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Extraction of Nickel from Morowali Laterite Ore with Hydrochloric Acid (HCl)

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Abstract

This study aims to determine the influence of temperature, leaching time, and the influence of hydrochloric acid concentration in the nickel extraction process, as well as to determine the optimum conditions of the laterite nickel extraction process using the Taguchi method which is influenced by hydrochloric acid concentration, temperature and leaching time. The laterite samples used came from the Bahodopi District, Morowali Regency, Central Sulawesi Province. Quantitative analysis using AAS (Atomic Absorption Spectrophotometer) with variables studied including acid concentrations of 0.5 M, 1 M, and 2 M, temperatures with levels of 30°C, 60°C, and 95°C, and leaching times of 3 hours, 6 hours, and 12 hours. The optimum conditions obtained from the results of the study were at a temperature of 95°C, a leaching time of 12 hours and a concentration of 2 M with the optimum absorbance obtained, namely 0.1635, the optimum concentration of 5.9693 mg /L with a percent of nickel recovery obtained of 1.41%.

Keywords: Laterite, nickel, leaching, Taguchi method, hydrochloric acid

Introduction

Indonesia is a country that is rich in natural resources, especially mining materials which are non-renewable natural resources. One example of such a resource is a mineral. Minerals are raw materials in the mining industry. One of the mineral resources that have the potential to be developed in Indonesia is nickel laterite (Arifin, 2015). Laterite is the result of weathering and enrichment of mafic/ultramafic rocks in the tropics so the chemical composition and mineralogy differ from one deposit to another (Subagja et al., 2016). In terms of potential reserves, Indonesia is known as one of the countries with the largest nickel reserves in the world. About 12% of the world's nickel reserves are in Indonesia in the form of laterite nickel ore. Nickel ore deposits are widely found in eastern Indonesia around the island of Sulawesi, the island of Maluku, and parts of the island of Papua (Solihin & Firdiyono, 2014).

Nickel laterite is a residual product of chemical weathering in ultramafic rocks (dunite, peridot) and their alterations (serpentinite). The weathering process in ultramafic rocks produces different nickel laterite characters and profiles (Lintjewas et al., 2019). One of the factors that influence the formation of laterite nickel deposits is the source rock (Kurniadi et al., 2017). Nickel in laterite nickel ore is associated with iron oxide and silicate minerals as a result of the isomorphous substitution of iron and magnesium elements in the crystal structure so that chemically and physically laterite nickel ore can be classified into two types, namely saprolite (silicate/hydro silicate) and limonite ores. (oxide/hydro oxide) (Subagja et al., 2016).

In several countries, at present several research and development activities have been carried out to obtain laterite nickel processing, including research and development activities to obtain nickel from laterite nickel through the hydrometallurgical process, research and development activities to obtain nickel metal by pyrometallurgy or a combination of hydro-metallurgical and metallurgical-pyro-metallurgical processes (Subagja & Firdiyono, 2015). Until now, the processing and refining of laterite nickel ore in Indonesia are carried out for saprolite ore with the results in the form of ferronickel and nickel matte while limonite laterite ore with lower nickel content has not been widely used (Fathoni & Mubarok, 2015). Laterite nickel ore in the saprolite layer which contains a lot of nickel is processed through a pyrometallurgical process while the limonite layer which contains little nickel is processed through a hydrometallurgical process (Astuti et al., 2015). The use of this hydrometallurgical method has the advantage that it produces a much purer main

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product compared to the use of the pyrometallurgical method (Wanta et al., 2018).

Hydrochloric acid as a medium in leaching is preferred because the process of recovering useful free acid is comparatively easier from impurities and solvent extraction (Li et al., 2019). Hydrochloric acid leaching is attracting much attention because it allows the extraction of large quantities of nickel in a short period. The chloride-based leaching process has several advantages over conventional hydrometallurgical processes, namely higher leaching yields, high stability of the chloro complex, and regeneration of leaching reagents (Permana et al., 2020). Physico-chemical factors affect the leaching process of laterite raw materials in hydrochloric acid. Several previous studies using hydrochloric acid as an agent for the leaching of nickel laterite indicated the presence of pre-roasting currents for leaching nickel laterite using hydrochloric acid (Li et al., 2020).

Variables that affect the dissolution of nickel ore are the type of ore, acid concentration, and temperature. The type of ore determines the consumption of solvent acid, while the increase in acid concentration and process temperature increases the nickel extraction percentage significantly (Solihin et al., 2014). The dissolution of nickel metal in laterite minerals is carried out with several variations including variations in solution concentration, dissolution time, and dissolution temperature. Generally, the Indonesian mining industry uses the Hydrochloric Acid leaching method where HCl is widely used as a leaching reactant because it is considered more optimal in extracting nickel metal from a mineral compared to other methods (Purwanto et al., 2003).

