Analysis of Nickel as a Raw Material for the Electric Vehicle Battery Industry

Muhammad Rizki Budiansyah[1)], Tri Setiyono[2)], Davry Sandi Imanda[3)] and Yudi Prastyo[4)]
[1)] Industrial Engineering / Faculty of Engineering, Universitas Pelita Bangsa , Universitas Pelita Bangsa
Jl. Kalimalang Inspection No.9, South Cikarang, Bekasi Regency

Abstract:- Indonesia is one of the countries that has large nickel reserves in the world. One strategy to meet the high demand for nickel in the future, laterite nickel can be used as an alternative feedstock, this is also due to the depletion of nickel sulfide reserves. The purpose of this paper is to discuss the global energy system that is in the midst of a significant energy transition in reducing the use of dirty energy that produces greenhouse gas emissions and switching to using environmentally friendly energy. One example is the use of electric cars with battery energy sources derived from nickel, this of course opens up great opportunities for the future of the nickel mining industry in Indonesia considering the nickel potential in Indonesia is the number one largest in the world. In this study, researchers used the literature study method with a skunder data approach. One of the government's plans in overcoming nickel in Indonesia, namely by limiting the export of raw nickel ore, by down streaming and making electric vehicle fuel. With the existence of electric vehicles in Indonesia, it is expected to help solve the problem of air pollution and the availability of petroleum.

Keywords:- *Nickel, Battery Raw Material, Electric Vehicle.*

I. INTRODUCTION

Mineral resources in Indonesia have quite a lot of potential and are almost spread throughout the archipelago. Indonesia is rich in mineral resources so that it generates considerable income for the country through taxes and royalties every year. According to the United States Geological Survey (USGS), Indonesia's nickel reserves are number one in the world, Of the 2.67 million tons of nickel production worldwide, Indonesia has produced 800 thousand tons, far outperforming the Philippines (420 thousand tons of Ni), Russia (270 tons of Ni), and New Caledonia (220 thousand tons of Ni) then also Based on data from the Ministry of Energy and Mineral Resources in 2020, the resilience of nickel reserves in Indonesia reached 2.6 billion tons of reserves with a reserve life of 27 years. [1]

Nickel ore in nature is divided into 2 types, namely nickel sulfide and nickel oxide which is often called laterite. In general, nickel sulfide is in the subtropical hemisphere while laterite is in the tropics. The amount of laterite nickel resources is greater than the amount of nickel sulfide. Based on data published in 1988, Indonesia occupies the second position in the world for nickel resources. The location of laterite resources in Indonesia is in Eastern Indonesia (KTI), especially in Southeast Sulawesi, Halmahera North Maluku, and Gag island Waigeo Papua islands. Electric batteries are a very important component of an electric car, as a source of energy to run the engine. This source of driving energy is what distinguishes electric cars from conventional oil-fueled cars, so they are more environmentally friendly because they reduce air pollution. Li-ion batteries use lithium and cobalt metal elements as electrodes, while NiMH utilizes nickel.[2]

Batteries are a key component of electric vehicles with an importance percentage of 60% of the constituent components of other electric vehicles. The battery is used as a current source for the electrical system as a place to store electrical energy during the charging process. Even in terms of price, around 30-40% of battery prices are the total production costs of an electric vehicle, causing the price of electric vehicles to be around 40% more expensive than the price of conventional vehicles. Thus, to support the government's program in accelerating the development of electric vehicles in the country by developing electric vehicle battery components domestically, especially in the production process. In addition to supporting government programs, another reason Indonesia wants to produce electric vehicle batteries domestically is considering the potential of raw materials for electric vehicle batteries which are quite abundant, one of which is nickel[3]

II. PURPOSE AND TARGET

The purpose of this writing is to determine the potential of nickel ore minerals as battery raw materials that can be used as energy materials for electric cars that can support the government in overcoming pollution problems caused by conventional vehicle emissions. While the target of this study is to find out the Type of Nickel Material and Effective Content to be used asa standard for making Electric Batteries for Electric Vehicle.

