Abstract—Law No. 4 of 2009 and PenMen ESDM 7/2012 are the starting point of direction and strategy to acceleration of research and technological development of metallic minerals extraction process into pure metals such as copper cathode. Research and technology development of copper minerals extraction process include beneficiation, hydrometallurgy, pyrometallurgy and electrometallurgy. These processes done beside to produce copper cathode and also produce waste such as SO2 and slag, which are adversely impact on the environment. Along with the increasing production costs, energy and environmental issues, the identification and mapping of every stage of the process of mineral extraction of copper needs to be done to select and application certain process that an environmentally friendly. Development process of copper minerals extraction with chemical's solution and bacteria's which are more environmentally friendly are smart choice that can be done through cooperation between universities, industries and government to fulfill and achieving government's policy for building upstream and downstream industries integrated. The benefits of the integrated cooperation will increase and accelerating the achievement of the self-sufficiency of copper, increased value added of natural resources, improved of human resources capabilities, etc. The important benefit of the development of the extraction process routes are the business become more competitive and sustainable environment and also will be able to accelerate the implementation of Law No. 4 of 2009 and PenMen the ESDM 7/2012.

Keywords—copper minerals, extraction, environmentally friendly, law No 4/2009

I. INTRODUCTION

A. Background

Copper is minerals that has economic value contained in the earth's crust, combine with sulfides, oxides, carbonates, oxide and silicates in the rock. Copper is the metal with the structure of the crystal cube is malleable, ductile and a good conductor of heat and electricity. Currently, the spectrum application copper and copper alloys in various sector such as the industrial electrical and electronic, machine and industrial equipment, building and construction, transportation and general product and consumer in the world as shown in Fig. 1.

Generally, copper alloys such as Brass (55% weight) and Zn (45% weight), Bronze (Copper + Tin) (16 parts copper, 1 Tin), Al bronze (Al and Copper) with levels of 7.5 - 8% Al, Si Bronze, 40-45%: Constantan 30%: steam condenser, Monel: 65-70% Nickel and Fe and Mn, Beryllium copper: nickel Cobalt, such as multi-leveled. Copper minerals are classified into sulphide and oxides copper minerals, whereas oxides minerals are a naturally oxidation product of sulphidic minerals. Therefore, usually oxides and sulphidic copper minerals are in adjoining site. Whereas sulphidic copper minerals are mainly treated by pirometallurgical processes route and oxides minerals by hydrometallurgical leaching processes, mainly by heap leaching with sulphuric acid, and subsequent solvent extraction and electrowinning process route.

Fig. 1. Spectrum application of copper in the world
B. Indonesia’s Government Policy

Indonesia is one of the 20 countries exporters copper concentrate produced by PT. Freeport Indonesia 240,000 ton/year, PT. Newmont 280,000 ton/year, a smelter with a production of 261,000 tons/year and raffinate as much as 181,000 tons/year [1]. In addition, Indonesia is one of the 10 countries that have copper mineral reserves of 4.1 billion tons. The potential of natural resources owned by Indonesia's largest copper contained in Papua. Other potential spread in West Java, North Sulawesi and South Sulawesi. The latest data from the Geological Agency of the Ministry of Energy shows that Indonesia has a copper resource of 4,925 million ton of ore reserves amounted to 4,161 million tons of copper ore [2].

Indonesia is ranked 20th in the world based on the location of the mine and copper production capacity. PT Freeport Indonesia was ranked third, while PT Newmont Nusa Tenggara are in eleventh position. Ranked first and second is the state mining company in Chile. Similarly, Indonesia including the country into four worlds as an exporter of copper, after Chile, Peru and Australia, while the country's largest importer of copper are China and Japan.

Based on data from copper consumption in 2011 account for 348,000 ton and is assumed consumption rate of 1.25%/year [2], consumption projection of copper and copper alloys until 2030 is predict to reach 2 million tonnes as shown in Fig. 2.

