- REPLY TO COMMENT ON PAPER

International Journal of Mining and Geo-Engineering

IJMGE

IJMGE 59-2 (2025) 171-174

DOI: 10.22059/IJMGE.2025.395582.595254

Magnesium oxide production from dolomite ore

Hasan Vafaei Jirsarai [a, *], Ziaeddin Purkarimi [a], Reza Parvareh [a], Behrouz Karimi Shahraki [a], Seyed Ramin Bani Hashemi [a] and Morteza Dehghani [a]

[a] *Iranian Mineral Processing Research Center (IMPRC).*

Article History:

Received: 01 March 2025.
Revised: 10 May 2025.
Accepted: 31 May 2025.

ABSTRACT

In this study, the production of magnesium oxide (MgO) from dolomite ore ($CaMg(CO_3)_2$) sourced from a mine in the southern region of the country was investigated. Following sample collection, dolomite was transported to the Iranian Mineral Processing Research Center for XRF, ICP, XRD, and TGA-DTA analyses. The results of mineralogical and chemical analyses indicated that dolomite and calcite were predominant minerals, both critical for magnesium production. The calcination process at a particle size of 3 mm and a temperature of 800°C converted dolomite into an oxide phase. Magnesium oxide was subsequently produced through acid leaching using 2M HCl at a solid-to-liquid ratio of 5:15 at 70°C for 3 hours. The precipitation process using NaOH at a pH of 8–9 resulted in the formation of magnesium hydroxide, which was further heated at 600°C to convert it into magnesium oxide (MgO).The results demonstrated that the complete production of magnesium oxide is feasible at the Iranian Mineral Processing Research Center. This study highlights the high potential of the dolomite mine in the southern region as a source of raw material for MgO production and emphasizes the need to develop industrial infrastructure to complete the value chain of this strategic material.

Keywords: *Magnesium, Dolomite, Calcination, Acid Leaching.*

1. Introduction

Magnesium, the eighth most abundant element in the Earth's crust, plays a vital role in various industries due to its unique properties, including low density, high strength, excellent formability, and good electrical and thermal conductivity. Dolomite ore is one of the most important sources for magnesium extraction. Composed of calcite and magnesite, dolomite is widely regarded as an ideal raw material for producing magnesium and its compounds. Formed primarily through regional metamorphism, this rock typically contains at least 45% magnesium carbonate and appears naturally white, though impurities may introduce gray, pink, green, or black hues. Dolomite has a specific gravity of approximately 2.6 g/cm³, a hardness of 3.5–4 on the Mohs scale, and a vitreous to pearly luster. Significant dolomite deposits exist worldwide, particularly in regions, such as Indonesia. This study explores hydrometallurgical techniques for extracting magnesium from dolomite ore, which are among the most efficient methods for producing magnesium and its derivatives. The research focuses on magnesium oxide production from dolomite sourced from a southern region of the country, analyzing a composite reserve sampled from multiple stations with varying compositions. The experimental procedures and results are presented in detail, offering insights into optimizing magnesium extraction and production from mineral resources.

2. Material and methods

This research investigated dolomite sourced from a mine in southern Iran. Composite samples were prepared by blending material from five sampling stations with equal weight percentages from different areas of the mine. The results of XRF and XRD analyses are presented in Table 1 and Figure 1. XRF data revealed that the dolomite samples contained Caro, MgO, Na_2O, SiO_2, Al_2O_3, P_2O_5, SO_3, K_2O, and Fe_2O_3, with CaO and MgO as the predominant compounds and the others as minor constituents. XRD analysis confirmed that most peaks corresponded to dolomite, with additional minor peaks attributed to $CaCO_3$ and SiO_2 impurities. The composite dolomite samples were crushed to ≤3 mm using jaw and roller crushers at the Iran Mineral Processing Research Center. This particle size was selected to minimize fines (preventing agglomeration during calcination) while ensuring complete calcination. The crushed samples were then calcined at 800°C for 5 hours, decomposing the dolomite into calcium oxide (CaO) and magnesium oxide (MgO). Subsequent leaching was performed using 37% hydrochloric acid (2 M concentration) at a solid-to-liquid ratio of 1:3 and 70°C for 3 hours to solubilize the primary dolomite components, magnesium and calcium. After leaching, the solution was filtered to remove the negligible insoluble residue. The filtrate was then treated with 10 M sodium hydroxide to adjust the pH to 8.5–9.5, precipitating magnesium hydroxide ($Mg(OH)_2$). Due to the temperature sensitivity of $Mg(OH)_2$, precipitation was conducted below 60°C. The precipitated $Mg(OH)_2$ was collected via filtration and subsequently calcined at 600°C for 1 hour to produce magnesium oxide (MgO). The complete process flow is illustrated in Figure 2.

