits. Bucket-line dredging is the main method of mining large placer tin deposits.

The vein and disseminated tin deposits usually are mined by open pit method. The ore is drill and blast then transported to a concentrator where it is crushed and ground. The process is further by using gravity concentration method. Gravity concentration methods which involve passing the concentrate in a stream of water over equipment such as jigs, spirals, or shaking tables. Magnetic or electrostatic separation is used to remove the heavy mineral impurities. Lastly, cassiterite concentrate is the end product which containing about 70% tin.

However, in the real world, it is nearly impossible to obtain the 100 % product from any process. By processing the tin ores, it will yield side product which is tin tailings. These tin tailing might contain cassiterite mineral that not fully liberated from other minerals that it associated. Further step need to be taken in order to extract the remaining valuable mineral.

The term *amang* that commonly used in Malaysia is refer to tin tailing which is rich in heavy minerals such as arsenopyrite, pyrite, cassiterite, wolframite, rutile, zircon, and iron oxides. The content of heavy metal for every *amang* can be different due to many factors. Therefore, the samples received from Rahman Hydraulic Tin Sdn. Bhd. (RHT) from two different plants which is Kota Bunyih Mill (KBM) plant and Mini Mill (MM) plant, so the content also might be different as well.

However, in Rahman Hydraulic Tin Sdn. Bhd., these *amang* also known as pyritic *amang* which the pyritic term is an adjective of pyrite mineral. Pyrite is a brass-coloured mineral, FeS_2 , which is most common sulphide mineral. It is a metallic luster mineral that also called fool's gold. Pyrite is burned to sulphur dioxide to produce sulphuric acid. Basically, *amang* in RHT not only contain pyrite mineral but some other sulphide minerals such as arsenopyrite and galena also exist.

1.2 Problem Statement

Based on the chemical analysis there is certain percentage of tin found in *RHT Amang*. The recovery of tin in *amang* can generate extra income and it can be recovered. The samples were obtained from two different locations, so the behaviour of these samples also different due to the different processing process for each sample undergone. The heavy minerals that involved also need to be known, as it can help in the further process to recover tin in *RHT Amang*. The behaviour of the tin in *RHT Amang* is uncertainty, so characterization of *Amang* from Rahman Hydraulic Tin Sdn. Bhd. must be recovered. The tin that loss in the *RHT Amang* might be because of it interlocking in the other minerals. Therefore, the alternative method to preconcentrate the tin must be study to recover the tin in *RHT Amang* economically.

1.3 Objectives

The objectives of this study are:

- To evaluate and characterise the *amang* from Rahman Hydraulic Tin Sdn. Bhd.
- To preconcentrate the tin in *RHT Amang*.

1.4 Scope of Research

The scope of this research is to characterize the *amang* from Rahman Hydraulic Tin Sdn Bhd. In this study two samples of *RHT Amang* were obtained from two different plants which is Kota Bunyih Mill Plant and Mini Mill manually. As the samples as received is damn condition, the sample were dried prior sampling. For characterization, the samples are characterized by moisture content, specific gravity, optical microscopy,

Particle Size Distribution (PSD), Scanning Electron Microscopy (SEM), Loss of Ignition (LOI), X-ray Fluorescence Analysis (XRF) and X-ray Diffraction Analysis (XRD). Simple floatation concept to float sulphide mineral was also applied to study the possibility of concentrate the tin by floatation process.

CHAPTER 2

LITERATURE REVIEW

2.1 'Amang'

Tin tailing which is also known as *amang*. *Amang* is by-product heavy metal such as ilmenite, zircon, monazite, xenotime etc. that associated with tin ore. Zulfahmi et al. (2012) stated that the XRD analysis of *amang* samples show the presences of arsenopyrite, realgar, chalcopyrite, pyrite, hematite and quartz minerals. Arsenopyrite can be oxidized slowly then releasing arsenic into water system. Realgar known as arsenic sulphide that have specific gravity of 3.5. The specific gravity for soil sample and *amang* was 2.67 and 3.37 respectively.

Hamzah et. al. (2009) stated that *amang* is rich in heavy minerals containing rare earth elements. Rare earth elements have different applications in various types of industries. The tin tailing that contained heavy minerals which in turn will be economically beneficial to the mineral industries. Rahman Hydraulic Tin Sdn. Bhd. is one of the largest tin mine in Malaysia that extract tin from ore, they also produce *amang*.