![Fig. 2. Consumption of copper and copper alloys](image)

To increase the added value of metal and entrenchment minerals, Indonesian Government issue the Law No. 4 of 2009 on the prohibition and termination contain mineral exports, which became effective in 2014 and PenMen EMR No.7/2012 on mineral added value is a turning point and once for direction and strategy research development of process technology as well as extraction copper mineral. Promulgation of Law No. 4 in 2009 is expected to encourage the growth and development of research and technology development process of extraction, production of various forms of material and product-based, which is able to integrate upstream and downstream copper-based raw materials in the country.

C. Purpose and Benefits

The purpose of this study is mapping, identification, and selection of copper minerals extraction process route shall be done based on economic and environmentally friendly. Based on the mapping of copper mineral extraction process at least be able to integrate four critical aspects of the strategic value, they are:

a. Increase added value the copper minerals as per the Law No. 4 of 2009

b. Understand step of existing extraction process route that shall be improve in order efficient and environmentally friendly

c. Develop extraction process route and its setting parameter process of cupper minerals based on investment, cost of production and environmentally friendly aspects

d. Synergize and integrate of roadmap research in universities, institutions and industry to find out the best extraction process route in term of economic and environmental aspects.

II. LITERATURE REVIEW

A. Commercial copper mineral

Copper is most commonly present in the earth’s crust as copper-iron-sulfide and copper sulfide minerals, such as chalcopyrite (CuFeS2) and chalcocite (Cu2S). Copper also occurs to a lesser extent in oxidized minerals such as carbonate, oxides, hydroxyl-silicates and sulfates [3]. Copper metals, usually called copper cathode with 99.99% Cu. Typical copper minerals contain 0.5% Cu (open fit) and 1-2% (underground mines). Common copper sulphide minerals usually classified primary copper mineral such as chalcopyrite and enargite, and secondary copper minerals are chalcocite, covellite and bornite. To increase of the concentration of copper, copper minerals are processed using the comminution which aims to reduce the size of the mineral to 0.25 mm and beneficiation that separating metallic minerals with gangue resulting concentrate. Concentrate products, besides containing precious metals Cu, Au and Ag, also contains 29 other metals including rare metals such as Bi, Cd, Co, Mo, Sb, Se, Te. Although the levels are very small at about 10-40 ppm, but has a high economic value, when processed and purified [2].

B. Copper production

In general, extraction of copper minerals is classified into 3 processes routes, namely pyrometallurgy, hydrometallurgy and electrometallurgy as shown in Fig. 2. As the name implies, pyrometallurgical process is using heat to process the mineral into pure metal. In other words, this process requires energy intensive and expensive equipment and high qualification of human resources. In contrast to hydrometallurgical process, this process utilizes solubility and selectivity of the metal in the solution and the solvent. In addition, this process can also use the help of bacteria or micro-organisms to separate the sulfur from the mineral. Generally hydrometallurgical process is slow but very effective for a
low mineral content. The final stage of the extraction of copper is electrometallurgy, which is a process that uses electrical current and a solution with the principles of electroplating. Both of copper Impure or as a pregnant liquid solution is processed into pure copper or called copper cathode.

In the process of pyrometallurgical processes route, extracted copper minerals into copper cathode through the stages of crushing, flotation, drying, smelting, converting, fire refining, electrorefining. This pyrometallurgical process route produce slag and emission SO2 gas that causes acid rain and has negative impact to environment. Electrometallurgical process is electrorefining that regarding to increase the purity of copper, called copper cathode. The electrometallurgy is use electric current and in acid solution condition, where impure copper attached on anode and the pure copper at cathode.

In the hydrometallurgical process route, extraction of copper minerals is use acid solution and solvent extraction and also bacteria and followed by electrowinning processes to produce copper cathode with a purity of 99.99% Cu. The hydrometallurgical process is usually done for low grade of copper less than 0.5% weight Cu. There are 6 method employed for the leaching of copper minerals, namely in-situ leaching, dump leaching, heap leaching, vat leaching, agitation and pressure oxidation leaching. The copper-based hydrometallurgical extraction process emphasized on solvent extraction and bioleaching which are alternative that have the business outlook and environmentally friendly.

**1) Pyrometallurgical processes route**

Until now, 80% copper with a purity of 99.99% Cu was produced using a combination of pyrometallurgical process- electrometallurgical route and the remaining 20% of copper is produced using a hydrometallurgical process route. This process uses a concentrate grading 20-30% Cu as a raw material to produce copper anodes which would then be purified using electrorefining process.

