



Extraction of Fe and Al from red mud using carbothermic reduction followed by water leaching

Humma Akram Cheema, Sadia Ilyas, Muhammad Farhan, Ji-hye Yang, Hyunjung Kim*

Department of Earth Resources & Environmental Engineering, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea

ARTICLE INFO

Keywords:

Red mud recycling
Carbothermic roasting
Metallic iron
Water leaching

ABSTRACT

Red mud, a solid byproduct from bauxite ore processing for Al_2O_3 production, encompasses valuable industrial metals, including Fe and Al. The objective of the present study was to investigate the feasibility of an integrated route for the efficient use of red mud for the multistep extraction of Fe and Al. Carbothermic roasting was performed in the presence of Na_2CO_3 to reduce iron oxide to metallic iron. Optimal roasting conditions (reductant dosage: 1 g, temperature: 900 °C, time: 120 min, and charge ratio 10:5:1) yielded a 95.6 % recovery of the magnetic fraction. Applying a magnetic gradient of 0.1 T resulted in a 92.5 % recovery of metallic iron. Subsequent water leaching, performed under optimal conditions (time: 120 min, temperature: 70 °C, pulp density: 10 %), achieved a 98.5 % leaching efficiency of Al from a nonmagnetic fraction, with and without sodium carbonate, demonstrating 26 % efficiency. Incorporating sodium salt during carbothermic roasting facilitated the reduction of iron oxide to metallic iron and activated alumina for leaching. Finally, a value-added Al product, AlPO_4 , was precipitated from the leachate. This approach primarily attempts to contribute to a more circular economy, reducing waste and minimizing the environmental impact.

Introduction

Red mud, also recognized as bauxite residue, results from the industrial production of alumina through the Bayer process [1,2]. Approximately 1–2 tons of red mud is generated for every ton of alumina produced, with an annual collection of around 150 million tons from alumina production plants [3,4]. The red color of the residue is attributed to its high Fe(III) oxide content [5]. The chemical composition of red mud varies based on the origin of the bauxite ore, encompassing Fe_2O_3 , Al_2O_3 , SiO_2 , Na_2O , TiO_2 , and other trace elements, notably rare earth [6,7]. The presence of heavy metals in red mud poses environmental and health risks if not properly managed and disposed of. These metals can leach into the environment, contaminate water sources, and potentially accumulate in the food chain, negatively impacting ecosystems and human health. Therefore, responsible handling, storage, and disposal of red mud are crucial to prevent heavy metal contamination and associated hazards. However, red mud poses substantial challenges in handling and disposal due to its substantial volume, high alkalinity (pH 10–12.5), and variable mineralogical composition [3,8]. Common methods for treating red mud include dry stacking and marine disposal. Still, these approaches are not environmentally friendly as they result in

the leaching of hazardous substances into the surroundings. Furthermore, red mud is a precursor of various industrial metals, presenting economic value if valuable components can be recovered and used.

Several initiatives have been undertaken in recent years to use red mud directly in various applications for environmental conservation [4], wastewater treatment [9], and the manufacturing of building materials such as cement [10,11], ceramics [12,13], geopolymers [14,15], and glass [16]. Red mud also finds application in the field of catalysis, where metal oxides like iron and aluminum can serve as catalysts or support materials for various reactions, including environmental cleanup, biodiesel production, petrochemical processes, and CO_2 utilization [17]. However, these treatments often result in pollution and create challenges for subsequent processes [18]. Red mud recycling is crucial to reduce waste, preserve resources, minimize environmental impact, and comply with regulations. Additionally, such recycling supports the transition toward a more sustainable and circular economy by promoting efficient resource use and reducing dependence on virgin materials. Previous research on the recycling of iron and aluminum from red mud primarily focused on hydrothermal methods, magnetic separation [19–21], acid leaching [22,23], and sintering [18,24]. However, the dispersion of fine iron oxides in red mud renders these extraction

* Corresponding author.

E-mail address: kshjkim@hanyang.ac.kr (H. Kim).

<https://doi.org/10.1016/j.jiec.2024.02.007>

Received 5 November 2023; Received in revised form 8 January 2024; Accepted 3 February 2024

Available online 6 February 2024


1226-086X/© 2024 The Korean Society of Industrial and Engineering Chemistry. Published by Elsevier B.V. All rights reserved.

Extraction of Fe and Al from red mud using carbothermic reduction followed by water leaching


Humma Akram Cheema, [Sadia Ilyas](#), [Muhammad Farhan](#), [Ji-hye Yang](#), [Hyun Jung Kim](#)  

Show more 

 Add to Mendeley  Share  Cite

<https://doi.org/10.1016/j.jiec.2024.02.007> 

[Get rights and content](#) 

 [Full text access](#)

Highlights

- A novel integrated process for maximum utilization of red mud was proposed.
- Fe and Al were recovered by carbothermic reduction followed by water leaching.
- The addition of Na_2CO_3 helps improve magnetic yields and leaching efficiencies.
- 92.5% Fe and 98.5% Al were recovered by recycling red mud.
- Industrial metals were recovered and waste volume decreased by up to 32.6%.



Journal of Industrial and Engineering Chemistry

Supports open access

11.6
CiteScore

6.0
Impact Factor

[Articles & Issues](#) ▾

[About](#) ▾

[Publish](#) ▾

[Order journal](#) ↗

[Search in this journal](#)

[Submit your article](#) ↗

[Guide for authors](#)

Volume 136

Pages 1-634 (25 August 2024)

[← Previous vol/issue](#)

[Next vol/issue >](#)



Journal of Industrial and Engineering Chemistry

Supports open access

11.6
CiteScore

6.0
Impact Factor