Kiong et. al. (2003) stated that the *amang* from the study area are essentially abundant with heavy minerals that include ilmenite, monazite, zircon, xenotime, rutile, cassiterite, wolframite, arsenopyrite and pyrite among others. *Amang* samples from different localities show different dominant heavy minerals. Alnour et.al. (2017) stated that analysis results from different plants show that monazite and zircon samples have high concentration of uranium and thorium which are sources of the increasing radioactive level.

Zulfahmi et al. (2012) stated that *amang* was dominated by 98% of sand fraction while silt and clay were represented by 0.6% and 1.4% respectively. The base soil that totally weathered meta-sedimentary rock can be classified as clay texture. Quartz minerals are typically resistant to chemical weathering whilst feldspar group tends to change to clay minerals.

Yang-bao et al. (2012) stated that the fresh surface of the tin ores is grey black. The ores have veinlet and veinlet-disseminated structures. Due to high content of metal sulfides, the ores are compact and lumpy. The analyses of XRD and SEM, cassiterite and stannite are the main forms of tin mineral while the content order of metal sulfides is pyrrhotite > pyrite > arsenopyrite > sphalerite > galena > chalcopyrite. There is also bismuthinite distributed sporadically in the ore. Gangue minerals are mainly quartz and sericite, with minor dolomite, ankerite, siderite, and chlorite.

The tin is believed in the form of interlocking with *amang*. Interlocking is defined as two or more things engage with each other by overlapping or by the fitting together of projections and recesses. Kiong et al. (2004), stated that the *amang* at Klian Intan still contains economical quantities of cassiterite which have not been recovered by the treatment plant. The cassiterite grains present are vary in size from fractions of (1 – 2) mm and euhedral. Certain of the cassiterite have tapiolite exsolutions. Cassiterite grains are found associated with sphalerite, pyrite and quartz.

Further can be made to recover more cassiterite in *amang* such as pyrometallurgical reduction smelting process. López et al. (2018) stated that mainly cassiterite and columbotantalite are found in concentrate from mining tailings. The greatest recovery of Sn more than 95% was obtained when using CaCO₃ as the flux in the pyrometallurgical reduction smelting process. Risk (2017) stated that Elementos Limited (ELT) has

published a pre-feasibility study to reprocess 3.7Mt of tailings, grading 0.30% Sn and 0.13% Cu, at a rate of 650 kt/yr, recovering 47% of the tin, producing 900 t/yr of tin at an all-in cost of US 467c/lb.

2.2 Cassiterite

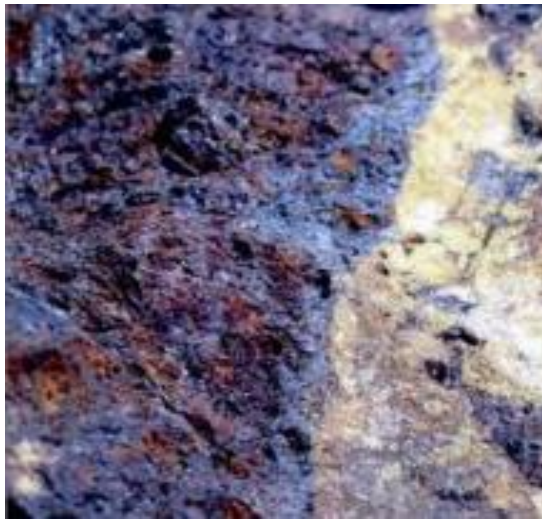


Figure 2.1: The image of cassiterite and iron oxide. (Camm S., 2010)

Cassiterite is usually reddish- brown to nearly black but it can be yellowish and ruby; white to grey streak, adamantine lustre; crystal often pyramidal and prismatic, may also be massive and granular; cleavage prismatic.

Bulatovic (2010) stated that cassiterite can be classified into three major groups; first cassiterite contained in pegmatitic veins contain significant quantities of $(\text{Nb, Ta})_2\text{O}_5$ with traces of wolframite and manganese and this kind of cassiterite is fragile and tends to slime during grinding. Second, cassiterite from quartz veins. This type of cassiterite contain about 1% $(\text{Nb, Ta})_2\text{O}_5$ and about (0.3-0.4)% wolframite. Third, cassiterite from sulphide veins typically contains vanadium, sulphur and wolframite.