III. RESEARCH METHODOLOGY

The methods used in this study are:

- *Literature Study*

The literature study was conducted by collecting information related to existing Nickel reserves in Indonesia and the development of nickel material as raw material for the Electriclectric Vehicle battery industry

ISSN No:-2456-2165

➢ *Data Collection*

Research data consists of primary data and secondary data. Skunder data is data obtained from other sources of information and not from direct research

IV. RESULTS AND DISCUSSION

➢ *Distribution of Nickel Production in Indonesia*

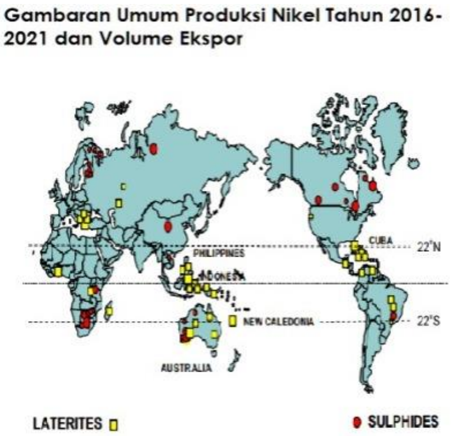

Fig 1. Nickel production overview Year 2016-2021 and export volume.

Nickel is a strategic commodity as a vital industrial raw material today that has high economic value. The geographical location of Indonesia which is in the equatorial zone with a tropical and subtropical climate, makes nickel reserves in Indonesia abundant.[4]Nickel spread in Indonesia is laterite nickel which has an important role in the global nickel industry. Laterite nickel accounts for 40% of total global nickel production of 1 million tons. As much as 70% of all the continent's nickel resources are contained in laterite Laterite nickel is currently beginning to be used as the main material for manufacturing lithium batteries for electric vehicles with high quality. The global industry has begun to shift from fossil fuels to electric fuels, in order to reduce gas emissions and be considered more efficient. This is supported by the ambition of Southeast Asia as a region with a target of achieving zero emissions by 2050 and 2065 The efforts made by the governments of each country are to establish policies to stop fossil fuel subsidies and increase efficiency to prevent sporadic growth in energy demand The European Union also began campaigning to reduce air pollution, one of its efforts was to establish a policy that banned the sale of engined cars internal or conventional combustion by 2035.The policy will certainly encourage consumers to switch to electric vehicles, because conventional vehicles will not be able to be registered in European Union countries. With the ambition of countries in the world to start transitioning to renewable energy, Indonesia will benefit greatly. The reason is, Indonesia is a country with abundant nickel reserves, so nickel production in Indonesia is increasing per year. Based on data from the U.S Geological Survey, nickel production in Indonesia is growing rapidly to make Indonesia the country with the largest nickel export production in the world.[5]

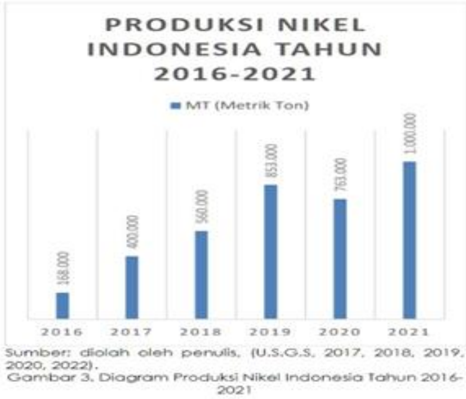

Fig 2. Indonesia's nickel production diagram 2016-2021

The diagram above shows the increase in nickel production in Indonesia, in 2016-2017 there was an increase of 232,000 metric tons. In 2017-2018 the increase in nickel production amounted to 160,000 metric tons. Then, in 2018-2019 the increase in nickel production was 293,000 metric tons. However, there was a decrease in nickel production in 2019-2020 by 90,000 metric tons. This is due to the impact of COVID-19 to hamper nickel production Nickel production soared again in 2020-2021, nickel production in Indonesia reached 1,000,000 metric tons, the largest in the world