Concentrate produced by comminution to minimize the size of the mineral grains through a process of gradual crushing. Mineral grain size reduction aims to obtain high contact surface area which will accelerate the process of separation of mineral and other metals with gangue on beneficiation or flotation process. Briefly pyrometallurgical process route is described at each stage.

**a) Smelter**

Smelting process involves the application of heat, copper concentrates, waste and fluxes to integrate and enable the separation of copper minerals of iron and other impurities. The basic principle of this process is to oxidize S and Fe from CuFeS2(s) with an excess of oxygen. CuFeS2(s) is melted at a temperature of 1220-1250 oC to produce a mixture of molten copper matte [1]. The reaction is taking place according to

\[
2\text{CuFeS}_2 (s) + 3.2\text{O}_2(\text{g}) \rightarrow \text{Cu}_2\text{S}-2\text{FeS(l)} + 1.5 \text{FeO(s)} + 2.5\text{SO}_2(\text{g}) \quad \ldots (1)
\]

SO2 gas is harmful to the flora and fauna so it must be remove before its released to the atmosphere. Furthermore, with the addition of silica, SiO2 as a flux and reacts with CuO slag to produce Fe2SiO3 form, which its separates from the liquid matte copper. The reaction is taking place according to

\[
2\text{FeO(s)} + \text{SiO}_2 (s) \rightarrow \text{Fe}_2\text{SiO}_3(l) \quad \ldots (2)
\]

Fe2SiO3 is known as slag and then separated from Cu2S.

**b) Converting**

In the converter (such as continuous Mitsubishi converter), high-silica flux and compressed air or oxygen is introduced into the molten copper matte through a pipe called tuyeres. In the converting take place FeS elimination or slag forming stage [1]. The reaction FeS with SiO2 is taking place according to

\[
2\text{FeS (l)} + 3\text{O}_2 + \text{SiO}_2 (s) \rightarrow \text{FeSiO}_4 (l) + 2\text{SO}_2(\text{g}) + \text{heat} \quad \ldots (3)
\]

FeSiO4(l) is molten slag.

Copper forming stage where reaction takes place at temperatures of 1200 oC. Liquid matte with oxygen reacts according to

\[
2\text{Cu}_2\text{S} + 3\text{O}_2 \rightarrow 2\text{Cu(l)} + 2\text{SO}_2(\text{g}) + \text{heat} \quad \ldots (4)
\]

Due to the resulting copper and SO2 gas known as blister copper.

**c) Fire Refining**

Blister copper is still in a liquid state and reacted with oxygen so that the oxidation reaction occurs with the impurities still on the blister copper. At this stage, reduction reaction occurred between copper and oxygen by using to feed a reducing gas such as ammonia. Furthermore, casted molten copper in the form of slabs for purified in electrorefining process.

**d) Electro Refining**

Electrorefining is final stage of pyrometallurgical process that aims to obtain pure copper with the principle of electroplating by placing a copper anode in a sulfuric acid solution so that copper ions form and move to the cathode. Electrorefining process using DC current that produces copper with a purity level of 99.99%, called
copper cathode. The basic principle of electrorefining is the reaction of oxidation-reduction (redox), where copper is electrochemically dissolved from the anode into the electrolyte, producing Cu cations and electrons where Cu is oxidized at the anode [1], then a solution of Cu is reduced and deposited on the cathode. Redox reactions at the anode and cathode as shown in equation (5), (6) and (7) for the overall redox.

Anoda reaction
Cua
d
o
da  Cu2+ + 2e-  E = -0.34 V ……… (5)

Cathode reaction
Cu2+ + 2e-  Cucat
ho
de
de  E = + 0.34 V ……… (6)

The overall reduction-oxidation (Redox)
Cuanode (impure)  Cupure  E = 0.0 V ……… (7)

In this electrorefining process, anode copper still contains a lot of impurities such as Ag, Au, As, Co, Ni, O, Pb, S, Pb, Se will be in H2SO4 solution. Therefore, impurities must be separated from the solution H2SO4 [1]. Copper cathode will be melted into Furnace for further processing continuous casting, fabrication alloys and parts and its application.

