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Research Paper

The Effect of Impurities on Nickel Content In Ore Samples Using Oven and Roasted Preparation Methods

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Abstract: This research was conducted using two sample drying methods: the oven method and the roasting method. Elemental analysis was carried out using the X-Ray Fluorescence (XRF) Epsilon 4 instrument. The study investigated the influence of impurity metals on nickel (Ni) content, particularly the presence of silica (SiO_2) and magnesium oxide (MgO). The results showed that silica (SiO_2) plays a significant role in affecting nickel content. The higher the silica content, the lower the detected nickel content. This is supported by negative correlation coefficients of -0.9725 for the oven method and -0.9090 for the roasting method. The coefficients of determination were 94.58% and 82.62%, respectively, indicating a strong relationship between silica and nickel content. In addition, the relationship between MgO and Ni also showed a negative trend. An increase in MgO content was followed by a decrease in Ni content. The correlation coefficients were -0.9678 for the oven method and -0.9651 for the roasting method, with coefficients of determination of 93.66% and 93.13%. These results confirm a very strong influence of MgO on Ni content. A t-test was conducted to determine whether there was a significant difference between the two drying methods in nickel content measurement. The calculated t-value was 0.013, while the critical t-value was 2.18. Since the calculated value is lower, the null hypothesis (H_0) is accepted, indicating no significant difference between the oven and roasting methods.

Keywords: Nickel Ore; Impurities; Oven; Roasting; Silica.

1. Introduction

Indonesia has abundant nickel reserves. According to the United States Geological Survey (USGS), Indonesia holds 72 million tons of nickel, equivalent to 21% of the world's total nickel reserves, which are estimated at around 100 million tons. Based on a 2019 geological survey, the reserves are projected to last for 27 years until 2047 for pyrometallurgical processing and 73 years until 2093 for hydrometallurgical processing.

Southeast Sulawesi is one of the provinces in Indonesia that holds a potential reserve of 97.4 billion tons, spread across an area of 480 thousand hectares [1]. Lithologically, North Konawe Regency is composed of ultramafic rocks that serve as the host for laterite nickel deposits. The morphology of this area consists of hilly terrain with steep, moderately steep, gentle, slightly gentle, and flat slopes [2]. The thickness of laterite nickel deposits on gentle and slightly gentle slopes in the limonite zone contains 1.99% Ni, while the saprolite zone contains 2.13% Ni. In contrast, the

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thickness of laterite nickel deposits on moderately steep slopes has a nickel content of 1.01% in the limonite zone and 1.46% in the saprolite zone [3].

Nickel ore is a metal whose applications are well known in various industries, particularly in metal plating and alloys. The processing of limonite-type laterite nickel ore typically employs hydrometallurgical techniques, which are considered more economical due to relatively low energy consumption and operational costs [4]. The solvent used in this process is a solution of H_2SO_4. A review of several journal articles shows that the nickel content in a given ore ranges from 0.95%, 1.42%, to 2.94%, while the remaining components are considered impurities [5]. One of the operational parameters that can affect the nickel purification process is the operating temperature, as indicated by the increase in nickel extraction percentage in line with the rise in temperature [6]. Besides operating temperature, another parameter that influences the percentage of nickel extraction is the solvent concentration [7]. Higher concentrations of H^+ ions facilitate the dissolution process by effectively binding the nickel oxide present in the nickel ore. The optimal conditions for producing high-purity nickel during leaching are a temperature of 90°C and an H_2SO_4 solvent concentration of 5M. [8]

Based on the research conducted Impurities in the form of metals affect the quality of nickel plating on “ST42” steel. Observations of impurity elements before plating pure steel showed that the highest metal impurities were Fe at 85.90%, Cu at 3.71%, and Pb at 0.06%. These research results indicate that the presence of metal impurities influences the durability and quality of the nickel coating on the steel. [9] [10]

The research conducted the research conducted by Adrianto et al., titled “The Effect of Silica on the Nickel Content in Laterite Ore,” shows that SiO_2 (silica) has a strong influence on the nickel content in the ore. The higher the silica content in the ore, the lower the nickel content. This is supported by a correlation coefficient test of -0.9561 and a determination coefficient of 91.4%, indicating a very strong correlation between the two variables. [11]