Bulatovic (2010) also stated that tin deposits are hydrothermal deposits (hydrothermal and mesothermal) but magmatic deposits seldom contain tin mineralization. Tin may be present in pegmatitic ore bodies which can be classified into two basic types; quartz-cassiterite lenses in granite when cassiterite is associated with topaz, beryl and to a lesser degree, sulphides and the other one is sulphide deposits where cassiterite associated with arsenopyrite, pyrite, chalcopyrite and pyrrhotite.

2.3 Arsenopyrite



Figure 2.2: The image of arsenopyrite (Camm S., 2010)

Michael (2013) stated that arsenopyrite, also known as Mispickel, an iron sulfoarsenide mineral (FeAsS), the most common ore of arsenic. Arsenopyrite forms monoclinic or triclinic crystals with an orthorhombic shape. The colour of arsenopyrite is silver-grey to white. It is a metallic mineral that have hardness in range 5.5 to 6.0. Arsenopyrite mineral specific gravity is 5.9-6.2. It is most commonly found in ore veins that were formed at high temperature in associated with gold, tin ore, tungsten, galena and quartz. Arsenopyrite also disseminated in limestone, dolomites, gneisses and

pegmatites. Arsenopyrite mineral is used for pest control, manufacture of dye and chemical and leather treatment. Arsenopyrite also minor source of gold.

2.4 Chalcopyrite



Figure 2.3: The image of chalcopyrite (Camm S., 2010)

Michael (2013) stated that chalcopyrite is most common copper mineral (CuFeS_2). It has specific gravity of 4.1-4.3 and hardness 3.5-4.0. Chalcopyrite is a metallic mineral and a member of group sulphide minerals that crystallize in the tetragonal system. It typically occurs in ore veins deposited at medium and high temperatures. Chalcopyrite is primary mineral found in igneous rock and hydrothermal vein which is associated with pyrite, cassiterite, pyrrhotine, sphalerite, galena, calcite and quartz. Chalcopyrite is deeper in colour than pyrite, more brittle and harder than gold. Zulfahmi et al. (2012) stated that chalcopyrite usually darker yellow and its occurrences is often massive. Chalcopyrite is soluble in nitric acid and its alteration products are secondary copper minerals.

2.5 Pyrite

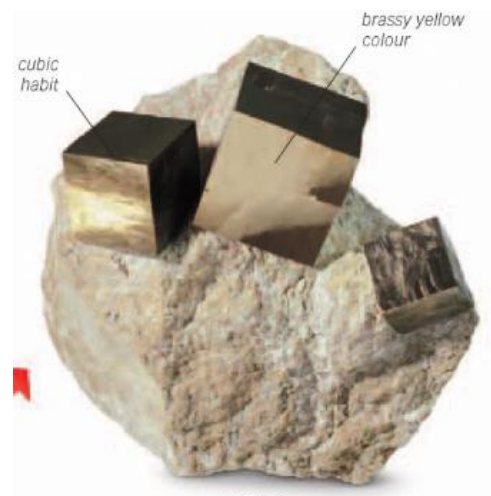


Figure 2.4: The image of pyrite (Bonewitz R. L., 2012)

Michael (2013) stated that pyrite also known as fool's gold. Pyrite is a sulphide mineral (FeS_2) that have specific gravity 4.9-5.2 and hardness 6.0-6.5. It is a cubic pale brass-yellow in colour. Pyrite is a metallic mineral that occur with other sulphide ores genetically associated with basic and ultrabasic rocks and together with pyrrhotine and chalcopyrite. Pyrite found in igneous rock as an accessory mineral, in sedimentary rock especially black shale as nodules, in metamorphic rocks and mostly in hydrothermal veins, in replacement deposits and contact metamorphic rocks. Zulfahmi et al. (2012) stated that pyrite is a common sulphide minerals and is usually associated with oxides in quartz vein, sedimentary rock and metamorphic rocks. Pure pyrite contains 46.67% iron and 53.33% sulphur; its crystals display isometric symmetry. Pyrite is formerly used for the production of sulphuric acid. Abundant of pyrite in mine, leads to acid mine drainage problem.