Based on the description of each stage of pyrometallurgical process routes above can be made summaries of pyrometallurgical processes as shown in Table 2.

TABLE I. SUMMARY OF PYROMETALLURGICAL PROCESS ROUTE

<table>
<thead>
<tr>
<th>Process</th>
<th>Preparatory</th>
<th>Product</th>
<th>Cu-grade</th>
<th>Cu-recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mining</td>
<td>Remove minerals from ground and surrounding hill</td>
<td>Copper and other minerals (slag, gangue)</td>
<td>0.5-1%</td>
<td>95%</td>
</tr>
<tr>
<td>2. Converalting</td>
<td>Crushing to create small particles or large materials</td>
<td>Liquid concentrate</td>
<td>20-40%</td>
<td>85-90%</td>
</tr>
<tr>
<td>3. Separation</td>
<td>Separate of most grade</td>
<td>Copper minerals, liquid concentrate</td>
<td>impurity removal</td>
<td>95%</td>
</tr>
<tr>
<td>4. Stacking</td>
<td>Stacking of concentrate</td>
<td>Copper</td>
<td>0.3-2.3%</td>
<td>90%</td>
</tr>
<tr>
<td>5. Transporting</td>
<td>Transporting of concentrate</td>
<td>Copper</td>
<td>0.3-2.3%</td>
<td>90%</td>
</tr>
<tr>
<td>6. Electrocoating</td>
<td>Electrocoating of concentrate</td>
<td>Copper</td>
<td>0.3-2.3%</td>
<td>90%</td>
</tr>
</tbody>
</table>

2) Hydrometallurgical processes route
Generally, copper minerals are classified into sulphide and oxidic copper minerals, whereas oxidic minerals are a naturally oxidation product of sulphidic mineral. Therefore, usually oxidic and sulphidic copper minerals are in adjoining site [4]. Sulphidic copper minerals are mainly treated by pirometallurgycal processes and oxidic minerals by hydrometallurgical leaching processes, mainly by heap leaching with sulphuric acid and subsequent solvent extraction and electrowinning process.

Hydrometallurgical processes route can use either raw material comminution product (fine particles) and flotation (concentrate). Copper mineral raw material is dissolved using one of the leached agent such as H2SO4, Ammonia + O2, dilute H2SO4 + O2, or Acid + Ferric chloride [5,6] Extraction by using this hydrometallurgical process route accounts for 4.5 million ton of copper cathode/year (or approach 20% of total copper production) and most of this is produced by heap leaching [7].

Heap leaching is treated materials oxides secondary sulfide such as chalcocite (Cu2S) covellite (CuS), agglomerated and acid cured and bacteria-assisted. Cu grade 0.3-2.3%, particle size 12-50 mm, leach time month to years Cu in pregnant liquid solution (PLS) 1.5-8 gr/liter and Cu recovery up to 90%. Typical copper minerals heap in heap leaching are 4-12 m high and have a base area of several thousand square meters and are made up 100,000 – 500,000 ton of copper minerals [7]. As for the integrated leaching, solvent extraction and electrowinning are presented in Fig. 4.

Fig 4. Copper minerals leaching, solvent extraction and electrowinning process route

Copper minerals leaching solution, solvent extraction electrowinning route has a limitation and an opportunity, among others, [8] but not limited to:
1. Limited to oxidized copper minerals or leachable sulfides
2. Approximate 20% of world copper cathode produce and 80% is still produced by smelting and refining of chalcopyrite (CuFeS2) concentrates
3. Develop to extend hydrometallurgical process route to chalcopyrite minerals and concentrates.
4. Develop to treat high arsenic concentration minerals directly (limit of 0.5% As)

3) Electrowinning process
Unlike the electrefining process in which the raw material is in the form of copper anode is dissolved in H2SO4 solution, using raw materials electrowinning copper from leach solution, SX electrolyte. Electrowinning process entails applying an electrical potential between inert Pb-Alloys with 1.35% Sn and 0.07-0.08% Ca anodes and steel (304, 316L, LDX duplex steel) as blank cathode in CuSO4-H2SO4 electrolyte [1]. The pure copper produce on cathode, while O2 and H2SO4 are generated at the anode.