3. Results and discussion

3.1. The effect of heat on dolomite calcination

The thermogravimetric (TGA) and differential thermal analysis (DTA) results, presented in Figure 3 demonstrated the thermal behavior

* Corresponding author. *E-mail address:* hasan.vafaei@ shahroodut.ac.ir (H. Vafaei Jirsarai).

Table 1. XRF Analysis results of the composite sample from five sampling stations.

Element	P_2O_5 (%)	SO_3 (%)	TiO_2 (%)	MgO (%)	CaO (%)	Al_2O_3 (%)
Composition (wt. %)	0.01	0.46	0.01	19.08	33.19	0.1
Element	L.O.I (%)	Fe_2O_3 (%)	SiO_2 (%)	SrO (%)	K_2O (%)	Na_2O (%)
Composition (wt. %)	46.38	0.1	0.57	0.01	0.17	0.1

of composite dolomite samples within the 750-900°C temperature range, which was investigated to determine the optimal calcination conditions. Our analysis revealed two distinct decomposition events at 798.52°C and 915.38°C, corresponding to the decomposition of dolomite and calcite, respectively, with a total mass loss of 19.47%. Systematic calcination experiments conducted at 750, 800, 850, and 900°C for 5 hours to monitor the thermal decomposition process, as shown in Reaction 1:

$$CaMg(CO_3)_2 \rightarrow CaO + MgO + 2CO_2 \quad (1)$$

XRD analysis of the calcination products showed complete dolomite decomposition at 800°C, resluted in well-defined and high-purity CaO and MgO. These findings, supported by the data in Figure 4, establish 800°C as the optimal calcination temperature. Moreover, Figure 5 provides visual evidence of the pronounced structural transformations occurring during calcination at this temperature.

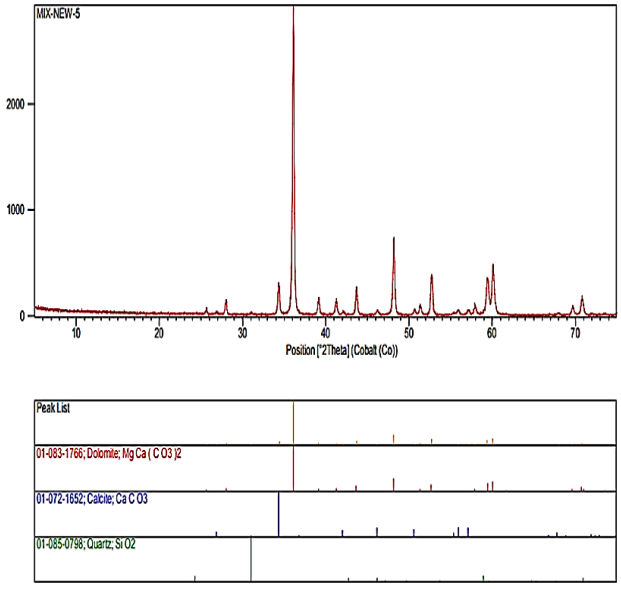

Figure 1. XRD diagram of the combined sample of five sampling stations.

3.2. The effect of hydrochloric acid concentration on leaching of calcined dolomite

In the leaching experiments conducted at 70°C with a liquid-to-solid ratio of 3, the concentration of hydrochloric acid (HCl) varied from 0.5 to 2 M. The results indicated that magnesium extraction increased with rising HCl concentration. Over a 3-hour leaching period, increasing the HCl concentration from 0.5 M to 2 M enhanced the dissolution of calcined dolomite from 2.4% to 99.07%. Images of the hydrochloric acid leaching process and the filtration of the leachate are shown in Figures 6 and 7, respectively.

3.3. The effect of sodium hydroxide addition on magnesium hydroxide precipitation

The hydrochloric acid leaching solution has a pH of 2.5, and sodium hydroxide must be added to precipitate magnesium oxide. The pH rapidly increases from 2.5 to 8 upon NaOH addition, but the rise from 8 to 9 occurs slowly, during which magnesium hydroxide gradually

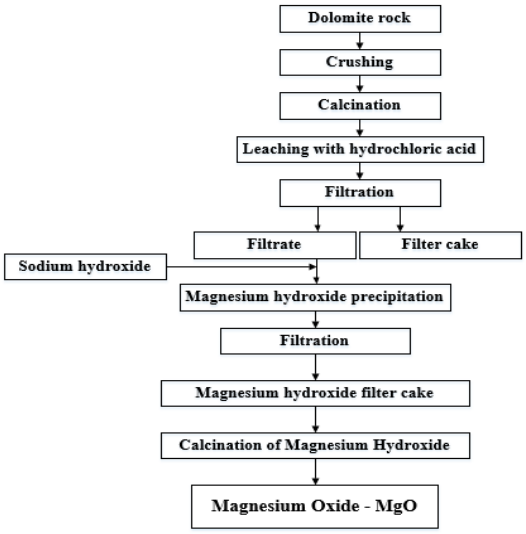

Figure 2. Flowchart of magnesium oxide production test procedures.