2.6 Rutile



Figure 2.5: The image of rutile. (Ismaiel et. al. 2017)

Michael (2013) stated that the most abundant of three naturally occurring forms of titanium dioxide (TiO_2). Rutile usually forms reddish-brown in colour but also yellowish-red, black or pale brown. It also hard, brilliant metallic and slender crystals. Rutile has specific gravity 4.2-5.6 and hardness 6.0-6.5. It is an accessory mineral that associated with iron, niobium and tantalum. Rutile occurs in variety of igneous rocks, schists, gneisses and metamorphic limestone and quartzites. It also become concentrated in alluvial deposits and beach sands. Rutile is an economically important titanium mineral.

2.7 Ilmenite

Michael (2013) stated that ilmenite is an iron black to brownish-red in colour, heavy, metallic oxide mineral, composed of iron and titanium oxide (FeTiO_3). The name of ilmenite is derived from the Ilmen Mountains, Russia. Ilmenite has specific gravity 4.5-5.0 and hardness 5-6. The crystals usually thick and tabular but often massive and compact. Ilmenite occurs as an accessory mineral in igneous rocks, for example gabbro and diorite in quartz veins. It also associated with hematite and chalcopyrite. Ilmenite is

resistant to weathering, it occurs extensively in alluvial deposits with magnetite, monazite and rutile. Ilmenite forms solid-solution series with geikielite and pyrophanite in which magnesium and manganese, respectively which replace iron in the crystal structure. Ilmenite is used as the major source of titanium and iron.

2.8 Particle size analysis

Wills (2006) stated that particle size analysis is importance in the grinding quality determination and in establishing the degree liberation values from the gangue at various particle sizes. In the separation stage, the product size analysis is utilized to determine the ideal size of feed to the process for maximum efficiency and to determine the range of size of any losses that occur in plant. The exact size of irregular particle cannot be measured as the terms of “length”, “breadth”, “thickness”, or “diameter” have little meaning because these quantities can be determined in many different values.

Wills (2006) also stated that sieve test is the most widely used method for particle size analysis. Sieve test could cover a very wide range of particle size, this factor being the one of the most industrial importance. Sieve test is a common method of size analysis that particles finer than about 75 μm are usually referred to being in “sub-sieve” range. However, size of particles down to about 5 μm can be carried out by modern sieving methods.

Allen (1981) stated that sieve analysis is one of the simplest and most widely used method of particle size analysis that covers the approximate 20 μm to 125mm of size range by using standard woven wire sieves. Micromesh sieves extend the range about 5 μm and punched plate sieves extend the upper range.

Horiba (2013) stated that a spherical particle can be described using a single number which is the diameter because every dimension is identical. The multiple length and width are used to describe non-spherical particles. These descriptions provide greater accuracy, however greater complexity. Therefore, various techniques make the convenient assumption that every particle is a sphere. The reported value is usually an equivalent spherical diameter but the shape factor causes disagreements when different particle size analysers measure the particles. Every measurement method determine size through the use of its own physical principle. For instance, a sieve will have a tendency to emphasize the second smallest dimension because of the way particles must orient themselves to go through the mesh opening. Flaky or plate-like particles will orient to maximize drag while sedimenting shifting the particle size in the smaller direction. A size distribution from the smallest to the largest dimensions can be produced by using light scattering device that will average the various dimensions as the particles flow randomly through the light beam.

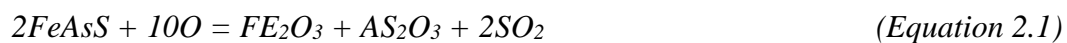
Brittain (2002) stated that analytical sieving is one of the simplest methods for deducing the powdered solid particle-size distribution. In sieve test analysis, the sample simply passes through wire meshes that have various sizes openings, then measures how much of the sample is retained on each sieve. Sieving is one of the fundamental methods for the powders classification and it is the method of choice for determining the coarse powders size distribution. Sieving is most suitable for powders whose average particle size exceeds (25–50) μm , however this method can be used for finer grades of powders if it is properly validated and executed. Sieving analysis is difficult to use for oily or cohesive powders because these kind of powder tend to clog sieve openings.