Permana et al. (2020) have researched the Leaching of Low-Grade Laterite Nickel Ore Using the Atmospheric Acid Leaching Method in Hydrochloric Acid Media (HCl). In this study, 75% of the nickel that could be extracted after the leaching process used hydrochloric acid for 90 minutes with an acid concentration of 4 M at room temperature 75 °C.

Based on the description above, the authors are interested in conducting research with the title "Nickel Extraction from Morowali Laterite Ore with Hydrochloric Acid".

Based on the formulation of the problem above, the purpose of this study is to determine the effect of temperature, concentration, and leaching time of hydrochloric acid on nickel content in laterite ore originating from Morowali.

Methods

This research is an experimental study based on nickel content analysis of the extraction results of laterite ore with differences in leaching time, temperature, and concentration of hydrochloric acid. Meanwhile, nickel content analysis was carried out using AAS analysis (Atomic Absorption Spectrophotometer) to determine the amount of nickel content in each sample.

The tools used in this research are oven, mortar, pestle, Whatman filter paper (hardened) no. 52 and 54, buncher funnel, Erlenmeyer filter flax, vacuum pump, filler (rubber suction), 100 ml beaker, magnetic stirrer, petri dish, vial, thermometer, test tube, dropper, spatula, sieve, stirrer, digital balance, measuring cup, measuring flask and AAS.

The materials that will be used in this study include Laterite ore from the Bahodopi sub-district, Morowali Regency, Central Sulawesi Province, and hydrochloric acid solution (HCl).

Sample preparation

Sample preparation aims to prepare the sample so that it is ready to be tested. The sample used in this study is laterite rock originating from the Morowali area. The sample preparation procedure is to weigh 1000 grams of the sample using a digital scale, then the weighed sample is heated or dried in an oven at 110 °C for 3 hours to remove the moisture content. After that, the dried samples were mashed using a mortar and pestle, then sieved using a 200 mesh sieve.

Extraction process

The extraction process that will be carried out in this study is to use three factors, namely temperature, time, and the concentration of the acid solution used. These three factors will affect the extraction results from each sample. The extraction process carried out in this study is as follows:

1. 20 grams of fine laterite was weighed, then put into a 1000 mL beaker, and added 100 mL of 0.5 M hydrochloric acid (HCl) solution. Cover the glass surface tightly with aluminum foil so that the mixture does not evaporate. This step was repeated for concentrations of 1.0 M and 2.0 M.
2. 2. Heat the mixture on a hot plate at room temperature and stir using a magnetic stirrer for 3 hours.
3. The mixture was filtered using a Buchner funnel lined with filter paper.
4. Perform steps 1-4 for temperature variations of 60°C and 95°C, as well as time variations of 6 hours and 12 hours.

After the leaching and filtering process, the nickel content in the filtrate was analyzed using AAS (Atomic Absorption Spectrophotometer) and the results of the analysis were recorded. The analytical data that has been obtained from the sample analysis process using the AAS tool are processed to obtain the optimum conditions and percent recovery of nickel.

Results and Discussion

The results obtained through research conducted, namely data analysis of nickel content contained in laterite ore by going through the extraction process on the effect of temperature, concentration, and leaching time of hydrochloric acid.

Analysis of nickel content

Analysis of nickel content was carried out on samples extracted from nickel from laterite ore which were influenced by 3 factors, namely temperature, concentration, and leaching time of hydrochloric acid. Laterite samples that have gone through the leaching process were analyzed using Atomic Absorption Spectrophotometry (AAS). The nickel calibration curve is made by connecting the absorbance value of the standard solution as coordinates (y) and the concentration of the standard solution as abscissa (x) to obtain a linear regression equation as shown in Figure 1.

