An Alternative Approach for Production of Non-Metallurgical Grade Aluminium Hydroxide Utilizing Low-Grade Bauxite

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Abstract

The Bayer process is used worldwide for aluminium hydroxide (ATH) production with 95 % used for aluminium production and the remaining 5–6 % used for non-metallurgical applications. The untapped low/inferior-grade bauxite deposits on the western coast of India have an alumina content up to 40 %, and high Fe_2O_3 (40 %), with SiO_2 (2–8 %), CaO (2–4 %) remain unutilized due to their inferior quality and small and pocket deposits. Employing a different route other than the Bayer process, this low-grade bauxite is utilized to produce sodium aluminate liquor using sodium bicarbonate. The reagent is used to digest aluminous compounds in the bauxite at a temperature of 180–200 °C to form an intermediate product. The intermediate product is calcined and washed to extract alumina into a clear sodium aluminate solution which is further processed through CO_2-assisted precipitation with seed to yield non-metallurgical aluminium hydroxide. The developed process offers a viable alternative to the Bayer process for processing low-grade bauxite, benefiting bauxite mine owners and industries producing non-metallurgical alumina.

Keywords: Low-grade bauxite, Sodium bicarbonate route, Sodium aluminate, Non-metallurgical grade ATH.

1. Introduction

The western coast of India in Gujarat state contributes a significant portion to India's bauxite production, with a approximately 8–10 % share in the country's overall bauxite production of 22.7 million tonnes in the year 2024 [1]. However, these deposits remain largely unexplored due to their low alumina content (35–40 %) and high levels of iron oxide (35–40 %), silica (2–8 %), and calcium (2–4 %). As a result, they remain unutilized, contributing to the decline in bauxite exports from the state and possibly not used in the Bayer process for alumina production. To date, most efforts have been focused on the characterization and beneficiation of bauxite. However, this low/inferior grade bauxite can be used to produce aluminium hydroxide (ATH) for non-metallurgical applications.

Non-metallurgical grade ATHs/Specialty-grade aluminium oxides and hydroxides are used in a variety of applications, in chemicals such as PAC (polyaluminium chloride) and alum, including fire-retardant fillers, cosmetics as bulking agent and opacifier, toothpaste, antacids, paints, pigments, printing ink, catalysts (e.g. pseudoboehmite), glass ceramics, refractories, etc. For these specialized uses, specific grades of hydroxides or oxides are required, tailored to each application. Key factors that determine suitability include soda content, particle size, purity, and product brightness [2, 3]. Reduced yields of aluminium hydroxide precipitate from sodium aluminate solutions, along with its slow precipitation kinetics, have led researchers to explore alternative methods for enhancing recovery and quality particularly when the alumina products are intended for non-smelting applications [4] In addition to its flame-retardant properties, aluminium hydroxide filler also contributes to a marble-like translucency in cast acrylic. This has led to the development of products marketed as commonly used in applications such as kitchen countertops and bathroom panels. The degree of translucency depends on how closely the refractive indices of aluminium hydroxide (gibbsite) and the polymer match. The aluminium hydroxide can be used as a filler in a polymer matrices [5]. Aluminium hydroxide produced from the Bayer process, is an inorganic mineral product used as a fire retardant filler and is available in large volumes and various particle size distributions with consistent physical and chemical properties [6]. Approximately 95 % of aluminium hydroxide in an alumina refinery is used for the production of smelter-grade alumina while on an average 5–6 % is of non-metallurgical grade in Asian and African countries [7]. In Europe and North America its production has increased up to 20 %.

The European Union (EU) funded ENSUREAL initiative is primarily driven by the need for more environmentally friendly and sustainable methods to process predominantly low-grade bauxite ores. This has led to the exploration of a potential revival of the Pedersen process, which was effectively used between 1928 and 1969 to produce alumina at a plant in Høyanger, Norway, with a capacity of 17 000 t/y. The process effectively addresses all these issues and has the potential to be a zero-waste operation, generating by-products that can be utilized in other industries [8]. The Bayer Process produces aluminium hydroxide with a whiteness of up to 70–75 % which is ground to produce aluminium hydroxide for non-metallurgical applications with a whiteness of up to 85 to 86 %. [9] and the material obtained tends to have larger or irregular particles. Additional grinding or milling can be used to improve particle uniformity and whiteness. Unlike the Bayer process, the approach suggested herein is the production of non-metallurgical ATH through the sodium bicarbonate route which produces aluminium hydroxide with a whiteness of up to 90 % and results in finer and more uniform particles without the need for additional grinding. The process know-how has been developed by exploring low-grade bauxite from the western coast region which presently remains unutilized and unexplored.

In the process, the aluminous compounds in the bauxite reacts with sodium bicarbonate to form dawsonite ($NaAl(CO_3)(OH)_2$). The dawsonite is heated to about 600–700 °C process to decompose it into solid sodium aluminate and carbon dioxide. The resulting sodium aluminate is subsequently extracted in liquid form and utilized in a precipitation process with CO_2 purging to produce aluminium hydroxide of up to 90 % whiteness and fineness of d_{50} size 10–12 µm. This process enables the effective use of inferior or low-grade bauxite, thereby enhancing the potential for bauxite miners and speciality grade alumina producers.

2. Materials and Methods

2.1 Materials

The bauxite was sourced from the Gujarat region in India and chemicals such as sodium carbonate (Qualigens, Thermo Fisher Scientific India) and sodium bicarbonate (Qualigens, Thermo Fisher Scientific India), were used in various experimental steps. The chemical analysis of bauxite was done using wet chemical method and is shown in Table 1. Reactive SiO_2 was determined gravimetrically. Table 2 presents the mineral composition of the bauxite. The analysis was carried out with a PANalytical X'Pert Pro MPD diffractometer (Netherlands), using Cu Kα radiation (λ = 1.541 Å).

The bauxite is composed of low alumina i.e. 37 % Al_2O_3, high iron i.e. 36 % Fe_2O_3 and low SiO_2 (2 % silica) as shown in Table 1. The mineralogical composition of bauxite in Table 2 indicates that gibbsite is the predominant mineral in the alumina phase. The iron phase mainly consists of hematite (31 %) and alumogoethite (4.82 %). Silica is primarily present as kaolinite (1.63 %),

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