Brittain (2002) stated that the Tyler Standard Scale is a widely used classification scheme for sieve sizes. In this system, the standard is based on a wire cloth with 200-

mesh sieve. The wire diameter used for a 200-mesh screen is 53 μm and the opening size is 74 μm . The ratio between the adjacent screen scale sizes is square root of two. Therefore, the openings areas of each sieve are twice those of the next-finer sieve. Besides, the ratio between the openings widths of alternate sieves in the series is two. Closer sizing can be attained using screens that have a fixed width of opening ratio which equal to the fourth root of two.

2.9 Loss of Ignition (LOI)

Marshall (1911) stated that vesuvianite and arsenopyrite decrease in weight after the chief constituents of the gangue of paigeite are ignited. Arsenopyrite changes with the following reaction:



The weight of the ferric oxide remain after the reaction is about half that of the arsenopyrite; therefore half weight of the arsenopyrite is loss in ignition. Lim et. al. (2009) stated that the sample contain As and heavy metals (Fe, Cu, Pb, Mn, Cr, Cd, and Zn) was in a slightly wet state containing 9.6% water and value of loss on ignition (LOI), which indicates the proportion of total organic matters, was 9.3% and organic carbon content among all organic matters was 3.9%.

Cadioux et. al. (2006) stated that arsenopyrite-rich replacement zones contain 10 to 20 volume % sulphide minerals with traces of visible gold and oxide minerals like ilmenite and magnetite. Arsenopyrite-rich replacement zones hosted by the basalt have composition similar to that of biotite-carbonate-altered which show higher loss of ignition than fresh basalt.

2.10 X-Ray Fluorescent (XRF)

Funtua et al (1997) stated that there is (0.5-1.7) % of tin concentrations in mine tailings. These may be attractive for reprocessing which depending on the market prices and operational cost. The determination of tin in cassiterite ores is a rapid and precise method by using radioisotope X-ray source. The factor of analysis can be considered when compared to the solution methods of fusion and acid digestion.

2.11 Mozley Table Separator

Gupta et.al. (2016) stated that units such as the Bartles Mozley table and the Bartles Crossbelt concentrator were first introduced for tin processing around 1967. Cassiterite is a powdery mineral which readily produces size particles of slime. Burt & Mills (1984) stated that the more widely used Bartles–Mozley separator and the Bartles Crossbelt concentrator superimpose, the slightly inclined surface with an orbital shear motion and are capable to recover as fine as 6 μ m.

Falcon (1982) stated that the feed is run onto the deck for a predetermined time period at the end of which the whole table deck assembly is tilted to about (15-20) ° to allow the remaining feed to drain. Then the table deck is tilted further to 45 degrees for the washing cycle. In tilting the table to 45 degrees, the concentrate discharge is directed into a different chute from the chute used for the table tailings. The deck assembly is returned to its original position after washing and then wash water closed.

Venugopal et al. (2005) stated that the Laboratory Mozley Mineral Separator is capable of treating particles in range of 2mm to 100 μ m. These particles are generally

treated on 'V' profile tray. However, the particles have less than 100 µm size particles are treated on flat tray. As the retention time of particles is increased, it reduces the yield of concentrate containing heavy minerals almost linearly in which the rate of decrease is based on upon the amount of water flow rate on the deck. The rate of reject sand removal from heavy mineral is vary with respect to the flow rate of water which a linear variation with (2.0 – 2.2) lpm and exponential variation with (2.6 -2.8) lpm. It is necessary to give the retention time for the particles closer to four minutes with high water flow rates with at least 2.6 lpm to produce quality product. However, further experiments need to be carried out with vary parameters for the confirmation.as the above conclusions are highly subjective.

2.12 Scanning Electron Microscopy (SEM)

Yang-bao et al. (2012) stated that the SEM images of cassiterite combined with pyrrhotite. Cassiterite is the main mineral where tin can be recovered. The mineral is unevenly distributed in part of the ores. The maximum volume content can be achieved is 40%. The cassiterite is euhedral column granular. The colour of cassiterite is light yellow or reddish brown in the transmitted light. Apart from individual crystal size up to 0.4 mm, most crystal size is smaller than 0.2 mm and some can even be smaller than 0.02 mm. Mostly, cassiterite in the ore shows disseminated output. According to the embedding different patterns, it can be further clasified into two patterns as the disseminated pattern and coated pattern. Cassiterite in disseminated pattern usually fills along pyrite grain, however some distributes along the edge of sphalerite, pyrite or other metal sulphides with little gangue minerals. Wraparound cassiterite which likely distributes in the inner of pyrrhotite is not very close to the other metal sulphides which

it has the character like part enrichment honeycomb. In these two cassiterite embedded patterns, wraparound cassiterite distributes widely while the disseminated cassiterite found in a small number of ore blocks.

