ISSN 3025-6674

Extraction Of Iron (Fe) As A Valuable Metal Content Of Nickel Slag Waste

Maryudi[a,1*], Syahrul Dwi Adi Candra [a,2], Muh. Azhar [a,3], Asdarina Yahya [b,4]

[a] Chemical Engineering Department, Faculty of Industrial Technology, Ahmad Dahlan University Yogyakarta 55191, Indonesia
[b]School of Chemical Engineering, College of Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia
[1]maryudi@che.uad.ac.id, [2]syahrulac29@gmail.com ; [3] azharsahu01@gmail.com; [4]asda@uitm.edu.my

*Corresponding author

ARTICLE INFO

Article history
Received January 15, 2024
Revised January 22, 2024
Accepted February 2, 2024

Keywords
Destruction,
Iron
Leaching
Nickel slag,

ABSTRACT

Nickel slag is a product that is formed at high temperatures to form metal alloys that are stable enough. It becomes a challenge for researchers to find methods for extracting valuable metals content. Leaching is one of the solid-liquid extraction methods that can be applied to separate important elements from a solid materials. By using strong acid solvents. Leaching of ferrous metal (Fe) as the main metal in nickel slags was carried out with a 98% 2M sulfuric acid extracting solution. Destruction of the leachate of nickel slag was then conducted to simplify the complex elements in the samples so that they can be easily analyzed .Destruction of nickel slag leachate samples was carried out using a destructive solutions in the form of nitric acid. The maximum yield of iron content was obtained at size of 140 mesh and 60 minutes with an iron content of 19,141 ppm. The minimum yield of iron content was obtained at 80 mesh-30 minutes of leaching with an iron content of 18,433 ppm. The maximum recovery results were obtained at 140 mesh-60 minutes leaching. Factors that can influences include solid sample size, extracting solution, mineral form in solids, complexity, pH, operating temperature, and leaching time.

1. Introduction

The mining metal and mineral processing industries produce 20% weight of the slag waste of steel production capacity [1]. Refer to Indonesian regulation (PP RI No.101, 2014) concerning Management of dangerous and poisonous material waste, slag waste was categorized as dangerous and poisonous material waste, specific origin using waste code B402. Slag means a by-product of the pyrometallurgy process that derived from the various metal ores and is classified according to the type of furnace used [2]. To avoid the generation of waste, it needs to apply 4R (reduce, reuse, recycle, and recovery) strategy.

Nickel slag is a product that formed at high temperatures in a stable metal alloy. It becomes a challenge for researchers to find a method for extracting certain valuable metals contents. The valuable metal contents can be used for certain needs, for example construction materials. Research on nickel slag that has been previously carried out includes: the behavior of Co and Ni in nickel slag during the leaching process uses aqueous liquid SO2 [3]. The utilization of nickel slag as raw material for Portland cement production and road construction also have been studied [4]. The other method to recover the valuable metals from nickel slag is by a leaching process using sulfuric acid at high temperature [5].

Recovery of metal component from nickel slag has also studied through an oxidative leaching at high pressure to obtain valuable metals such as Ni, Co and Cu [6]. The other potential utilizations of nickel slag are also developed such as aggregate for concrete, additional ingredient for cement clinker production, refractory bricks, glass ceramics [7]. Nickel slag contain several metals as well as complex mineral compound.

The metal and mineral content can be recovered to have the higher economical value, and also as an effort to handle waste from nickel industry. It hopefully can support the sustainability of environment. Nickel slag is classified as waste of hazardous and toxic material. Currently there have been many researches with the aim of utilizing the metal and mineral contents in nickel slag waste. There are many types of nickel slag processing. Utilization of nickel slag as a mixture for cement, aggregate for bricks, additional content for asphalt mixture, and other utilizations.

Utilization of iron (Fe) metal content in nickel slag waste is one of the most potential ways. The recovery of iron from nickel slag waste is still a challenge to obtain the optimum method. Since there are so many metal contents other than iron (Fe), it needs the appropriate technique to separate iron from other metal contents. The most common method of separation is the leaching or extraction method. Nickel slag commonly contains minerals i.e. iron (Fe), silicon (Si), chromium (Cr), manganese (Mn), nickel (Ni), calcium (Ca), sulfur (S), rubidium (Rb), zinc (Zi), lanthanum (La), and rhenium (Re). The highest percentage is iron, silica, followed by other types of metals [8].

2. Research Methodology

1. Materials

The material used were nickel slag which was obtained from nickel smelter in Maluku Utara, Indonesia, sulfuric acid 98% technical grade, pro-analytical nitric acid from Sigma Aldrich, filter paper, and distilled water.