Table 1. Nickel calibration standard solution

Concentration	Absorbance
0.05	0.014
1	0.032
4	0.116
10	0.279
20	0.524

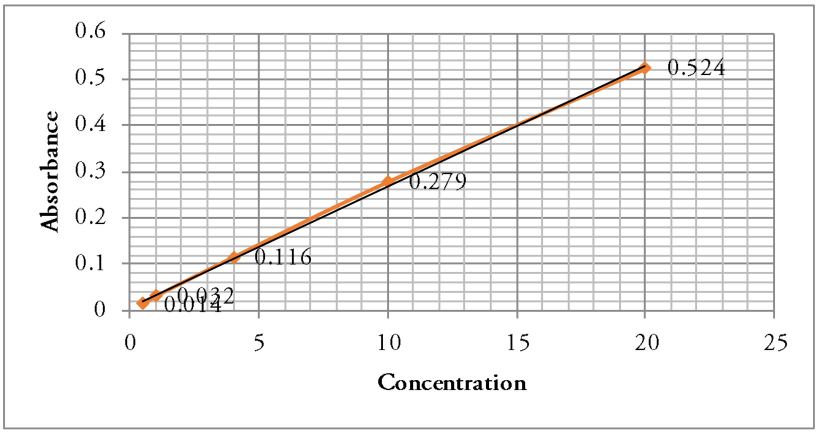

Figure 1. Nickle calibration

Table 2. Results of nickel content analysis using SSA

Acid Concentration (M)	Temperature (°C)	Leaching Time	Absorbance	Concentration
0.5	30	3	0.0965	3.4023
0,5	60	6	0.1380	4.9923
0,5	95	12	0.1845	6.7739
1	30	6	0.1640	5.9885
1	60	12	0.1880	6.9080
1	95	3	0.1620	5.9119
2	30	12	0.1660	6.0651
2	60	3	0.2030	7.4828
2	95	6	0.1935	7.1188

Determination of optimum conditions

The optimum condition is a condition where the nickel content analyzed is in the highest amount, as has been presented in **Figure 2**. The optimal results obtained are at a concentration of 2 M, a leaching time of 12 hours, and a temperature of 95 °C. From the results of the optimum conditions, the experiment was carried out again using the parameters that had been obtained. From the extract, the nickel content was analyzed again using atomic absorption spectrophotometry. From **Table 3** the concentration from the use of optimum conditions is 5.9693 mg/L to obtain a recovery value of 1.41%.

Nickel is located in the periodic table which has the symbol Ni with atomic number 28, and is a transition metal element with mass number 58.71. Nickel (Ni) is a silver-white metal discovered in 1751 and the main alloying element that provides strength, toughness, and corrosion resistance. Nickel is widely used in various commercial and industrial applications, such as stainless steel, copper shielding, the battery industry, electronics, aircraft industrial applications, the textile industry, gas turbine power plants, and strong magnets because of its corrosion resistance (Muas, 2019).

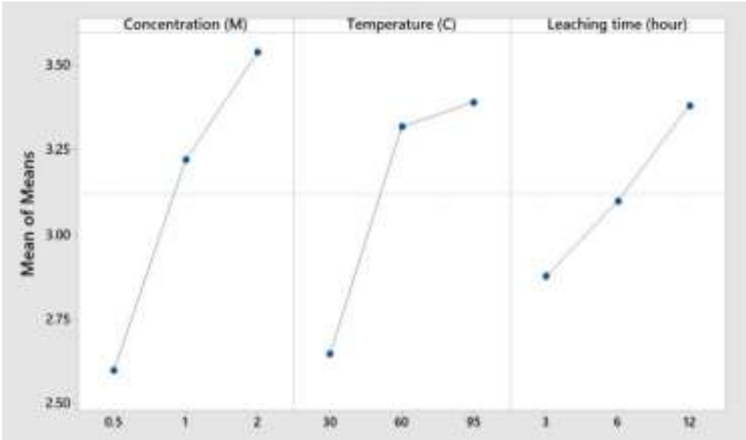

Figure 2. Optimum condition graph

Table 3. Optimum Condition Analysis Results

Acid Concentration (M)	Temperature (°C)	Leaching Time	Absorbance	Concentratio n
2	95	12	0.1635	5.9693

The initial stages in this research include crushing, drying, and grinding. At this stage, the destruction aims to change the sample size to be smaller so that the drying process can take place more quickly. Samples that have been crushed are then weighed as much as 1000 grams using a digital balance, then put in the oven for 3 hours at a temperature of 110°C to dry and remove moisture. After 3 hours the sample was removed and cooled and then crushed using a mortar and pestle and sieved using a 200mess sieve, then weighed again using a digital balance.

Then 20 grams of finely ground soil samples were added and 100 ml of 0.5 M hydrochloric acid was added, then extracted using a magnetic stirrer at temperatures of 30°C, 60°C, and 95°C and leaching time for 3 hours, 6 hours, and 12 hours. o'clock. The leachate was filtered using a Buchner funnel, Whatman filter paper, and a vacuum pump. After that, analyze the nickel content using SSA.