Electro winning of copper chemistry occurring on
Cathode reaction
\[ \text{Cu}^{2+} + 2e^- \rightarrow \text{Cu} \quad E = 0.34 \, \text{V} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (8) \]

Anode reaction
\[ \text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^- \quad 0.5\text{O}_2 + 2\text{H}^+ + 2e^- \quad E_o = -1.23 \, \text{V} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (9) \]

The overall electrowinning reaction is sum of reaction equation (8) and (9) in the present of sulfate ion
\[ \text{Cu}^{2+} + \text{SO}_4^{2-} + \text{H}_2\text{O} \rightarrow \text{CuO} + 0.5 \text{O}_2 + 2\text{H}^+ + \text{SO}_4^{2-} \quad E = -0.89 \, \text{V} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots (10) \]

Although using different raw materials by electrorefining, electrowinning can produce copper cathode with 99.99% Cu and oxygen gas at the anode and regenerated sulfuric acid in the electrolyte. Generally, electrowinning process usually use current densities above 450 Ampere/m², operation time for 6-7 day. Stripped copper cathode from stainless steel cathode blanks and theoretical energy consumption for plating 1 ton of copper is therefore 754 kWh/tCu. The other process parameter electrowinning is current efficiency 93-95%, surface area stainless steel blanks at 240–320 A/m² from a solution containing 32 to 37 g/l Cu and 160 to 180 g/l H₂SO₄. To keep the solution is always clean, the electrolyte stream is cleaned by column flotation followed by filtration through garnet sand and anthracite. Special grades of guar are used as smoothing agents, and acid mist suppressants, either chemical, mechanical or a combination of both are common.

4) Bioleaching
In general, bioleaching is a process described as being “the dissolution of metals from their mineral source by certain naturally occurring microorganisms”. Term of bioleaching is referring to the conversion of solid metal values into their water-soluble forms using microorganisms [9]. Bioleaching is also applied to a wide variety of base-metal sulphides, mainly in large-scale heap bioleaching operations located in Chile, Peru and Australia. In these operations, copper is extracted from minerals secondary copper sulphides such as covellite (CuS), chalcocite (Cu₂S) and bornite (Cu₅FeS₄), and the primary copper sulphide, chalcopyrite (CuFeS₂). [10]

Bioleaching is an operation in which the copper sulphide is extracted using bacterial cells chemolithotrophic and grow at a pH close to 1. Study based microorganism growth temperature grouped mesophilic, thermophilic and hyperthermophilic. Microbes or bacteria has been done through the dump and heap (USA) and in situ (Kosaka-Japan) with a copper content in a row is 0.15-0.20%, 0.5%, 0.15 to 0.25% and production capacity reached 2500, 6800, 800 tons / year of copper [11].

III. METHODOLOGY
The process is a combination of materials, facilities, methods, people, energy and environment that transforms the added value of the raw material into a product. By using this definition, each process such as pyrometallurgical process can identify to find out the factors that source of cause the process inefficient, uncompetitive and have a negative impact on the environment.

Mapping extraction process of copper minerals is used to determine step of the process where is inefficient, high cost, not competitive and produce wastes such as slag, SO₂ gas and others that have adversely impact to environmental as criteria in determined the selection and determined the extraction process route. By using this mapping extraction can be clustering both copper minerals basis, extraction process route weather pyrometallurgical process route, hydrometallurgical process route (by using solvent extraction and/or bacteria use). Usually each step of process route has potential to be improve in term of type of solution, type of microorganism and its parameter and process route to achieve a maximum yield, increase productivity and lowest adversely to environment.

IV. RESULT AND DISCUSSION
The aim and implementation strategy of research and technological development of the copper mineral extraction process route is closely associated with copper mineral types, feasibility and environmental impacts. Therefore, in the formulation of related issues such type of copper minerals basis, technology copper extraction process route for determining clustering research and technology development process of extraction that efficient and environmentally friendly.

A. Copper minerals
A naturally occurring material in which a metal or its compound occurs is called a mineral. A mineral from which a metal can be extracted economically is called an ore. Ores are invariably found in nature in contact with rocky materials. These rocky or earthy impurities accompanying the ores are termed as gangue or matrix. The principal commercial copper mineral as shown in Table 1.

