Current Status and Development Trends of China's Alumina Production Technologies

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Abstract

In recent years, China's alumina industry has experienced rapid development, with significant increases in both production capacity and output. Substantial progresses have been made in areas such as efficient resource utilization, green and low-carbon development, and digital intelligence. This paper provides an overview on the production status of China's alumina industry, analyses the future key challenges in achieving high-quality development, and outlines the major research directions for future technological advancement, which include the efficient utilization of low-grade bauxite resources, the development of non-bauxite aluminium-bearing materials, green calcination of aluminium hydroxide, full-process digitalization and intelligentizing, and large-scale bauxite residue disposal. The study aims to provide a reference for technological innovation and sustainable development in the alumina industry.

Keywords: Alumina, Efficient Resource Utilization, Green and Low-Carbon, Digital Intelligence, Trends

1. Introduction

In recent years, the global alumina industry has experienced rapid growth, with continuous increases in both production capacity and output. In 2024, global alumina capacity exceeded 180 million tonnes, with production surpassing 140 million tonnes. Among these, China's alumina capacity reached 107.3 million tonnes, with output totalling 85.52 million tonnes. Under China's national strategy background of carbon peaking and carbon neutrality, and the construction of a digital China, green, low-carbon transformation and digital intelligence empowerment have become the two major themes in the development of China's alumina industry. Particularly under the global trend toward green and digital intelligence development, China's alumina industry faces a series of new challenges, including the deterioration of bauxite resources, intensified environmental pollution, increased complexity in production management, and labour shortage. There is an urgent need to accurately identify and analyse technological breakthrough directions in the efficient use of bauxite resources, low-carbon process innovation, and digital transformation. This will enable scientific and technological innovation to drive industrial advancement and support the high-quality development of the traditional alumina industry [1].

Therefore, based on a systematic review of domestic and international alumina production and technological development, this paper analyses key technical bottlenecks and future development trends, with the aim of providing a reference to technological progress and sustainable growth of the alumina industry.

2. Current Status of China's Alumina Industry

2.1 Production Capacity and Output

In 2024, China's alumina production capacity reached 107.3 million tonnes, mainly distributed in the provinces of Shandong, Shanxi, Guangxi, and Henan. Among them, Shandong accounted for 33.7 million tonnes (31.41 %), Shanxi 26.45 million tonnes (24.65 %), Guangxi 17.1 million tonnes (15.94 %), and Henan 11.65 million tonnes (10.86 %). The distribution of alumina production capacity across provinces is shown in Figure 1.

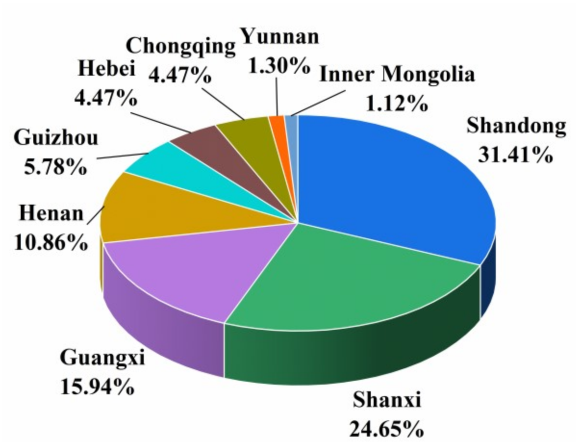

Figure 1. Distribution of alumina production capacity by province in China.

In 2024, China's alumina output totalled 85.52 million tonnes. The top three producing provinces are Shandong, Shanxi, and Guangxi, which altogether contributed 76.21 % of the nation's total. Shandong produced 29.60 million tonnes (34.61 %), Shanxi 20.33 million tonnes (23.78 %), and Guangxi 14.54 million tonnes (17.00 %). The distribution of alumina output across provinces is shown in Figure 2.