➢ *Laterite Nickel Extraction as a Raw Material for Battery Manufacturing*

Nickel hydroxide precipitation from leaching solutions uses magnesia (MgO) as a neutralizing agent with control of pH, temperature and precipitation time to obtain the best conditions that provide the highest percent of nickel precipitation with as few impurities as possible that participate in precipitation. Referring to the research conducted, nickel hydroxide precipitation can be carried out with three different reagents (namely NaOH, NH3 and MgO) using an artificial solution of Ni-Co-Fe sulfate with complex formation using 25% NH3 solution, it was obtained that MgO reagents provide a higher percent of precipitation compared to NH3 and NaOH.

Leaching of laterite nickel ore is carried out at atmospheric pressure in a sulfuric acid solution.

After leaching, iron precipitation process is carried out with neutralizing reagents.

Nickel hydroxide precipitation from solutions that have been precipitated with iron using (MgO or NH3) as a pH regulating reagent Nickel hydroxide precipitation is carried out under pH conditions, temperature, precipitation time, and seed addition (Best conditions). To produce high quality MHP products, characterization of nickel hydroxide products is also carried out including analysis with X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM), Particle Size Analyzer (PSA) and Atomic Absorption Spectrophotometer (AAS).

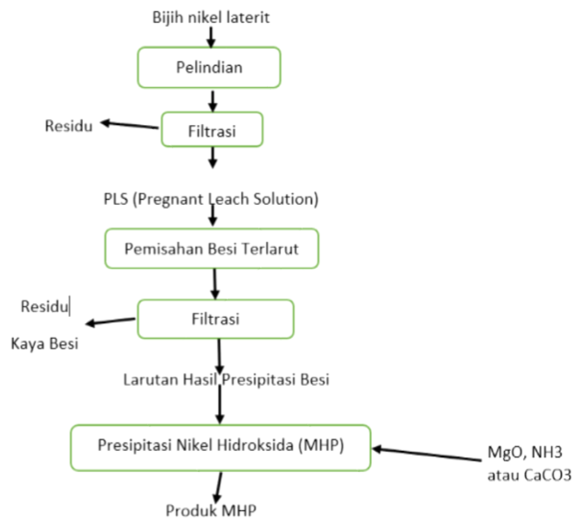

Fig 3. Nickel hydroxide precipitation experiment flow diagram

Precipitation of mixed hydroxide precipitate (MHP) from solutions leaching nickel laterite ores that have been precipitated by iron is an established and economical method for obtaining nickel and cobalt as intermediate products (Vaughan et al., 2013). The MHP precipitation process was first implemented at Cawse in 1998. Currently various MHP projects are also developed in Gordes META (Turkey), Ravensthorpe (First Quantum Minerals Ltd), Vermelho (Brazil), Ramu (Papua New Guinea and Young), Mount Margaret and Kalgoorlie (WA). Generally, alkaline reagents such as caustic soda (NaOH), soda ash (Na_2CO_3), slaked lime $Ca(OH)_2$, magnesium hydroxide ($Mg(OH)_2$) and magnesia (MgO) are used to increase the pH of solutions by lowering the solubility of metals so that nickel and cobalt precipitate (Kose and Topkaya, 2011; Katsiapi et al., 2010). Magnesia (MgO) is the most widely used neutralizing agent in the MHP precipitation process. This is because magnesia is cheaper when compared to caustic soda and soda ash and does not produce contaminated products such as slaked lime. In the MHP precipitation process, MgO consumption is an important parameter for the economics of this process MHP usually contains 15 to 25% Ni with 0.1-1% Co, 40-50% moisture.The main problem in the MHP precipitation process is that MHP is generally contaminated with unreacted Mn, Al, Ca and MgO. In addition, MHP precipitation also precipitates Mn and it is necessary to precipitate in two stages to control Mn precipitation to obtain a purer product. Conditions for MHP precipitation can be seen through the metal-hydroxide equilibrium graph It can be seen that Mn^{2+} and Mg^{2+} ions have an equilibrium region not far from Ni^{2+} and Co^{2+}, especially if the activity of these two metals is high enough. This leads to manganese and magnesium contamination in MHP products.