2. Procedures

2. 1. Leaching process

This step was conducted for extracting metals, especially iron from nickel slag. The research was conducted based on the previous research method that has been done [8]. The leaching process was carried out using equipment that depicted in the Figure 1. The equipment comprised a three-neck flask assembled together with a magnetic stirrer, thermometer, stand, and upright cooler. Process leaching was done by mixing 60 ml sulfuric acid 2M with 15 g of nickel slag. Leaching temperatures used in the research was 100°C. The flask was immersed in the oil during heating process to reach a stable temperature. The experiment was conducted at various temperature and sulfuric acid concentration. that was based on several literatures which is based on the results of research conducted by previous researchers [8].

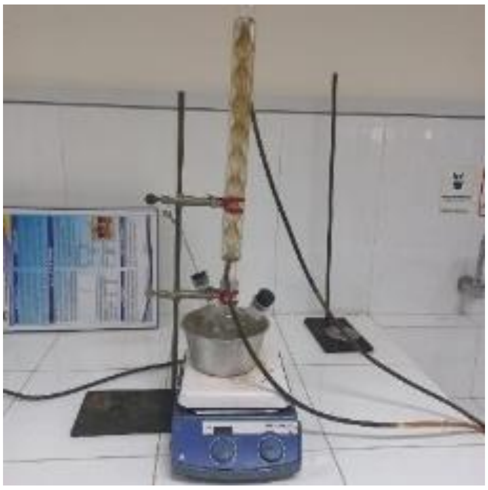

Fig.1 Leaching equipment set

During leaching process, magnetic stirrer was set at 250 rpm. The experiments were carried out with various size of nickel slag i.e., 60 mesh, 80 mesh, and 140 mesh, and also various leaching time i.e., 30, 60, and 90 minutes. After leaching process, the mixture was then separated by filtration process using filter paper into residual nickel slag and filtrate.

The filtrate was generally still concentrated and could not analyzed directly using AAS. The AAS analysis can be conducted only with the sample criteria being a clear solution without precipitate. Since filtrate was still concentrated, then filtrate must be treated through destruction process. Destruction was carried out using nitric acid solution for 30 minutes, and then heated until the nitric acid evaporates completely. The mixture was then filtered to separate liquid and sediment. The filtrate was then diluted with a measuring flask 50 ml with diluent solution using double distilled water. Result of dilution was then analyzed using AAS method.

2. 2. Iron content analysis

Spectrometry is a quantitative analysis method whose measurements are based on radiation acquired or absorbed by the atomic or molecular species of the analyte. The AAS method is one of several famous qualitative element analysis methods whose measurements are based on absorption light, use the exclusive long wave when atom of metal is in a free state [9]. The sample in the form of liquid is blown into the burner and burnt using oxygen combined along with oxidants that aimed for increasing temperature. And then as the result, a fine mist is produced. The ground state atoms that form in the fog passed through special rays and wavelengths. The rays are partially absorbed, which then claimed as absorbance. The ray passed is known as emission. Absorption that happened is proportional with the number of atoms in the flame [10].

2. 3. Dissolved Iron Weight Analysis and Recovery

Measurement of dissolved iron (Fe) was important to calculate recovery of iron from nickel slag waste. The recovery calculation is useful as a comparison of how much rate of iron (Fe) Which succeed in extraction from heavy beginning sample. From calculation This Also can be obtained what percentage of success the extraction was carried out. Calculation of dissolved iron and recovery can be carried out using the equation 1 and 2.

$$Dissolved\ Fe\ (g) = solvent\ volume\ (ml) \times Fe\ concentration\ in\ solution\ (g/ml) \quad (1)$$

$$Recovery = \frac{dissolved\ Fe\ (g)}{slag\ weight\ (g)} \quad (2)$$

3. Results and Discussion

3.1 Leaching

Fig.2 Leachate of nickel slag extraction (a) before destruction (b) after destruction

Leaching has been carried out for each sample variation and then the leaching results are first filtered using filter paper and then the results are put into each 50 ml sample bottle. The result of leaching process is depicted in the Fig. 2(a). This sample could not be analyzed directly, and need further treatment. The treatment was destruction of sample to meet the requirement of AAS method [11]. The sample after destruction process and filtration, is presented in the Fig. 2(b). The clear sample is ready to be analyze to determine the iron content.