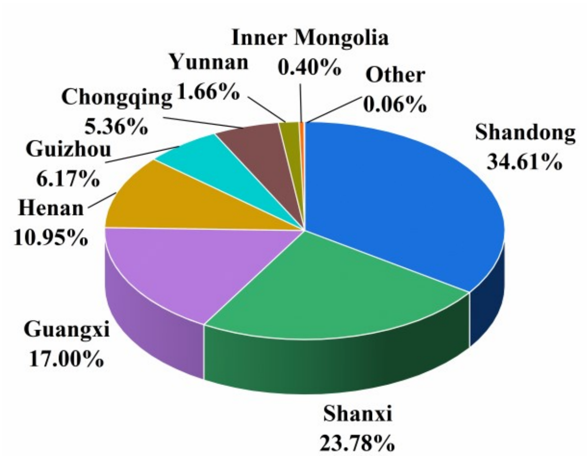

Figure 2. Distribution of alumina output by province in China.

2.2 Challenges of the Chinese Alumina Industry

2.2.1 High Pressure on Resource Supply

(1) Highly reliant on imports. China accounts for over 58 % of global alumina production, yet its bauxite resources make up only 2.39 % of the world's total [2]. Since 2019, China has imported over 100 million tonnes of bauxite annually, and the dependence on imported bauxites is constantly rising – reaching 63 % in 2024 and expected to hit 80 % by 2030.

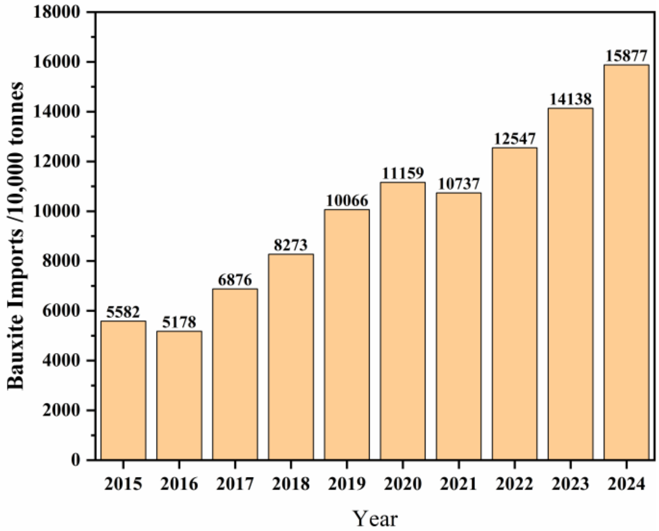

Figure 3. Changes in China's bauxite import volume and external dependence over the past decade.

(2) Declining bauxite quality. In recent years, the A/S ratio of domestically mined bauxite has been decreasing. Currently, the A/S ratio of domestically sourced bauxite used by alumina producers for feeding the grinders has dropped to 4–5; some producers even process bauxites with an A/S ratio as low as 2–3 in emergency cases.

(3) High impurity content in bauxites. Most alumina producers face challenges of high organic carbon, high inorganic carbon, or sulphur content in the bauxite, which lead to difficulties in production control and fluctuations of product quality.

2.2.2 Significant Gaps in Green and Low-Carbon Development

(1) High comprehensive energy consumption. In 2024, the average comprehensive energy consumption of China's alumina industry was approximately 9.44 GJ/t Al_2O_3, which was notably higher than the international advanced level of 7.99 GJ/t Al_2O_3.

(2) Low utilisation rate of bauxite residue. In 2024, China generated approximately 115 million tonnes of bauxite residue, with a comprehensive utilisation rate of around 12 %, ranking among the top globally. However, there remains a significant gap from the national target of 25 % utilisation rate of newly generated bauxite residue by 2030.

(3) High carbon emission intensity. The carbon emission intensity of China's alumina industry exceeds 1.0 tCO_2/t Al_2O_3, which remains a significant gap compared with the international advanced benchmark of 0.65 tCO_2/t Al_2O_3. Basic decarbonisation technologies in the alumina

sector have shown limited progress, and technologies such as green hydrogen calcination and green power calcination are still in the laboratory stage.
(4) Lack of demonstration effect on carbon capture technologies. China holds the top position globally in terms of the number of patents related to carbon capture technology; however, there remains a gap compared to internationally advanced levels in areas such as engineering commercialization, large-scale deployment, disruptive technological innovation, and system integration.

