Indonesian Journal of Chemical Research
http://ojs3.unpatti.ac.id/index.php/ijcr Indo. J. Chem. Res., 13 (2), 157-160, 2025

The Leaching of Manganese Ore from Patappa, Barru Regency, South Sulawesi

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Received: February 2025
Received in revised: July 2025
Accepted: September 2025
Available online: September 2025

Abstract

Manganese ores are considered economical and worth selling if they have a purity value above 40%. However, not all mined manganese metal minerals have the appropriate purity value. Manganese metal minerals can be processed using various hydrometallurgical methods to separate metal minerals from their associated minerals using solvents. The purpose of this study is to determine the results of manganese leaching recovery at each variation of temperature and percent solids and to determine the effect of both on manganese recovery. The findings of this study could significantly contribute to the field of metallurgy and mineral processing by providing a deeper understanding of the factors influencing manganese recovery. The method used in this study began with sample preparation. The results of sample preparation were analyzed using XRD (X-ray diffraction) and XRF (X-ray fluorescence). Some of the sample preparation results were leached with several variations in temperature; the leaching results were continued with analysis using AAS (Atomic Absorption Spectrophotometer). The results showed that increasing the leaching temperature and percent solids would increase the leaching reaction rate, resulting in higher Mn recovery.

Keywords: Manganese, leaching, temperature, percent solids, recovery

INTRODUCTION

Manganese ore, a vital raw material in industrial steel like ferromanganese, has diverse applications beyond Metallurgy. It is used in the production of dry batteries, animal feed, fertilizer plants (U.S. Geological Survey, 2019), and the chemical industry. Additionally, it is a key component in the manufacture of dryers for paints and varnishes and serves as a coloring agent in the ceramic and glass industries (Sontakkey, Mohanram, Aehdi, Aruna, & Lal, 2016). This underscores the significant industrial importance of manganese ore. Notably, the global demand for manganese ore is on a steady rise, adding urgency to the topic.

Manganese (Mn) is a mineral in Indonesia with significant economic potential, utility, and availability of reserves (Nur & Widodo, 2015). The untapped reserves of low-grade manganese ore in Indonesia (Ginting & Sufiandi, 2011) present a promising opportunity. With the existence of Government Regulation Number 7 of 2012, which prohibits the sale of raw mining materials abroad, we have the chance to add value to our mining materials. By processing these materials into semi-finished goods or final products, we can unlock the economic potential of manganese. This regulation applies to 14 types of precious metal ores, including manganese ore (Kementerian ESDM RI, 2017).

The process of transforming manganese ore is a versatile one, with the material being utilized in different ways depending on its content. Manganese ore with a content above 40%, commonly referred to as metallurgical grade, is processed pyrometallurgically into ferromanganese metal (Yiicel & Emin Ari, 2001). On the other hand, manganese ore with a content below 40% is used for the production of chemical compounds such as potassium permanganate, MnO_2, and others. This type of pyrolusite mineral manganese ore can be selectively dissolved in acidic conditions. The process of manganese leaching is reductive, and in its implementation, certain compounds are required to reduce the oxidation number of Mn from Mn (IV) to Mn (II) so that it can be dissolved using acidic compounds (Zhang & Cheng, 2007).

A study conducted by Das et al. (Das, Sahoo, & Rao, 1982) demonstrated the occurrence of a reaction between MnO_2 in low-grade manganese ore and ferrous sulfate. Under operational conditions involving a temperature of 90 °C, a stoichiometric amount of ferrous sulfate, and a solid-to-liquid ratio of 1:10, more than 90% of the manganese could be extracted from the ore. However, under these conditions, the resulting slurry was gelatinous and difficult to filter. Reductive leaching of deep-sea and low-grade manganese ores using aqueous SO_2 or sulfite salts has been increasingly reported. These reducing agents, commonly used as food preservatives, have shown high effectiveness particularly for high-grade manganese ores. Aqueous SO_2 has been applied in both percolation and agitation leaching processes. In such systems, SO_2 is oxidized to SO_4^{2-}, with $S_2O_6^{2-}$ potentially forming as a by-product depending on parameters such as solution pH, temperature, and redox potential. Manganese extraction rates exceeding 90% have been reported in these studies (Petrie, 1995). Additionally, glucose has been utilized as a reducing agent for leaching low-grade manganese ores (Pagnanelli, Furlani, Valentini, Vegliò, & Toro, 2004). In the present study, the effects of sulfuric acid concentration, leaching temperature, and solid percentage on manganese extraction efficiency were investigated, as well as the solubility of other metals such as iron. One of the main reasons for using molasses in this experiment is its abundance and low cost, as it is a by-product of the sugar industry.