The ratio of mineral content is statistically about 40:60. In order to recycle cassiterite from ore, importantly to choose the right grinding process to separate it from pyrrhotite completely. The result of Energy Dispersive X-ray Spectroscopy (EDS) analysis shows that the chemical composition of cassiterite is stable and the impurity is mainly iron which there are 95.40% SnO₂ and 4.22% FeO on average.

The principal tin mineral is cassiterite (SnO₂), a naturally occurring tin oxide containing about 78.8% of tin and the impurities may be vary from 65% to 78%. There are two complex sulphide minerals stannite (Cu₂FeSnS₄) a copper-iron-tin sulfide and cylindrite (PbSn₄FeSb₂S₁₄) a lead-tin-iron-antimony sulphide which these two minerals usually in association with other metals such as silver.

Yang-bao et al. (2012) stated that a detailed tin-polymetallic ore mineralogical characterization from Mengzi, Yunnan Province, China, was undertaken by automated electron microprobe-based mineral mapping and quantitative analysis methods. The results show that the most valuable metal is Sn with 0.98% of mass fraction. The chemical phase analysis result of tin in the ore has demonstrates that cassiterite and stannite are the main forms of tin mineral. The distribution rates of the two forms are 74.49% and 20.41% respectively. Meanwhile, valuable metal such as Cu (0.261%), Zn (0.612%) and Pb (0.296%) can also to be recovered.

Bultovic (2010) stated that there are three different groups of particle size of tin minerals disseminated in ore which is disseminated deposits, medium-coarse-grained and coarse-grained tin ore. In disseminated deposits, the cassiterite grains with range (0.2 -

0.001) mm is typically dispersed in gangue matrix and the cassiterite is quite difficult to be recovered. In medium-coarse-grained which is less disseminated ores the cassiterite grains with range of (1.0 -0.2) mm. The third group which coarse-grained tin ores have average cassiterite grain with size from (0.1-1) mm and higher.

Yang-bao et al. (2012) stated that the optimal grinding fineness is 0.037 mm in order to ensure that 90% of cassiterite and stannite can be liberated from other minerals. Tin mineral of cassiterite and stannite size distribution indicates that cassiterite and stannite in the ore are fine-grained. The size of stannite is finer than cassiterite. 62.46% of stannite is over 0.074 mm while 76.77% of cassiterite is over 0.074 mm.

Hamzah et al. (2009) stated that the SEM/EDX analysis on the minerals confirmed that the minerals are monazite, ilminite and zircon. ICP-OES is used to analyse rare earth elemental content and the results further support that heavy minerals are rich in rare earth elements. ICP-OES is referred to as inductively coupled plasma optical emission spectrometry. It is an analytical technique used for the detection of chemical elements.

Hamzah et al. (2009) stated that as the soil samples containing *amang* were taken to recover its heavy mineral, the morphology of each mineral was investigated by computer controlled (SEM/EDX). The SEM result shows that the surface morphology most samples are rounded to subrounded. The minerals were digested using microwave digestion system and then measured for its rare earth elemental content using inductively couple plasma-optical emission spectroscopy (ICPOES) and the result shows that soil and sediment in this study area contain heavy minerals monozite, ilminite and zircon. The separation method chosen for this study work well and the minerals were confirmed by SEM/EDX results and ICP-OES give the rare earth elements content of these minerals.

2.13 Mineral Separation Technique

Risk (2017) stated that Elementos Limited's studies confirmed that modern gravity and floatation technology with grinding and leaching of the tails should recover 47 % of the tin to a concentrate grading 51 % Sn from the tailings.