Effect of variations in acid concentration on the leaching process

Acid concentration is one of the factors that affect the leaching process. The acid concentration parameters used in this study were 0.5 M, 1 M, and 2 M. Where the total volume USD was 100 mL at each concentration. Based on table 4.2, it can be seen that the most influential concentration to obtain nickel with the most optimum value is the concentration of 2 M.

Several studies conducted by Goveli (2006) show that the higher the concentration of HCl solution used in the leaching process, the higher the nickel content obtained. This is because the speed of the extraction reaction is influenced by the presence of H^+ ions in the solution. The greater the number of H^+ ions, the speed of the reaction will increase because the breaking of bonds into monomers takes place better. The more H^+ ions in the acid solution, the greater the possibility of a reaction between H^+ ions and NiO molecules. The equation for the reaction that can occur according to (Li et al., 2020) is as follows:

$$NiFe_2O_{4(s)} + 2H^+ \rightarrow Ni^{2+} + Fe_2O_{3(s)} + H2O_{(l)} \quad (1)$$

$$NiO_{(s)} + 2H^+ \rightarrow Ni^{2+} + H2O_{(l)} \quad (2)$$

$$2NiO \cdot SiO_{2(s)} + 4H^+ \rightarrow 2Ni^{2+} + SiO_{2(s)} + H2O_{(l)} \quad (3)$$

Different concentrations of hydrochloric acid (HCl) with variations of 0.5 M, 1 M, and 2 M have different pH values. Based on the pH value for a concentration of 0.5 M of 0.301, for a concentration of 1 M of 0, and a concentration of 2 M of -0.301, it is known that the lowest pH value is at a concentration of 2 M. Based on research conducted by (Wanta et al., 2019), the lower the acidity (pH) of a solution, the more the number of dissolved ions, which means that the extraction process will be better. And vice versa, the solubility of an ion will decrease if the acidity (pH) is higher. This is following the optimum results obtained, where the lower the pH value used, the better the extraction process that occurs. The acidity level is inversely proportional to the pH value, the lower the pH value of a solution obtained, the higher the acidity level.

Effect of temperature variations on the leaching process

Temperature is an important parameter in determining the optimum condition of leaching results. The role of temperature in the process will affect the speed of the nickel laterite leaching process. To determine the effect of temperature on nickel laterite leaching, experiments were carried out at temperatures of 30°C, 60°C, and 95°C. From the research results obtained, the temperature with the highest nickel content is at a temperature of 95°C, this indicates that the use of high temperatures will also show a large percentage of nickel value. Similar results also occur in the study (Wanta et al., 2017) which in his research used temperature variations of 30°C, 60°C, and 85°C with the highest nickel content obtained at the highest temperature of 85°C. The same thing happened in the research conducted by Permana et al. (2020) where the increase in the percentage of nickel recovery will continue to increase following the increase in temperature until it reaches 14.4% at a temperature of 75°C.

In this study, it was proven that the higher the operating temperature used, the percentage of nickel recovery will also increase. The use of higher temperatures will cause the possibility of collisions between molecules to be higher so that the stages of formation of nickel products will also be higher. Temperature affects the leaching reaction kinetics. The higher temperature will cause the movement of each molecule to be faster and the possibility of the molecules colliding and reacting will also be greater, so the opportunity for nickel collection will be greater.

Effect of time variation on the leaching process

Leach time is also one of the influential parameters in the leaching process. Time is related to the rate of reaction which is expressed as the change in the concentration of a species with time. Optimization of the length of the stirring time to obtain optimal nickel yields. The time variations used are 3 hours, 6 hours, and 12 hours, where the highest nickel recovery time is at 12 hours. This happens because the longer the leaching time is given, the higher the nickel recovery percentage will be due to the longer contact time.

This is to the literature (Permana et al., 2020) where the longer the leaching process is carried out, the mineral recovery results will increase because the acid-solid contact process will continue to occur. The longer the reduction time for Ni recovery, the better. An up-and-down trend in the results after reduction shows that a lot of non-magnetic components are formed which are involved in the tailings for the time variable. The same thing happened to the research conducted by Ağaçayak & Aras (2017) wherein increasing the time of presence of ore particles in solution led to an increase in nickel extraction. Thus the number of dissolved metal ions from the particles that enter the solution increases with time.

Conclusion

Based on the research that has been carried out, it can be concluded that the optimum conditions obtained are the acid concentration of 2 M, temperature of 95°C, and leaching time of 12 hours with absorbance results of 0.1635 and nickel recovery percent of 1.41%. The higher the temperature used, the greater the nickel content obtained, and the longer the leaching time used, the tendency for the nickel recovery value to increase.

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