Therefore, in this study, a leaching method using sulfuric acid with the addition of molasses was employed. The manganese ore used was sourced from Patappa, Barru Regency. Previous research conducted in this area has primarily focused on increasing manganese content through beneficiation processes, utilizing differences in magnetic properties of the minerals to separate manganese ore from its impurities (Juradi et al., 2023). This study aims to provide insights into the potential utilization of local resources, particularly manganese ore, for industrial applications and refining processes.

METHODOLOGY

The manganese ore samples used in this study were obtained from Patappa, Barru Regency, South Sulawesi Province. They were then prepared and tested for their components using XRD and AAS tools.

The manganese ore obtained from the field has a relatively large and non-homogeneous size. Therefore, sample preparation is necessary to obtain the desired and homogeneous particle size. The preparation begins with reducing the particle size to -150 mesh using a mini jaw crusher and ball mill, aiming to liberate the valuable minerals from the gangue. Then, sampling is carried out using the coning and quartering method to obtain a representative sample and divide it for initial analysis and leaching purposes.

The leaching process was carried out using various temperature variations (50, 60, 70, and 80°C), percent solids (5, 10, 15, and 20% w/v), and leaching durations (90, 120, 150, and 180 minutes). The concentration of sulfuric acid used was 6% (v/v), with the addition of 5 mL of molasses and a stirring speed of 200 rpm. After the leaching process, the sample was filtered to obtain the filtrate for AAS analysis.

Determination of manganese recovery was carried out using the following equation (Awaliah, Yesfisari, Firdaus, & Wahab, 2023):

$$\alpha = Cp/Cpo \times 100\% \qquad (1)$$

Dimana:

α = Manganese recovery (%)

Cpo = Initial concentration (ppm)

Cp = Liquid phase concentration (ppm)

RESULTS AND DISCUSSION

Initial characterization of manganese ore samples using XRD (X-ray diffraction) and AAS (Atomic Absorption Spectrophotometry) analysis. The results of the XRD analysis can be seen in Table 1.

Table 1. Results of initial manganese ore sample analysis using XRD analysis

No	Minerals	Chemical Composition	Grade (%)
1	Manganite	MnO_2	13.99
2	Hematite	Fe_2O_3	18.09
3	Goethite	FeO (OH)	54.61
4	Jarosite	$KFe_3(SO_4)_2(OH)$	8.87
5	Mordenite	$Al_2Si_{10}O_{24}.7H_2O$	4.44

Table 1 shows that manganite is the carrier mineral of Mn metal, with a percentage of 13.99%. Meanwhile, the results of the initial analysis of the mangasnese ore using AAS show that the concentration of Mn is 195.233 ppm.

Leaching of manganese ore based on the effect of temperature

Manganese ore leaching was carried out using different leaching temperatures, namely 50 °C, 60 °C, 70 °C and 80 °C. Based on Figure 1. shows that Mn recovery after leaching using temperatures of 50 °C, 60 °C, 70 °C and 80 °C respectively is 16.186%, 16.736%, 17.461% and 18.962%. The recovery results show relatively low values. This is thought to be due to the presence of impurities that are dissolved in the leaching, thus reducing the recovery of manganese. According to research before (Sumardi, Mubarok, Saleh, & Firdiyono, 2012) in the leaching carried out in addition to manganese, there are other metals, namely iron, which are dissolved even though they are not desired. The iron that is dissolved will increase with increasing concentration and temperature. This dissolved iron is an impurity element that must be separated from the leach solution so that a purification process of the leach solution is needed by precipitating the iron element into its hydroxide. Based on the results of XRD analysis (Table 1) show that the percentage of iron-bearing minerals (Fe) is quite high, so the relatively small manganese yield can be affected by the presence of dissolved iron.

The high Fe content in the sample can also be extracted for use in various industries especially Fe_3O_4. Fe_3O_4 has the unique properties especially in nanometer scale such as super paramagnetic and ability to function at the cellular level that have a wide range of applications such as biosensor, magnetic hyperthermia and drug delivery system (Kurnia, Kaseside, & Iwamony, 2021).