Leaching variable of nickel slags affect the character of result solutions. Based on the experimental results, the unique blue leaching solution is the smaller particle size of nickel slag, the darker color of the solution. The darker solution means more material extracted. This is also characterized by the smaller particle size, the less residue left in the mixture.

3.2 Recovery of Iron

The AAS test have been conducted to determine the concentration of iron. The results are presented in the Table 1. The data show concentration of iron for different times and different sizes of nickel slag.

Table 1. Concentration of Fe in the leachate for various condition

Leaching time, min	Concentration of iron, ppm		
	Slag size of 60 mesh	Slag size of 80 mesh	Slag size of 140 mesh
30	18.433	18.749	18.847
60	18.540	18.777	19.141
90	18.740	18.625	18.958

Based on the data in Table 1, the dissolved iron concentration was calculated for each variation so that the iron weight in grams for each sample was obtained and then the recovery calculation was carried out to find out the recovery for various time and size of nickel slag. The results of leaching performance i.e., extracted iron weight, and recovery are presented in the Fig. 3 and Fig. 4.

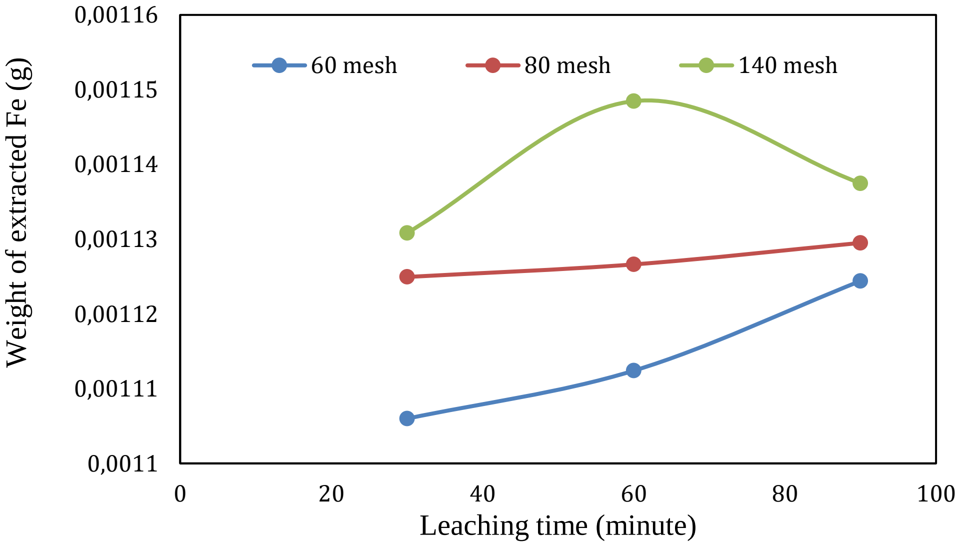

Fig. 3. Weight of extracted Fe

Fig. 3 has revealed that the longer time of extraction the higher extracted iron. The trend has been showed for slag size of 60 mesh and 80 mesh. However, at the slag size of 140 mesh, the trend is different with trend for slag size of 60 mesh and 80 mesh. The weight of extracted iron increase from 30 minutes to 60 minutes, and decrease at 90 minutes. It shows that the weight of extracted iron reached the optimum leaching time at 60 minutes. For slag size of 60 and 80 mesh, it looks that at 90 minutes, the yield still increases, however the increase is quite small. This result is in accordance with previous result [8].