2.2.3 Low Intelligence Level

(1) Inadequate perception and real-time monitoring in production processes. Key indicators in processes rely on regular manual sampling and laboratory testing, resulting in delayed analysis and a high rate of human error. Product quality is mainly inspected in laboratories, leading to a lag in adjustment instructions. On-site inspections rely mainly on manual recording, resulting in high omission rates in high-temperature and high-pressure areas. Sensors are primarily deployed for basic parameters such as temperature and pressure, while real-time monitoring devices for component analysis are not widely used, making it difficult to intervene promptly in cases of quality fluctuation.

(2) Limited modelling and optimised control capabilities. Current DCS (Distributed Control System) only support basic PID control loop, lacking adaptive optimisation capabilities. Mechanism models under complex operating conditions are insufficiently accurate, AI substitution rates are low, and autonomous decision-making technologies remain in the experimental stage.

(3) Experience-based production scheduling and management, and low digitalisation level. Production scheduling relies heavily on human experience, with disconnected data streams on orders, equipment status, and energy costs, resulting in delayed deliveries. Bauxite residue dam monitoring mainly depends on manual inspections, with delayed risk warnings for dam failure. Digital twin applications are limited to specific operations, and full-process visualisation is insufficient.

(4) Low intelligence level in equipment management and maintenance. Maintenance of equipment is primarily conducted through scheduled repairs and emergency troubleshooting. Technologies such as AI fault prediction, vibration analysis, and thermal imaging diagnostics are scarcely applied in alumina refineries. Digitalisation of spare parts inventory management is weak, and procurement relies on empirical judgment, often resulting in overstocking or shortages.

(5) Isolated data silos and low integration. Alumina production involves multiple processes, including grinding, digestion, settling, precipitation, and calcination. The data standards of each system are inconsistent, and they operate independently., resulting in severe “data silos”. Data fragmentation limits holistic optimisation of production and hampers full-process collaborative optimisation.

3. Technological Progress in Alumina Production

In response to the challenges outlined above, recent R&D efforts in alumina production have focused on desilication, desulphurization, and decarbonization aiming at quality improvement of bauxites; desulphurization, decarbonization (including organic and inorganic carbon) and impurities removal during alumina production; recovery of valuable elements; and intelligent control of the production process. These efforts have achieved phased progresses and provided technical support for the extensive utilization of imported bauxites and domestic low-grade complex bauxites, thereby underpinning the sustainable and high-quality development of China's alumina industry.

3.1 Bauxite Upgrading Technologies

Extensive research has been carried out in China on the utilization of low-grade bauxites with high sulphur, high silica, and high carbon content. To address the technical challenges posed by high-sulphur bauxites, such as equipment corrosion, increased caustic soda consumption, and product quality declining, dedicated reagents for reverse flotation desulphurization, intelligent high-efficiency non-drive flotation equipment, and corresponding desulphurization processes have been developed, which enable industrial-scale utilization of high sulphur bauxite resources. For raw bauxites with sulphur content exceeding 8 %, the sulphur content in the bauxite concentrate can be reduced to 0.43 %. To tackle the high cost of alumina production from domestic low-grade bauxites, a non-drive flotation desilication technology for low-grade bauxite has been developed, based on independently developed non-drive flotation tanks, two-stage grinding, and new types of collectors. This technology increases the grade of concentrates to more than 1.8 times of the raw bauxites with an initial A/S ratio of 2–4. For low-grade bauxites with coarsely disseminated mineral grains, research has been focused on short-process, low-cost beneficiation technologies, to develop technologies and equipment that block the sources of harmful impurities. Industrial-scale trials have been conducted, increasing the A/S ratio of bauxite concentrate by over 1.5. Xi'an University of Architecture and Technology developed a roasting-based technology for upgrading high-sulphur bauxite. Using dry grinding and suspension calcination, a desulphurization rate of over 95 % has been achieved, with the technology successfully industrialized [3].

Figure 4. Application of flotation desulphurization technology for high-sulphur bauxite.

Figure 5. Application of non-drive flotation desilication technology for low-grade bauxite.