---

**Fig. 5.** Methodology Selection of Extraction Route

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**Table 1.**
TABLE II. PRINCIPAL COMMERCIAL COPPER MINERALS

<table>
<thead>
<tr>
<th>No</th>
<th>Mineral minerals</th>
<th>Chemical formula</th>
<th>Leaching reaction</th>
<th>% Cu Hydro, leach</th>
<th>Extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Native Cu</td>
<td>Cu</td>
<td>Cu + 2H₂SO₄ → CuSO₄ + H₂</td>
<td>98</td>
<td>Hydro, leach</td>
</tr>
<tr>
<td>2</td>
<td>Chalcopyrite</td>
<td>CuFeS₂</td>
<td>CuFeS₂ + H₂O → Cu₂O + Fe₂O₃ + S</td>
<td>84</td>
<td>leach, biol.</td>
</tr>
<tr>
<td>3</td>
<td>Pyrite</td>
<td>FeS₂</td>
<td>FeS₂ + H₂O → Fe₂O₃ + S</td>
<td>65</td>
<td>leach, biol.</td>
</tr>
<tr>
<td>4</td>
<td>Chalcocite</td>
<td>Cu₁₋ₓSₓ</td>
<td>Cu₁₋ₓSₓ + H₂O → Cu₂O + H₂S</td>
<td>79</td>
<td>leach, biol.</td>
</tr>
<tr>
<td>5</td>
<td>Cuprite</td>
<td>Cu₂O</td>
<td>Cu₂O + H₂O → 2Cu + H₂</td>
<td>64</td>
<td>leach, biol.</td>
</tr>
<tr>
<td>6</td>
<td>Siderite</td>
<td>CuOFe₂O₄</td>
<td>CuOFe₂O₄ + H₂O → Cu + Fe₂O₃</td>
<td>68</td>
<td>leach, biol.</td>
</tr>
</tbody>
</table>

Note: [Hydro] means:

a. Potential to develop and replace pyrometallurgical process route due to energy intensive and not environmentally friendly.

b. Leaching with solution or bioleaching and subsequent solvent extraction and electrowinning.

B. Mapping extraction process route

The technology of copper minerals extraction process route can be done with pyrometallurgy, hydrometallurgy such as solvent extraction and bioleaching (using bacteria) as shown in Fig 2. Along with the implementation of Law No. 4 of 2009, the mapping of copper ore extraction process technology as well as research and development focus is the improvement of process parameters based on the type of compound of copper minerals. Thus, the extraction process technology will be available according to the type of copper minerals, in addition to a more efficient process is also more environmentally friendly.

Principle of copper mineral extraction is isolating and separation pure copper from gangue and its oxide and compounds. In pyrometallurgical process route, every extraction process will be produce copper metal, slag and gas, especially SO₂ that have impact to environmental pollution, while hydrometallurgy route has by product waste water or sludge and bioleaching require very less energy and is free from environmental pollution and other problems.

In other words, either pyrometallurgy or hydrometallurgy is conventional methods used for extraction of copper from minerals, both are not free from the environmental pollution problems and economically very expensive, and requires lots of energy. Bioleaching of mineral is the only method considered as most convincing way to solve these problems, requires very less energy and is free from environmental pollution and other problems. Some improvement process pyrometallurgical process as shown in Table 2.

TABLE III. IMPROVEMENT OF PYROMETALLURGICAL PROCESS ROUTE

<table>
<thead>
<tr>
<th>Process</th>
<th>Process parameter</th>
<th>Product</th>
<th>Concentration</th>
<th>% Cu</th>
<th>Improve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mining</td>
<td>Remove mineral from ground and surrounding rock</td>
<td>Copper and other minerals</td>
<td>0.3-9</td>
<td>Yield copper</td>
<td></td>
</tr>
<tr>
<td>2. Commissioning</td>
<td>Crushing to create smaller particle size and increases surface area for pyrometallurgical process</td>
<td>Copper and other minerals</td>
<td>0.5-6</td>
<td>Field copper</td>
<td></td>
</tr>
</tbody>
</table>

C. Identification and selection extraction route

As shown by Fig.2, that there are three route where hydrometallurgical extraction process mainly leaching-solvent extraction-electrowinning and bioleaching-solvent extraction-electrowinning has the potential to be developed, especially in the low-grade copper minerals. Obstacles encountered in the application of leaching is a low extraction rate, while in bioleaching is to keep the bacterial growth control. Because it required the development of the critical process parameters that is able to produce high copper purity. For bioleaching process, setting critical process parameter extraction copper based on mineral or minerals type involve temperature, pH, residence time, concentrate size, concentration of solution, kinetic, adsorption and nutrient contents.

