Ultrasonically Enhanced Pre-leaching for the Removal of Organic Substances from Bauxite and Recovery of Leachate Through Wet Oxidation

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https://doi.org/10.71659/icsoba2025-bx006

Abstract

Organic impurities in bauxite severely hinder the normal production of alumina. This study proposes a low-temperature ultrasonic-enhanced alkaline leaching process aimed at directly separating organic impurities from bauxite and purifying the leachate through H_2O_2 oxidation and CaO precipitation. Under optimal conditions of ultrasonic power at 550 W, temperature at 80 °C, time at 60 min, and NaOH concentration at 200 g/L, the leaching rate of organic carbon from bauxite reached 91.02 %, an improvement of 19.01 % compared to traditional leaching methods. XRD analysis of bauxite samples before and after leaching, along with results from XRF, carbon-sulphur analysis, SEM-EDS, and AFM, confirmed the effective separation of organic impurities without causing any loss of bauxite, with the alumina to silica ratio increasing to 34.13. Subsequently, 20 % H_2O_2 and 800 mL/g of CaO were added to the leachate. Under ultrasonic power of 550 W and oxidation at 90 °C for 60 min, the organic carbon removal rate was 71.35 %. GC-MS analysis confirmed the successful removal of major organic compounds from the leachate, while the XRD results of the oxidation residue indicated that organic compounds were ultimately removed in the form of $CaC_2O_4 \cdot H_2O$ and $CaCO_3$. Furthermore, the study elucidated the radical reaction mechanism of H_2O_2 in oxidizing organic compounds in alkaline solutions. The proposed process operates at low temperatures and atmospheric pressure, generating no waste during the process, making it a clean, low-energy, and efficient method for the direct separation of organic substances from bauxite.

Keywords: Ultrasonic-enhanced leaching, Bauxite, Organic impurities, H_2O_2 oxidation, Clean processing.

1. Introduction

Alumina has been widely used in multiple fields such as ceramic manufacturing, electronics industry, catalyst preparation, construction materials, laser materials, and high-temperature materials due to its excellent properties and characteristics including low density, high melting point, high boiling point, strong corrosion resistance, and high hardness [1, 2]. Currently, on a global scale, the Bayer process, which utilizes bauxite as the raw material, remains the primary method for alumina production [3, 4]. However, due to the presence of a certain proportion of organic impurity in bauxite and the continuous accumulation of organic impurity during the Bayer liquor circulation process [5], the harm caused by organic impurity has long constrained the sustainable development of the alumina industry [6, 7].

Almost all the organic impurity in the Bayer process is introduced by bauxite, making the harm caused by organic impurity an inevitable issue [8]. In the dissolution process of bauxite, organic impurities will also dissolve in the sodium aluminate solution [9]. After the organic impurities dissolve in the sodium aluminate solution, they first alter the physical and chemical properties of the solution. One significant change is the increase in the dynamic viscosity of the sodium aluminate solution [10]. This not only makes the separation of red mud more difficult but also reduces the decomposition rate of seed, resulting in a decrease in the precipitation rate of aluminium hydroxide [11]. Secondly, the dissolved organic impurities form a layer of organic film on the surface of bauxite, which hinders the chemical mass transfer between the alkaline solution and the ore, directly reducing the leaching rate of alumina [12]. In addition, organic impurities can lead to a finer particle size and reduced strength of the resulting aluminium hydroxide products. This is detrimental to sedimentation and classification processes of aluminium hydroxide [13, 14]. Furthermore, organic impurities can decrease the whiteness of the final alumina product, resulting in lower product quality and impacting economic returns [15]. Lastly, the precipitation of low-molecular-weight oxalates can lead to accelerated scaling rates in decomposition tanks and reduce the lifespan of equipment [16, 17]. There is experimental data indicating that when the organic substance content in the Bayer liquor is 2.57 g/L, the seed decomposition rate decreases by 3.45 % [18]. In addition, for every 1 g/L increase in sodium oxalate concentration, the alumina output concentration will decrease by 1–2 g/L [19]. Therefore, it is essential to find a way to remove organic impurities from the Bayer process for the development of the alumina industry.

Currently, there are publicly reported methods for removing organic impurities from the Bayer process: bauxite roasting [20–22], mother liquor roasting [23], flotation [24, 25], crystallization [26], precipitation [27–29], ion exchange [30-32], membrane treatment [33,34], and wet oxidation [35, 36]. The above methods have their own advantages and limitations, which hinder their widespread adoption and implementation on a large scale. Compared to the enormous energy consumption generated by pyrometallurgical processes such as roasting, hydrometallurgy technology has more advantages.

In recent years, ultrasound has shown unique advantages as a novel intensification technology in the field of metallurgy [37]. Ultrasound is a type of mechanical wave with a frequency higher than 20 kHz, possessing high energy and short wavelength. During the wet leaching process, the cavitation and mechanical vibration effects generated by ultrasound can enhance the mass transfer of microbubbles formed in the liquid between the liquid and solid phases, and accelerates the movement of solid particles and uniformly disperses them in the solution [38]. When the microbubbles burst, not only does the solution's temperature temporarily increase, but microjets are also created at the solid-liquid interface. This reduces the thickness of the diffusion layer at the solid-liquid interface through stripping and erosion, generates new reaction interfaces, and accelerates the leaching reaction rate [39]. Compared to conventional leaching, ultrasound-enhanced leaching has the advantages of improved leaching effect and shortened leaching time, thereby reducing the apparent activation energy of the reaction and decreasing energy consumption [40].

In conclusion, this study utilized low-temperature ultrasonic-enhanced alkaline leaching to directly separate organic impurity from bauxite, and completed a closed-loop process by purifying the leaching solution through H_2O_2 wet oxidation and CaO precipitation. The effects of different experimental parameters (ultrasonic power, temperature, time and NaOH concentration) on the leaching rate of total organic carbon (TOC) were investigated. Furthermore, H_2O_2 oxidation and CaO precipitation technology were employed to oxidize and precipitate organic substances in leaching solutions to achieve the goal of recovering the leaching solution. The study also discussed the reaction mechanism of H_2O_2 oxidizing organic substance in alkaline solution.

5. Credit authorship contribution statement

Mengnan Li: Methodology, Data curation, Investigation, Validation, Writing-original draft.
Zhanwei Liu: Conceptualization, Supervision, Project administration, Funding acquisition, Writing-review & editing.
Jiaping Zhao: Writing-review & editing.
Wanzhang Yang: Writing-review & editing.

6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

7. Data availability

Data will be made available on request.

8. Acknowledgment

We gratefully acknowledge the support received from the National Natural Science Foundation of China (No. 22068021 and No. 52064030), Yunnan Young and Middle-aged Academic and Technical Leaders Reserve Talent Program, China (No. 202305AC160064), Kunming University of Science and Technology Analysis and Testing Foundation (2023P20223102016), Yunnan Major Scientific and Technological Projects (No. 202202AG050011, 202402AB080004 and No. 202202AG050007).

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