Nickel content is a major issue in the nickel mining business. According to the Ministry of Energy and Mineral Resources Regulation Number 11 Article 62A of 2019, products containing nickel below 1.7% are not allowed to be exported. This regulation poses a significant challenge for all nickel mining operations. The nickel content tends to be unstable and varies during the ore mining process [12]. This creates a major problem for nickel mining, namely determining the location and structure of the rocks and soils that form the ore, as well as their suitability to meet the desired nickel content standards. Nickel can degrade due to several factors, including those originating from the ore itself, the composition of the ore, and other elements and compounds naturally present in the soil during lateritization [13].

The pit at PT. X contains heterogeneous laterite nickel deposits, where the distribution of nickel (Ni) is uneven. Based on field observations, materials tend to accumulate with impurities (waste), which can reduce the Ni content. In the mining industry, especially in nickel extraction, the mineral composition and elements present in the ore greatly influence the final outcome of the mining process [14]. Two important components that are frequently analyzed are silica (SiO_2) and magnesium oxide (MgO). This study aims to measure the effect of silica (SiO_2) and magnesium oxide (MgO) impurities on the nickel content at PT. X to support the quality of the ore sold in accordance with sales qualifications.

2. Research and Methodology

2.1 Research Equipment and Materials

The equipment used in this study includes a digital scale, trays, jaw crusher, hammer, chute, cutting knife, double roll crusher, pulverizer, press machine, aluminum cups, XRF Epsilon 4, and JIS scoop. The materials used are nickel ore samples and rock impurities.

2.2 Research Procedures

The reactors consist of a centrally oriented conversion chamber within its' set-up and possessing several small air holes at the base. The chamber houses the feed to be converted while the combustion fuel for heat generation occupies the 'heating gap' between the chamber and the reactor itself.

Oven Method

Prepared materials were weighed with varying masses and coded according to the mass variations of 100 g, 400 g, 800 g, 1200 g, 1600 g, and 2000 g. After weighing, each coded sample was resized in wet preparation to -10 mm using a jaw crusher and hammer, then homogenized using a cutting knife. The homogenized samples were placed in trays labeled according to their mass variation and dried in an oven at 105°C. Once dry, the samples were resized again using a double roll crusher to -3 mm and reduced by the 4×5 matrix method using a 3D scoop. After matrix reduction, the samples were resized again using a pulverizer to 200 mesh and further reduced by the 4×5 matrix method using a 1D scoop. The samples were then pressed into aluminum cups using a press machine at 20 tons pressure. The resulting pellets were analyzed using the XRF Epsilon 4 [15].

Roasting Method

Prepared materials were weighed with variations of 100 g, 400 g, 800 g, 1200 g, 1600 g, and 2000 g and coded accordingly. Each coded sample was resized in wet preparation to -10 mm using a jaw crusher and hammer, then homogenized with a cutting knife. The homogenized samples were placed in trays labeled by mass variation, then dried using roasting technique by placing samples in a pan or roasting device and heating directly over a flame. Samples were continuously stirred to ensure even heat distribution on all particle surfaces. After drying, the samples were resized using a double roll crusher to -3 mm and reduced by the 4×5 matrix method with a 3D scoop. After matrix reduction, the samples were resized again using a pulverizer to 200 mesh and reduced with a 4×5 matrix method using a 1D scoop. The samples were then pressed into aluminum cups with a press machine at 20 tons pressure. The pellets formed were analyzed using the XRF Epsilon 4 [16].