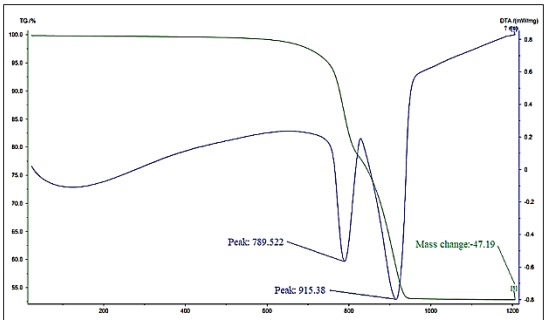

Figure 3. TGA-DTA diagram of the combined sample of five sampling stations.

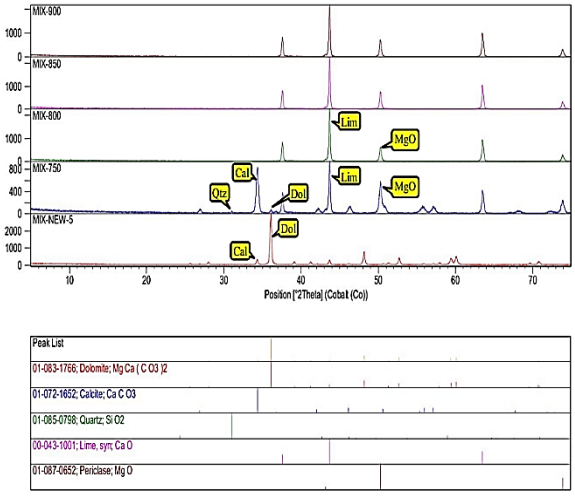

Figure 4. XRD pattern of the calcination of the composite sample at different temperatures.

Figure 5. Comparative images of the composite sample (right) pre-calcination state and (left) post-calcination state at 800°C.

Figure 6. Hydrochloric acid leaching of calcined dolomite.

Figure 7. Filtration of the hydrochloric acid leachate.

appears as a white precipitate at pH 8, with complete precipitation achieved at pH 9. After filtration, magnesium hydroxide can be separated from the solution. The XRD analysis results of the precipitated magnesium hydroxide, the supernatant solution, and the solid magnesium hydroxide are shown in Figures 8, 9, and 10, respectively. Note that the precipitation temperature must be maintained at 60°C due to the low solubility of magnesium hydroxide at higher temperatures.

3.4. The effect of heat on the conversion of magnesium dioxide to magnesium oxide

To produce magnesium oxide (MgO), the thermal decomposition of magnesium hydroxide ($Mg(OH)_2$) was carried out at 600°C for 1 hour. To optimize the decomposition temperature, $Mg(OH)_2$ was heated at 500°C, 600°C, and 650°C for 1 hour each. Based on the results, 600°C was selected as the optimal temperature due to a weight loss of 36% . The XRF results and XRD analysis of the thermally decomposed magnesium oxide are presented in Table 2 and Figure 11, respectively.

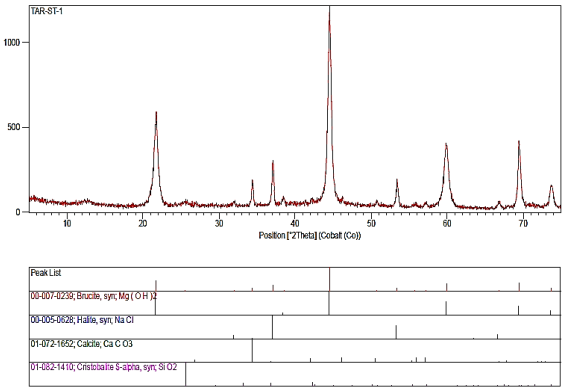

Figure 8. XRD analysis results of the precipitated magnesium hydroxide.

Figure 9. Precipitation solution of magnesium hydroxide.