Potential leaching for extraction of copper minerals are mostly related to the value of the investment, production cost and environmentally friendly. Extraction with leaching potential for replacing or as a new route in the future. However, when compared with bioleaching, leaching is still more expensive and environmentally friendly level is still lower.

The use of solvents and bacteria will be effective as an alternative to the extraction of copper minerals that has lower grade. Thus, the development of various kinds of solvents and bacteria is an important factor and determinant of the early success of the hydrometallurgical extraction of copper minerals based. In addition, the development and improvement of process parameters either solvent extraction and bioleaching will affect the kinetics of copper extraction and the resulting efficiencies.

D. Criteria of selection of extraction process route

Every production process will consider the many important aspects such as cost of production, efficiency, price, availability of raw materials and transportation costs. In addition, regarding with environmental issues, each production must not pollute the environment.
Therefore, the copper mineral extraction should take into consideration aspects of business and environmentally friendly. For the extraction process route selection, should consider every stage of the process.

E. Roadmap copper minerals extraction process

Acceleration technology-based extraction process both pyrometallurgy and hydrometallurgy (leaching, solvent extraction and bioleaching) and electrometallurgy can be done by creating a clustering of research and development centers in each university, research institute to support the needs of industry. Working together industry, universities and the government would be predicted to accelerate the implementation of Law No. 4 of 2009 and the added value either tangible or intangible such as sharing knowledge, experience, research and technology development process of extraction.

Should be aware that future sustainable development requires measures to reduce the dependence on raw materials and the demand for copper alloys. New of extraction processes for copper minerals must be developed by university, research institute and mining industry. In addition, improvement of already existing mining techniques should be done for increase of yield and environmentally friendly.

Copper-winning processes based on the activity of microorganisms such as bacteria or fungi offer a possibility to obtain copper from mineral resources. Bioleaching has virtually replaced roasting of arsenic-rich refractory gold concentrates. In the roasting process, arsenic is converted to arsenic trioxide, a highly toxic form of arsenic that requires disposal in specialized waste facilities. In the bioleaching process, arsenic is cobalt precipitated with iron in a stable form, and can be safely disposed of at the treatment plant site.

The traditional methods used for extraction of copper are either pyrometallurgy or hydrometallurgy. However, both the methods are not free from environmental problems. In pyrometallurgical method, the mineral is crushed and milled to a fine pulp and then concentrated by flotation using chemical reagents. The concentrate formed is smelted and electrolytically refined, however refining process creates environmental problems. It releases lots of metal ions in their wastes, it also releases lots of sulphur dioxide during smelting which causes environmental pollution. In hydrometallurgical method ore concentrate is leached by chemical methods followed by solvent extraction and electro-wining, however this method is not also free from environmental complexity but also from non-competitive economics.

V. CONCLUSION

Based on the data and discussion can be drawn several of conclusions as follows:

1. Until now pyrometallurgical still dominates 80% of the production of copper cathode-based sulphide minerals which are not environmentally friendly. Along with environmental issues, hydrometallurgical be a promising option for producing copper cathode in the future, because in addition to more environmentally friendly is also the cost of investment, production and qualification of resources is not high.

2. Act. No. 4 of 2009 is an entry point and a starting point for research and technological development of various types of mineral extraction processes copper in Indonesia so that the copper mineral concentrates can be processed into copper cathode.

3. Synchronization and integration between government policy, research and technology development process copper and mineral extraction industry to implement Law No. 4 of 2009 through the formation of clusters of research.

4. Optimization of technological parameters of copper minerals extraction processes to obtain optimum yield copper are on prospecting business and at the same time environmentally friendly.

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