Alnour et al. (2017) stated that *amang* factories use combinations of wet shaking table for separate tin ores, heavy minerals and sands by density and gravity, rotary driers, magnetic and rapid magnetic separators to separate magnetic from non-magnetic minerals, electrostatic, plate and high tension separators to separate conductor from non-conductor minerals, lanchute for intermediate separation, air tables for separating heavy from light minerals.

The combination of gravity preconcentration and flotation are the processes that usually being used in tin processing. Gravity preconcentration is the separation of minerals based on differences in specific gravity. A gravity concentration process is designed to recover very high grades of valuable ore material into very small masses. The gravity concentration separation process gets more complex as the specific gravities between the valuable mineral and the gangue get closer.

Wills (2006) stated that gravity separation method can be used to treat variety of materials which ranging from heavy metal sulphides like galena that has specific gravity 7.5 to coal that has specific gravity 1.3 at particle size in some cases below than 50µm. gravity separator are very sensitive with the slimes present which slime can increase the viscosity of the slurry and reduce the efficiency of separation. Hamzah et. al. (2009) stated that the separation involves a gravitational separation and magnetic separation

using large volume of water and strong hand magnet respectively. Sample containing monazite, ilmenite, and zircon were separated by 8000 G hand magnet.

Flotation separation is defined as a concentration process whereby finely ground ore is dispersed in water containing a flotation reagent which causes selected mineral to become hydrophobic. Wills (2006) stated that froth floatation process allows the selective treatment of low grade complex ores. The principles of floatation is physic-chemical separation method that use the difference in surface properties of valuable mineral and the unwanted gangue minerals. It can be used to separate complex mineral such as lead-zinc, copper-zinc, etc. Floatation is initially developed to treat sulphides of copper, zinc and lead. Then the field of floatation expanded to treat platinum, nickel and gold-hosting sulphides and oxides. For example, hematite, cassiterite, oxidised minerals and non-metallic ores.

Wills (2006) stated that magnetic separator detect the difference in magnetic properties between ores mineral. It is used to separate valuable and gangue minerals. For example, tin –bearing mineral cassiterite that usually associated with traces of magnetite or wolframite. It can be removed by magnetic separator.

Rosenblum et. al. (2000) stated that in the Frantz Separator a less magnetic group of minerals which is paramagnetics was extracted in three fractions plus a nonmagnetic residue (diamagnetics), to permit rapid identification and quantification of the heavy minerals. Hess (1956), Rosenblum (1958), and Flinter (1959) have described and referenced data on operation of this magnetic separator as in Figure 2.6.

Extracted by hand magnet	Extracted by Frantz magnetic separator at 20° side slope and 23° forward slope (values in amps.)			
Ferromagnetic	Paramagnetics			Diamagnetics
	0-0.45	0.46-0.70	0.71-1.40	over 1.40
magnetite	microilmenite	hypersthene	monazite	zircon
microilmenite	ilmenite	chromite	actinolite	rutile
	almandite	hornblende	tremolite	sillimanite
	chromite	augite	rutile	kyanite
	hypersthene	epidote	zircon	corundum
	hematite	anthophyllite	tourmaline	pyrite
	limonite	staurolite	spinel	gold
	siderite	spinel	anatase	cassiterite
	malacon	xenotime	corundum	anatase
		actinolite	clinozoisite	apatite
		biotite	sphene	muscovite
		hematite	sillimanite	andalusite
		limonite	kyanite	galena
		tourmaline	muscovite	leucoxene
		pyrope	zoisite	marcasite
		malacon	pyrope	
		columbite		
		monazite		
		microilmenite		

Figure 2.6: Common minerals distribution based on magnetic susceptibility.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This project is to evaluate tin in *amang* samples are received from Rahman Hydraulic Tin Sdn. Bhd., Perak. The two samples were actually from different plant at Rahman Hydraulic Tin Sdn. Bhd. namely Kota Bunyih Mill (KBM) and Mini Mill (MM).

3.2 Flow of Research Work

The methodology of the studies is shown in Figure 3.1. Comminution process for the raw sample did not take part in this research as the sample is already fine. The step is started with drying, sampling then mineral characterization processes respectively.