Fe^{2+} and Zn^{2+} precipitation lines also indicate that there will be zinc and iron present in MHP products if they are in PLS. The sequence of ion precipitation from left to right (low pH to higher pH) begins with Fe^{3+}, Al^{3+}, Cr^{3+}, and Zn^{2+} precipitation. Therefore, the process of recycling nickel hydroxide intermediate products needs to be carried out first eliminating iron, aluminum, zinc and chromium ions if these metals are present in PLS.

According to Kyle (2010), precipitation of nickel hydroxide with MgO takes place through reactions next:

$NiSO_4 + MgO + H_2O \rightarrow Ni(OH)_2(s) + MgSO_4$ (1)

$CoSO_4 + MgO + H_2O \rightarrow Co(OH)_2(s) + MgSO_4$ (2)

$MnSO_4 + MgO + H_2O \rightarrow Mn(OH)_2(s) + MgSO_4$ (3)

The precipitation of nickel to nickel hydroxide is carried out by the addition of OH^- ions from the slurry

$MgO(Mg(OH)_2)$ corresponds to Reaction 4:

$Ni^{2+} + OH^- = Ni(OH)_2$ (4)

Standard chemical potentials (μo), $Ni(OH)_2$, Ni^{2+} and OH^- can be used to determine the standard free energy value of precipitation $Ni(OH)_2$ corresponds to the following equation:

$\Delta G°_{reaksi,298} = \mu°_{298}\ Ni(OH)_2 - [\mu°_{298}\ Ni^{2+} + 2\mu°_{298}\ OH^-]$ (5)

The standard chemical potential value for Ni^{2+} = -11,530 cal, for $Ni(OH)_2$ = -108,300 cal and for OH^- is -37,595 cal. So that at the standard free energy of the nickel hydroxide precipitation reaction at a temperature of 25 °C or 298 K is: $\Delta G°_{reaction,298}$ = -108,300 - 11,530 + 2(-37,595) = - 21,580 cal. In the activity Ni^{2+} and $Ni(OH)_2$ is equal to 1, then

$\Delta G°_{reaksi,298} = -RT\ln\{\} = RT.2{,}303.2.\log(a_{OH^-}) = -RT.2{,}303.2.pOH - 21.580 = -2727{,}39\ pOH \frac{1}{(a_{OH})^2}$

pOH = 7,91

pH = 6,09

From the calculation above, the precipitation of nickel into nickel hydroxide can be done at a temperature of 25oC with a pH greater than 6.09. The precipitation of nickel to nickel hydroxide can also be predicted using a pH-potential diagram (Pourbaix diagram) Ni-H_2O The MHP process is considered more economical than MSP and has become the preferred choice of Ni precipitation as an intermediate product in recent years. This is because the MHP process does not require the use of an autoclave and does not use hydrogen sulfide gas reagents which are considered dangerous and require high-pressure oxidative leaching for the purification of sulfide precipitates. In reality, the capital cost of the MHP process is competitive with MSP. The downside of precipitation with MHP compared to MSP is that it is less selective of some impurities such as magnesium and manganese.

ISSN No:-2456-2165

Process Features	Mixed Sulphide (Jha et al 1981) (Simons 1988) (Kyle 2010)	Mixed hydroxide (White 1998) (Harvey et al 2011)
Temperature/Pressure	90-120 0C 200-1000 kPa H2S	50 0C 101 kPa Air (Atmospheric)
Equipment	Pressuirsed Reactor, Gas Handling	Ambient Pressure Continuous Stirred Tank Reactor
Precipitant	H2S/NaSH, NaOH	MgO
pH	2.5	7,5
Selectivity for Ni,Co vs.	Fe, Al, Mn, Mg	Mg, Mn (partially)
Reactor scaling	High	Low
Reaction extent	>98 %	~90 Stage 1, >98% Stage 2
Single passs residence time	0.5 – 2 hour	~3 hours
Seed recycle	100 – 400%	~100%
Refining	Pressure oxidation leach	Atmospheric leach

Fig 4. Comparison of mixed sulphide precipitate (MSP) precipitation with mixed hydroxide precipitate (MHP).