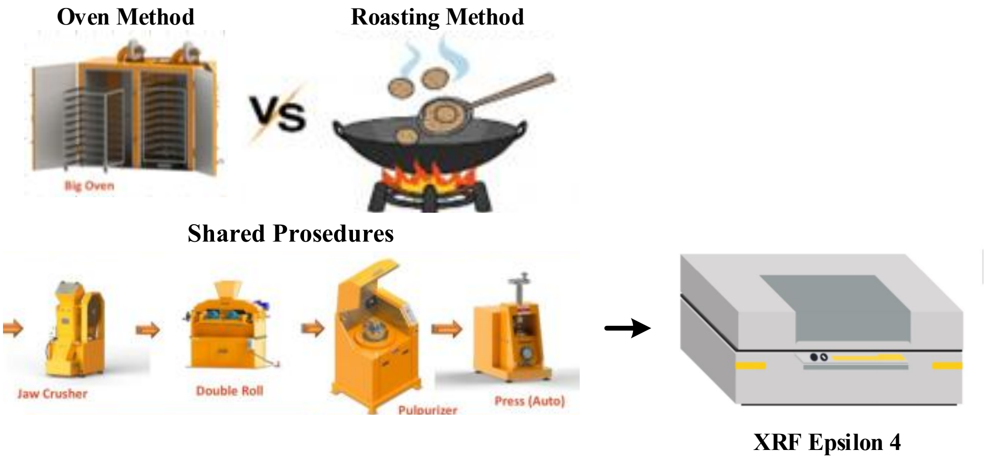


Fig 1. Research process design

2.3 Result Analysis

Each obtained sample will be analyzed for correlation coefficient, determination coefficient, and T-test analysis.

3. Results and Discussion

3.1 Correlation Coefficient and Determination Coefficient Tests

Analysis Results of Ni and SiO_2 Elements

The effect of SiO_2 impurities on the Ni content in ore samples using the oven and roasting methods is presented in the form of a graph in Figure 2.

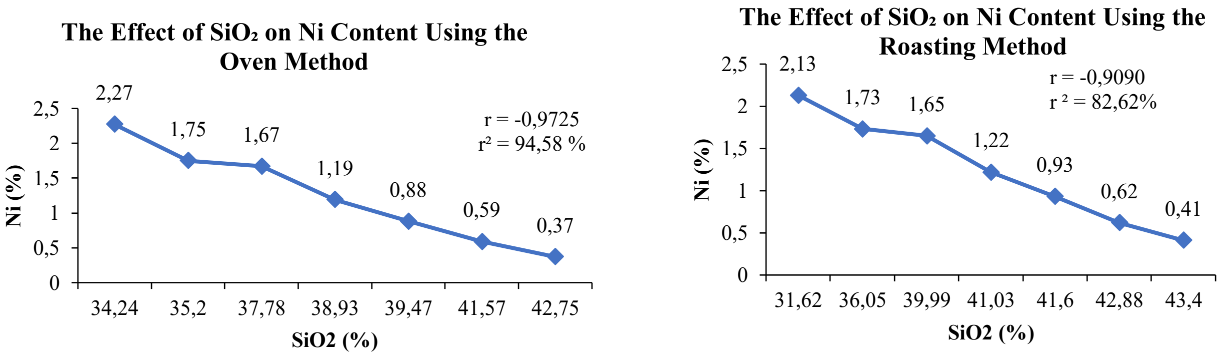


Figure 2. The Effect of SiO_2 on Ni Content Using the Oven Method (left) and the Roasting Method (right)

Figure 2 shows a decrease in nickel content for both methods, oven and roasting. This indicates that silica (SiO_2) has an effect due to its adsorbent properties, which enable it to bind heavy metals, including nickel. This process occurs through physical interaction between the silica surface and metal ions, where nickel ions can become trapped within the silica structure. [17]

The calculation of the correlation coefficient, which aims to reveal the relationship between variables, yielded an r value of -0.9725 for the oven method and -0.9090 for the roasting method. These results indicate that the independent variable (X), silica (SiO_2), and the dependent variable (Y), nickel (Ni), have a negative relationship. This means that every increase in X is followed by a decrease in Y. [18]

In the determination coefficient test, the main purpose is to assess the extent to which the independent variable can explain variations in the dependent variable. In this study on the effect of silica (SiO_2) on nickel content (Ni), the determination coefficient (R^2) was 94.58% for the oven method and 82.62% for the roasting method. These values show that the contribution of variable X (SiO_2) to variable Y (Ni) is quite high, with silica's influence on nickel reaching 94.58% for the oven method and 82.62% for the roasting method. These findings align with the research conducted by [19], which showed a negative correlation: the higher the silica content, the lower the nickel content in the ore [20].