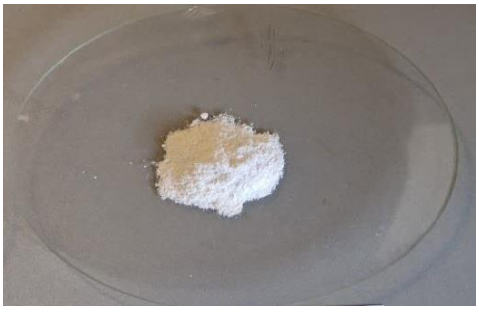

Figure 10. Solid magnesium hydroxide.

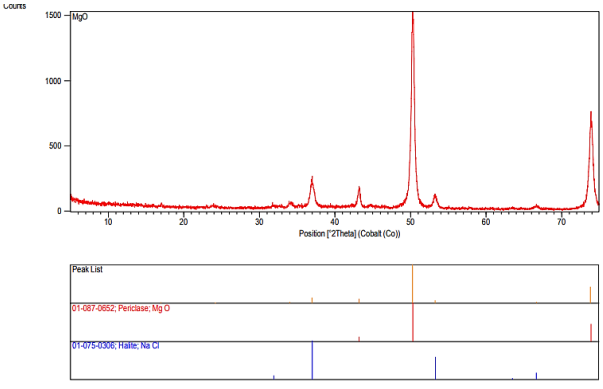

Figure 11. The XRD patterns of magnesium oxide.

Table 2. The XRF analysis results of magnesium oxide.

P_2O_5 (%)	SO_3 (%)	TiO_2 (%)	MgO (%)	CaO (%)	Al_2O_3 (%)
0.01	0.32	0.01>	75.81	5.77	0.99
L.O.I (%)	**Fe_2O_3 (%)**	**SiO_2 (%)**	**SrO (%)**	**K_2O (%)**	**Na_2O (%)**
12.41	0.94	0.64	0.01	0. 1>	3.01

4. Conclusions

A hydrochloric acid leaching process for magnesium extraction and magnesium oxide production from calcined dolomite ore was successfully demonstrated. Results showed that magnesium extraction efficiency increased with both rising hydrochloric acid concentration and an increased liquid-to-solid ratio. The addition of sodium hydroxide proved crucial for pH adjustment to between 8 and 9 to precipitate magnesium hydroxide ($Mg(OH)_2$), which is essential for optimal conversion to magnesium oxide (MgO). The optimized conditions included: dolomite calcination at 800°C, leaching with 2 M hydrochloric acid at 70°C with a 15:5 liquid-to-solid ratio for 3 hours, and pH maintenance at 8-9 for hydroxide precipitation. Thermal decomposition at 600°C was identified as the optimal temperature for converting magnesium hydroxide to magnesium oxide.

References

[1] Akhmedov, M., Dadakhodzhaev, A., & Guro, V. (2018). Technology of Processing of Navbakhore Dolomite on Magnesium Compounds. Open Access Journal of Chemistry, *2*(1), 1-6.

[2] Amer, A. (1996). A contribution to hydrometallurgical processing of low-grade Egyptian dolomite deposits. Hydrometallurgy, *43*(1-3), 345-356.

[3] Azizi, A., & Jafarnejad, M. (2017). Leaching of magnesium from dolomite ore in nitric acid solutions. International Journal of Mineral Processing, *166*, 45-51.

[4] El-Naggar, M. R., El-Kamash, A. M., & El-Dessouky, M. I. (2009). Extraction of magnesium from hydrometallurgical tailings by hydrochloric acid leaching. Journal of Hazardous Materials, *168*(2-3), 832-837.

[5] Kipouros, G. J., & Sadoway, D. R. (2001). Toward greener processes for the production of magnesium: An overview. Journal of Metals, *53*(5), 34-37.

[6] Liu, Y., & Li, J. (2015). A novel process for the extraction of magnesium from dolomite by vacuum aluminothermic reduction. Journal of Alloys and Compounds, *619*, 634-638.

[7] Royani, A., Sulistiyono, E., Prasetiyo, A., & Subagja, R. (2018). Extraction of magnesium from calcined dolomite ore using hydrochloric acid leaching. AIP Conference Proceedings, *1964*(1), 020030.

[8] Warren, J. K. (2016). Evaporites: A geological compendium (2nd ed.). Springer.

[9] Yildirim, M. (2008). Dissolution kinetics of Icel-Aydincik dolomite in hydrochloric acid. Journal of the Southern African Institute of Mining and Metallurgy, *108*(2), 127-132.

[10] Yildirim, M., & Akarsu, H. (2010). Preparation of magnesium oxide (MgO) from dolomite by leach-precipitation-pyrohydrolysis process. Physicochemical Problems of Mineral Processing, *44*, 257-272