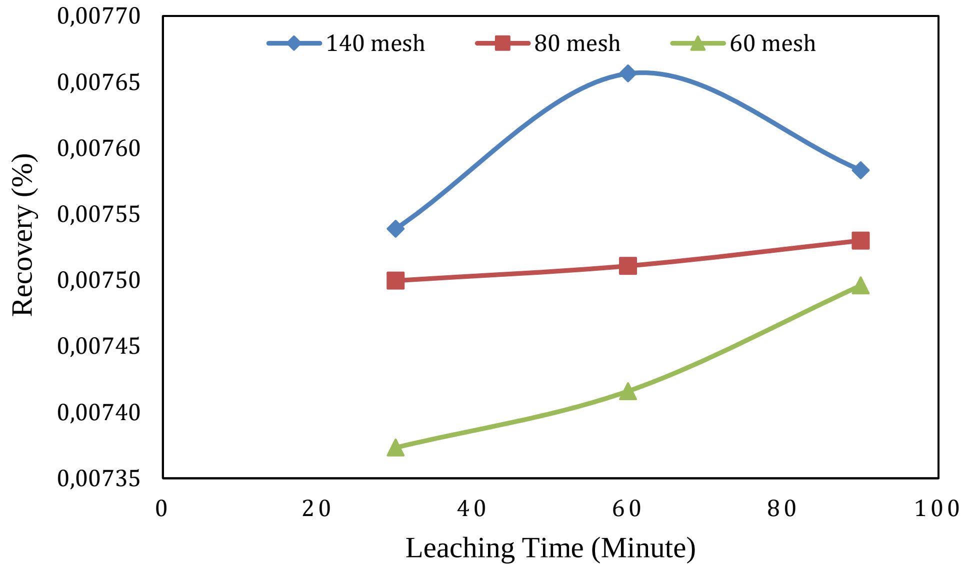

Fig. 4. Recovery of Fe

Fig. 4 shows that recovery of iron increases with the increase of leaching time for all variation of nickel slag size. The best recovery is achieved at leaching time of 60 minutes and nickel slag size of 140 mesh. The recovery is affected by leaching time and particle size. It is shown that the smaller particle sizes the higher recovery, and the longer leaching time the higher recovery obtained. However, the recovery trend for particle size of 140 mesh is quite different, there is a peak of recovery at a leaching time of 60 minutes.

Results of leaching metal can be influenced by numbers of factors. The factors are size of solid sample, extractor solvent, the form of minerals the solids, complexity, pH, operating temperature, and leaching time [12]. This study has shown that recovery of metal especially iron from nickel slag is small. It needs to explore intensively to obtain the effective method for extracting iron or other metal contents.

4. Conclusion

Leaching is a solid-liquid extraction method that can be applied to separation of important elements in a solid or semi-solid that is dissolved in a medium. The leaching process of nickel slag waste using sulfuric acid is affected by leaching time and particle size. The longer leaching time gives the higher recovery. The smaller particle size results in higher recovery.

References

[1] Gunawan, G., Oetojo, PD, Kusminingrum, N., Rahmawati, T., and Leksminingsih.: Utilization of Steel Slag for Environmentally Friendly Road Technology. *Pusjatan.* Bandung, 5 – 6. 2011.

[2] Piatak, NM, Michael BP, and Robert, RS Characteristics and environmental aspects of slag: A review, Applied Geochemistry, 1 – 31. 2014

[3] Gbor, PK, Ahmed, IB, Jia, CQ, Behavior of Co and Ni during aqueous sulfur dioxide leaching of nickel smelter slag, Hydrometallurgy, 57, 13-22. 2000 .

[4] Wu, Q., Wu, Y., Tong, W., Ma, H., Utilization of nickel slag as raw material in the production of Portland cement for road construction, Constr. Build. Mater, 193, 426-434.

2018.

[5] Huang, F., Liao, Y., Zhou, J., Wang, Y., Li, H., Selective recovery of valuable metals from nickel converter slag at elevated temperature with sulfuric acid solution, Sep. Purif. *Technol*, 156, 572-581. 2015 .

[6] Perederiy, I., Papangelakis, V.G., Buarzaiga, M., Mihaylov, I., Co-treatment of converter slag and pyrrhotite tailings via high pressure oxidative leaching, J. Hazard. Mater, 194, 399-406. 2011 .

[7] Xi, B., Li, R., Zhao, X., Dang, Q., Zhang, D., Tan, W., Perspective Constrains and opportunities for the recycling of growing ferronickel slag in China, Resour. *Conserv*. Recycling, 139, 15-16. 2018 .

[8] Majalis, AN, Permatasari, NV, Novitasari, Y., Wicaksono, N., Armin, D., and Pratiwi, R. (2020). Preliminary Study of Ferrous Sulphate Production from Nickel Slag Through the Leaching Process. *Jurnal Ilmu Lingkungan*, Vol.18 (1), 2020.

[9] Skoog, Douglas A. , Using Sulfuric Acid. Journal of Environmental Science, 18(1), 31-38. Principles of Instrumental Analysis. Philadelphia:Saunders. 2000 .

[10] Arinaldo, Pratama. Leaching Laterite Ore with Hydrochloric Acid. Thesis. Syarif Hidayatullah State Islamic University. Jakarta. 2016 .

[11] Asmorowati, Dian Sri., Sri, Susilogati Sumarti., and Ida, Iryani Kristanti. Comparison of Wet Digestion and Dry Digestion Methods for Analysis of Lead in Soil Around the FMIPA UNNES Chemistry Laboratory. *Indonesian Journal of Chemical Science,* 9 (3): 69-73. 2020.

[12] Settle, F.A. Handbook of Instrumental Techniques for Analytical Chemistry. River: New Jersey. 1997