Silica (SiO_2) is one of the main impurities in laterite nickel ore. High silica content can disrupt the smelting process and increase energy requirements in separation processes [21]. This information is useful for determining optimal excavation locations and more efficient processing strategies. Therefore, reducing silica content in nickel ore can improve nickel production yields [22].

Analysis Results of Ni and MgO Elements

The effect of MgO on Ni content in ore samples is presented in the form of a graph in Figure 3.

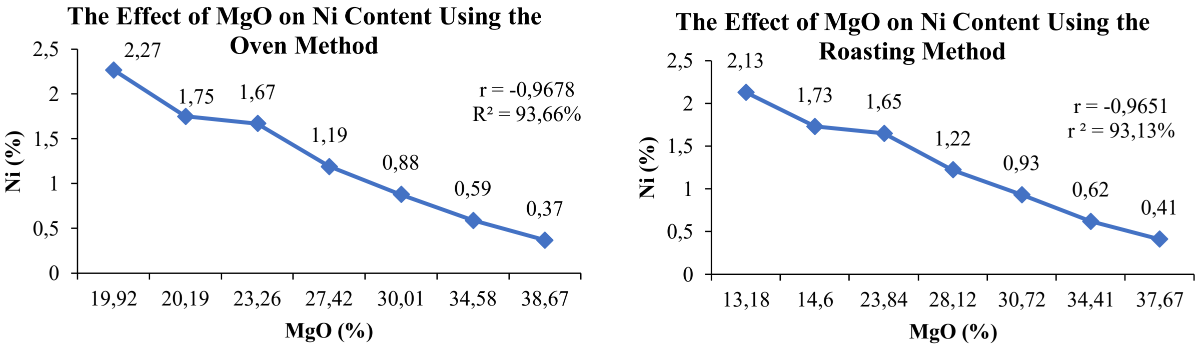


Figure 3. The Effect of MgO on Ni Content Using the Oven Method (left) and the Roasting Method (right)

Figure 3 shows a decrease in nickel content for both methods, oven and roasting. This indicates that MgO has a significant effect on the concentration of nickel ore. The inverse relationship between the two suggests that the management and processing of nickel ore must consider the MgO content to maximize nickel extraction yields. When the Ni concentration decreases, the MgO concentration increases. This is caused by geochemical or mineralogical processes where an increase in MgO can be associated with a reduction in nickel-bearing minerals [23].

The calculation of the correlation coefficient, which aims to reveal the relationship between variables, yielded an r value of -0.9678 for the oven method and -0.9651 for the roasting method. These results show that the independent variable (X), MgO, and the dependent variable (Y), Ni, have a negative relationship. This means that every increase in X is followed by a decrease in Y [24].

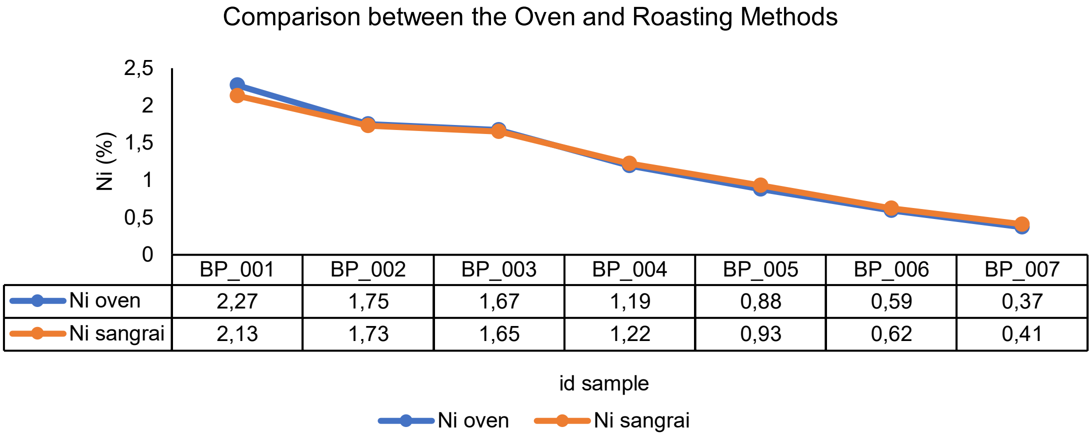
In the determination coefficient test, the main goal is to assess the extent to which the independent variable explains variations in the dependent variable. In this study on the effect of MgO on Ni content, the determination coefficient (R^2) was 93.66% for the oven method and 93.13% for the roasting method. These values indicate that the contribution of variable X (MgO) to variable Y (Ni) is quite high, with MgO's influence on Ni reaching 93.66% for the oven method and 93.13% for the roasting method. This aligns with the research conducted by [25], which showed an inverse relationship between MgO and nickel ore. A significant increase in MgO content corresponds with a decrease in nickel content.