➢ *The Government's Role in Indonesian Nickel*

In supporting the development of an integrated nickel industry, the Government will increase domestic nickel downstream, one of which is by increasing the number of smelters. The government targets the construction of 53 smelters by 2024, where in 2021 there are 19 smelters established with an additional 4 smelters targeted for completion by the end of the year. The four smelters are owned by PT Aneka Tambang Tbk. with a progress of 97.7 percent, PT Smelter Nickel Indonesia (100 percent), PT Cahaya Modern Metal Industri (100 percent), and PT Kapuas Prima Citra with work progress reaching 99.87 percent in the Regulation of the Minister of Energy and Mineral Resources Number 11 of 2019 concerning the Second Amendment to the Minister of Energy and Mineral Resources Number 25 of 2018 concerning Mineral and Coal Mining Exploitation, namely as of January 2020, nickel ore with grades below 1.7 percent cannot be shipped/exported raw abroad, The decision was made in an effort to maintain nickel reserves by considering the sustainability of the supply of raw materials from existing smelters, One of the reasons the government imposed a ban on nickel exports is that nickel can be used as a raw material for electric car components.[6]

There are two general impacts of the existence of the electric vehicle battery industry in the country. First, Indonesia can play a role in the global supply chain of electric vehicle batteries. But on the other hand, the existence of the electric vehicle battery industry is considered to have an impact on the environment. There are indications that during the production process of electric vehicle batteries, CO2 emissions are produced which can affect climate change. Based on the description above, researchers assess the need to analyze the life cycle of electric vehicle batteries in Indonesia to see how much environmental impact is generated from the domestic electric vehicle battery production process. Because Indonesia is currently building an integrated electric vehicle battery industry from upstream to downstream. In addition, an analysis of the domestic electric vehicle battery supply chain is needed to see how the existence of the electric vehicle battery industry in Indonesia can play a role in the global supply chain.

➢ *Electric Vehicle Battery Production Process Inventory Analysis*

Electric vehicle battery life cycle inventory includes input and output data on materials, energy and emissions throughout their life cycle. The inventory results are obtained by analyzing the Flow Diagram Process of electric vehicle batteries followed by using secondary data. The secondary data used by the researchers is inventory data sourced from several journals including Shipu Zhao and Fengki You and Guillaume Majeu-Bettez, et al[7]

Table 2. Electric Vehicle Battery Component Inputs and Outputs (per 1 kg battery)

Components	**Value**	**Weight**
Cathode	1.00	Kg
Anoda	1.00	Kg
BMS	0.03	Kg
Seperator	0.03	Kg
Modul and battery packaging	0.017	Kg
Electric energy	0.0075	MWH
Output waste		
Heat	10,5	MJ

Source:Bettez,2011

The following table 3 is presented which contains the inputs and outputs of each component in table 2 per 1 kg of battery.

Com Ponens	**Material**	**Value**	**Weight**
	Lithium hydroxide*)	0,250	Kg
	Nickel sulfate*)	0,542	Kg
	Combalt sulfate*)	0,542	Kg
Cathode	Manganese Sulfate*)	0,523	Kg
	N-methyl-2-pyrrolidone (NMP)**)	0,28	Kg
	Latex*)	0,0185	Kg
	N-methyl-2-Pyrrolidone (NPM)**)	0,28	Kg
Anoda	Graphite*)	0.494	Kg
	Carbon Black *)	0.0159	Kg
	Copper*)	0,50	Kg
	Sulfuric acid*)	0,080	Kg
	Copper**)	0,50	Kg
	Integrated circu **)	0,10	kg
Bms	Chromium steel 188/8**)	0,40	Kg
	Wire Drawing**)	0,50	Kg
	Sheet rolling**)	0,40	Kg
Seperator	PolyethyleneSepa granulate**)	0,050	Kg