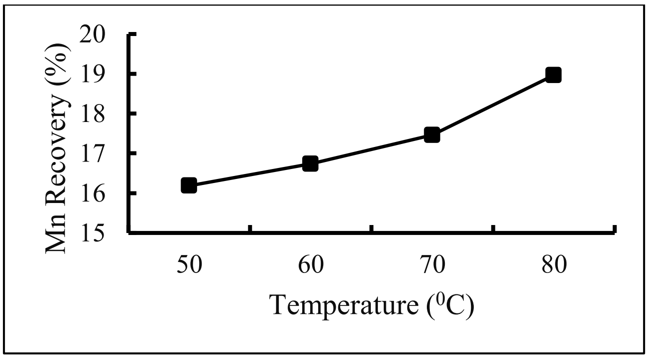

Figure 1. Graph of the effect of leaching time on Mn recovery value

As illustrated in Figure 1, the rise in temperature from 50 to 80 °C corresponds to a proportional increase in Mn recovery. The results of temperature variations using sulfuric acid and molasses-reducing agents showed that the highest Mn recovery was achieved at a temperature of 80°C. According to Arrhenius, in general, temperature dramatically affects the reaction rate. Increasing the temperature will increase the rate of the leaching reaction so that in the same leaching time with a higher temperature, the percentage of metal extraction will be higher (Sumardi et al., 2014). According to previous research (Permana, Kumalasari, Wahab, & Musnajam, 2020), in the leaching process, an increase in temperature enhances the frequency of molecular collisions. This is because temperature supplies energy to the ions in both the sample and the solvent, enabling them to move more rapidly. As the temperature rises, ion mobility increases, thereby raising the likelihood of collisions between ions. Consequently, the reaction rate increases.

Leaching of manganese ore based on the influence of solids percentage

The percentage of solids used in leaching manganese ore in this study were 5, 10, 15 and 20% (w/v).

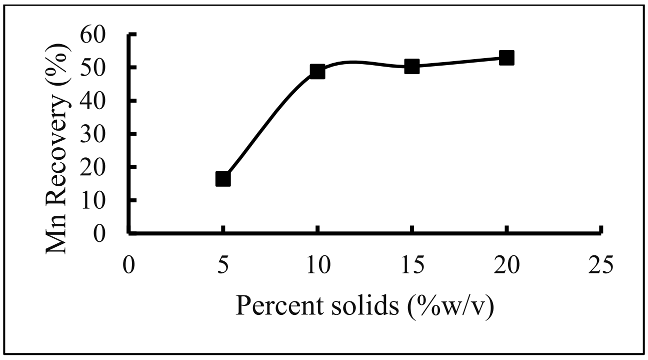

Figure 2. Graph of the effect of percent solids on Mn recovery value

Based on Figure 2. shows that Mn recovery after leaching using various percent solids variations of 5% (w/v), 10% (w/v), 15% (w/v), and 20% (w/v), respectively, are 18.965%, 48.819%, 50.327%, and 52.929%. The results of the increase in the percentage of manganese recovery will continue to increase following the rise in leaching solids and reach the highest recovery at a percent solid of 20% (w/v). Similar results have been shown by previous research conducted by (Awaliah et al., 2023), which shows an increase in Mn recovery against the percentage of solids. The percentage of solids in leaching will determine the leaching capacity. On the other hand, the higher the percentage of solids, the higher the viscosity of the solution, and it will affect the solubility of the oxidizer gas in the leach solution (Setyawan & Zaki Mubarok, 2015). However, as the percentage of solids increases, more leaching reagents and energy will be required.

CONCLUSION

Based on the results of manganese ore leaching based on the effect of temperature and percent solids, the following conclusions were obtained; Recovery of dissolved Mn at a temperature of 50 ℃ was 16.186%, a temperature of 60 ℃ was16.736%, a temperature of 70 ℃ was 17.461% and a temperature of 80 ℃ was 18.964%. Recovery of Mn from various variations of the percent solids of 5% (w/v), 10% (w/v), 15% (w/v), and 20% (w/v) were, respectively, 18.965%, 48.819%, 50.327%, and 52.929%. Based on the experiments conducted, the optimum temperature of manganese ore leaching was 80 °C, with an Mn recovery of 18.964%. Meanwhile, the optimum solids percentage is 20% (w/v), 52.929%.

ACKNOWLEDGMENT

The author would like to thank the Rector of Universitas Muslim Indonesia who has supported and provided research funds and LP2S Universitas Muslim Indonesia who has distributed the research funds. Thanks, are also conveyed to the Mining Engineering Study Program FTI UMI who has facilitated this research so that it can run well.

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