During the lateritization process, magnesium can interact with other minerals that affect the formation of nickel-bearing minerals. High MgO content is often associated with specific geological conditions that do not favor nickel accumulation, such as altered ultramafic rocks. The chemical weathering of ultramafic rocks causes changes in mineral composition, where MgO forms and affects nickel content. Rocks with higher MgO content tend to show lower nickel levels because magnesium ions can replace nickel ions within mineral structures [26].

In nickel processing, high MgO content can hinder ore reduction at high temperatures by forming olivine, thus complicating the reduction of metals such as Ni. This negatively impacts the yield and quality of the metal [15].

3.2 T-Test Analysis

The analysis results of Ni element in ore samples using the oven and roasting methods are presented in Figure 4.



	BP_001	BP_002	BP_003	BP_004	BP_005	BP_006	BP_007
Ni oven	2,27	1,75	1,67	1,19	0,88	0,59	0,37
Ni sangrai	2,13	1,73	1,65	1,22	0,93	0,62	0,41

Figure 4. Comparison of the Oven and Roasting Methods

Based on Figure 4, samples with codes BP_001 to BP_003 show that the percentage of Ni obtained by the oven method is higher than that of the roasting method. Meanwhile, for samples BP_004 to BP_007, the Ni values from the oven method tend to be lower than those from the roasting method. Based on the T-test results, the calculated t-value (t_hitung) is 0.013, which is smaller than the critical t-value (t_tabel) of 2.18. Therefore, the null hypothesis (H_0) is accepted, meaning that the population mean 1 does not differ significantly from population mean 2. The calculations of t_hitung and t_tabel are shown in Appendix 2.

The difference between the oven and roasting methods is that the roasting method generally does not meet the standards because the temperature and heating time in the roasting method vary. The higher the temperature and the longer the heating, the more chemical compositions change, resulting in either higher or lower nickel content compared to the oven method.

Advantages of the roasting method include shorter processing time and lower costs. However, it has the disadvantage of a higher risk of cross-contamination between samples due to the limited separation of sample containers [14].

Using the roasting method for drying requires special attention to possible contamination from the equipment used, as well as the instability of air conditions and temperature. According to the Japanese Industrial Standard (JIS) applied in laboratories, the oven method is recommended for drying because it reduces contamination levels and maintains a stable temperature around 105°C. This stability ensures the sample composition remains unchanged and only water vapor evaporates without causing chemical reactions in the compounds contained in the sample.

4. Conclusion

Silica (SiO_2) plays an important role in influencing the nickel (Ni) content in nickel ore. The higher the silica (SiO_2) content, the lower the nickel (Ni) content. This is supported by the correlation coefficient test results, which show a value of -0.9725 for the oven method and -0.9090 for the roasting method, as well as the determination coefficient test results of 94.58% for the oven method and 82.62% for the roasting method, indicating a very strong relationship between these two variables. The relationship between MgO and Ni is inversely proportional, where an increase in MgO content is followed by a decrease in Ni content. This is supported by the correlation coefficient test results showing negative values of -0.9678 for the oven method and -0.9651 for the roasting method, along with determination coefficients of 93.66% for the oven method and 93.13% for the roasting method, proving a very strong relationship between MgO and Ni. There is no significant difference between the oven and roasting methods in measuring nickel content. This is supported by the T-test results for both methods, with a calculated t-value of 0.013 and a critical t-value of 2.18, meaning the calculated t-value is smaller than the critical t-value.

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