ISSN No:-2456-2165

Rator	granulate**)	0,050	Kg	Polypropylene,
Module and battery packaging	terphalate	1,00		Polyehylene Kg
Electric energy	highvoltage	0,0075	MWH	Electricity
Out put		10,5	MJ	

Source:*) Zhao and Yaou,(2019)**)Bettez et all,(2011)

There are two general impacts of the existence of the electric vehicle battery industry in the country. First, Indonesia can play a role in the global supply chain of electric vehicle batteries. But on the other hand, the existence of the electric vehicle battery industry is considered to have an impact on the environment. There are indications that during the production process of electric vehicle batteries, CO2 emissions are produced which can affect climate change.[8]

V. CONCLUSION

After conducting the above research, researchers know that Nickel spread in Indonesia is laterite nickel which has an important role in the global nickel industry. Laterite nickel accounts for 40% of total global nickel production of 1 million tons. As much as 70% of all the continent's nickel resources are contained in laterite Laterite nickel is currently beginning to be used as the main material for manufacturing lithium batteries for electric vehicles with high quality.[9][10] Precipitation of nickel to nickel hydroxide can be done at a temperature of 25oC with a pH greater than 6.09, The MHP process is considered more economical than MSP and is the main choice of Ni precipitation as a product, This is because the MHP process does not require the use of an autoclave and does not use hydrogen sulfide gas reagents which are considered dangerous and require high-pressure oxidative leaching for the purification of sulfide precipitates. In supporting the development of an integrated nickel industry, the Government will increase domestic nickel downstream, one of which is by increasing the number of smelters.

REFERENCES

[1]. "Increasing Investment and Downstream Nickel in Indonesia".
[2]. M. & Zaidan, W. Garinas, and K. ...... Nickel Mineral Raw Materials........., "STUDY OF NICKEL MINERAL RAW MATERIALS FOR ELECTRIC BATTERIES IN THE SOUTHEAST SULAWESI REGION," 2021.
[3]. R. A. Ulfa, M. Sidik Boedoyo, and N. A. Sasongko, "BATTERY LIFE CYCLE ANALYSIS FOR ELECTRIC VEHICLE DEVELOPMENT IN INDONESIA IN SUPPORT OF NATIONAL ENERGY SECURITY LIFE CYCLE ASSESSMENT OF BATTERY FOR ELECTRIC VEHICLE DEVELOPMENT IN INDONESIA TO SUPPORT ENERGY SECURITY."
[4]. M. & Zaidan, W. Garinas, and K. ...... Nickel Mineral Raw Materials........., "STUDY OF NICKEL MINERAL RAW MATERIALS FOR ELECTRIC BATTERIES IN THE SOUTHEAST SULAWESI REGION," 2021.
[5]. Indonesia-the-largest-nickel-production-in-the-world".
[6]. F. Y. Zein and S. R. Susanto, "Factors in the Selection of South Korea as Indonesia's Strategic Partner in Electric Vehicle Development."
[7]. "Cendekia Niaga Journal of Trade Development and Studies," 2023.
[8]. S. Application of Electric Cars in Surabaya, L. Choirun Nisa, and A. Susanti, "Strategy for Implementing Electric Cars in Surabaya as Smart Mobility I N F O A R T I K E L ABSTRACT," 2023.
[9]. "LATERITE NICKEL ORE RESOURCE ESTIMATION".
[10]. P. Ninasafitri et al., "Presipitasi Mixed Hydroxide Precipitate (MHP) dari Ekstraksi Nikel Mixed Hydroxide Precipitate (MHP) Precipitation from Laterite Nickel Extraction as a Raw Material for Making Batteries: Review of the Manufacturing Process."