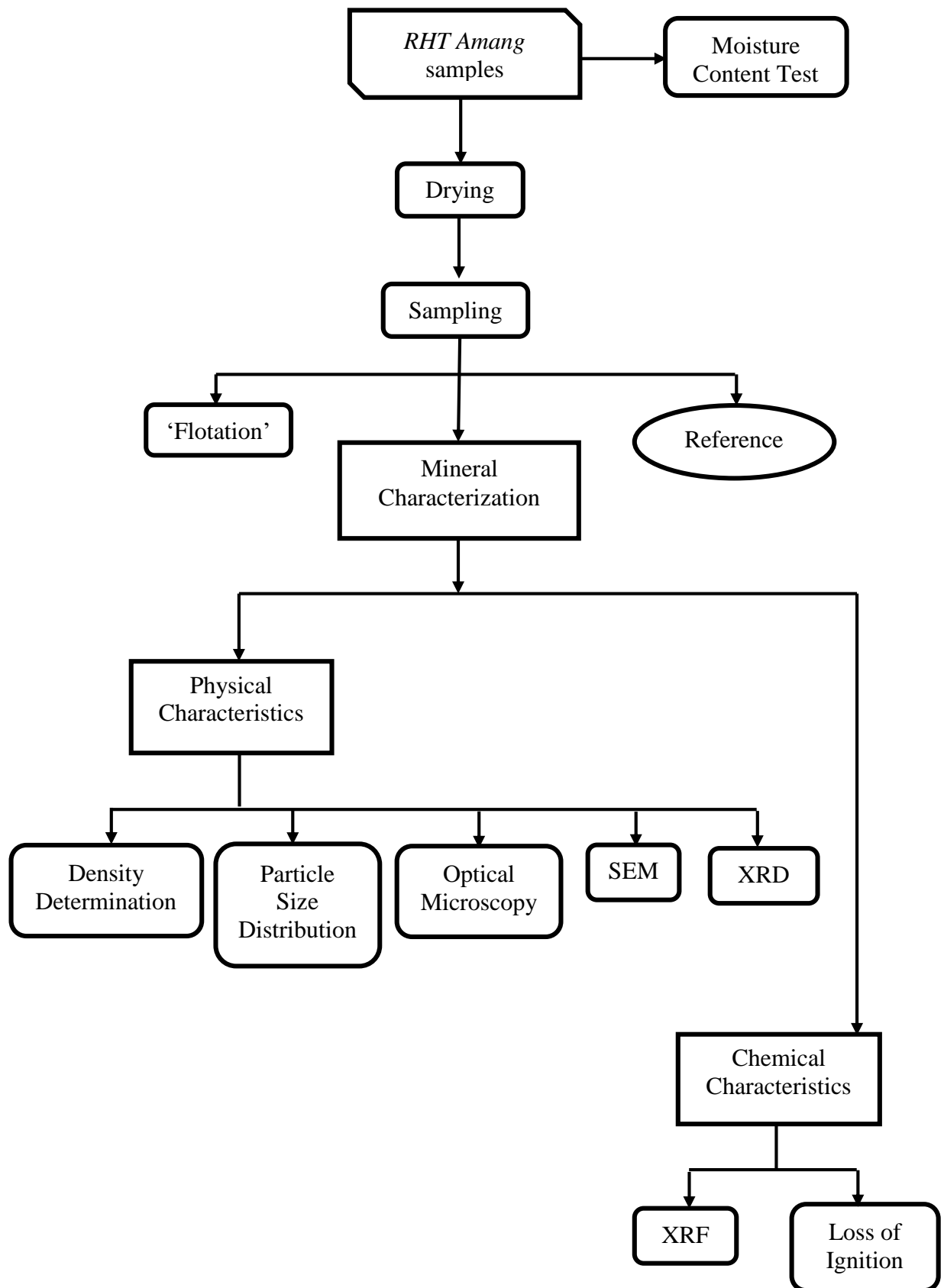


Figure 3.1: A flowchart of characterization of RHT Amang.

3.3 Raw Material

Approximately 12 kg of *amang* samples were received from Rahman Hydraulic Tin Sdn. Bhd.. These samples were obtained from two different location which one of it from Kota Bunyih Mill (KBM) Plant and the other one from Mini Mill (MM) as shown in Figure 3.2 and Figure 3.3. The samples cannot be differentiate precisely by using naked eyes because the size of the samples are fine also the colour are similar. However, some of big grains in sample KBM can be seen.



Figure 3.1: Sample MM



Figure 3.2: Sample KBM