3.2 Energy-Saving and Carbon-Reduction Technologies in Alumina Production

Energy-saving and carbon-reduction in the alumina industry mainly involve energy efficiency improvement and carbon capture technologies. In terms of evaporation technology, Chalco Shandong Co., Ltd. has adopted seven-effect evaporation, with a stable steam-to-water ratio of 0.18 t steam/t water, with key parameters superior to requirements for production. Recently, Henan Jiuyie Chemical Equipment Co., Ltd. has developed eight-effect evaporation technology, which is being put into use and is expected to further reduce the steam-to-water ratio. In terms of large-scale calciners, Shenyang Aluminium and Magnesium Engineering and Engineering Institute Company Limited (SAMI) has developed China's first intelligent roasting optimization system, achieving a single-line capacity of over 1.5 million tonnes per year and a 15 % improvement in thermal efficiency. After being commissioned at Shanxi Xinfa Chemical Co., Ltd, the specific heat consumption per tonne of alumina has dropped by 3.2 %, saving over 10 million RMB annually, and achieved stable operation under extreme conditions such as gas pressure fluctuations.

In the field of carbon capture, Chalco Shandong Co., Ltd. launched the "Shandong No.1" carbon capture project. Targeting four circulating fluidized bed calciners, it adopts a combined process of temperature swing adsorption (TSA) and pressure swing adsorption (PSA), with an annual CO_2 capture capacity of 51.1 kt. Upon completion, this will become China's first 10 000-tonne-scale carbon capture demonstration project in the alumina industry.

3.3 Advanced Impurities Removal Technologies in Alumina Production

For desulphurization in alumina production, the mature industrialized method is mainly wet oxidation desulphurization, which involves adding solid oxidants or introducing air or oxygen into the sodium aluminate solution to gradually oxidize low-valence sulphur species into high-valence forms. While this method can partially address the issue of S^{2-}, it is less effective for oxidizing $S_2O_3^{2-}$ in the process and cannot fully eliminate the negative impact of sulphur accumulation on the Bayer process. aluminium Corporation of China (CHINALCO) has developed a wet deep oxidation process that enables simultaneous desulphurization and decarbonization, which has been industrialized. This technology reduces S^{2-} in the pregnant liquor by over 65 % and organic carbon by over 65 %, creating favourable conditions for efficient downstream impurities removal in the form of sodium carbonate.

For organics removal, industrialized methods mainly include adsorption of macromolecular organics, crystallization via cooling, and oxalate removal by adsorption. To address the slow degradation and poor removal efficiency of humic substances in sodium aluminate solution, equipment and processes have been developed, which reduce the solution absorbance by 10–20 % and organic carbon concentration in the process by 5–10 %. Based on the co-existence, transformation, and co-removal mechanisms of macromolecular organics and sodium oxalate, a coordinated removal technology has been developed to remove both, achieving oxalate removal rates over 30 % and solution absorbance reduction of 8–28 %. The issue of two types of organic substances significantly affecting the stability of alumina production has been solved in a comprehensive and effective manner. Additionally, based on studies of nucleation of sodium oxalate crystals and their growth mechanisms during cooling crystallization, a technology for controlling the crystal morphology of sodium oxalate through stepwise cooling and for efficient removal has been developed. Without the use of any crystallization additives, the technical challenge associated with the difficulty in controlling the crystal morphology of sodium oxalate during the initial cooling process has been successfully addressed. The removal efficiency of sodium oxalate exceeds 30%, and the resulting precipitated particles exhibit well-defined spherical crystalline structures

3.4 Recovery of Valuable Elements in Alumina Production

In the Bayer process of alumina production, the sodium aluminate solution and bauxite residue are enriched with various valuable elements such as lithium, vanadium, and scandium.

For lithium recovery, CHINALCO pioneered to innovate a complete set of technologies and equipment for efficient lithium recovery from bauxite-associated resources and built China's first lithium carbonate production line within an alumina refinery, achieving production and quality targets [4]. Henan Institute of Geological Survey [5] enriched lithium-bearing bauxite via flotation separation, obtaining bauxite concentrate with 61.72 % Al_2O_3 and A/S ratio of 11.45, and a lithium-rich concentrate with 0.57 % Li_2O and 78.97 % recovery rate. After acid leaching of the lithium-rich concentrate, the Li_2O leaching rate reached 94.64 %, and finally obtained a lithium carbonate product with 99.56 % purity.

For vanadium recovery, CHINALCO developed a key technology that simultaneously removes sodium oxalate and recovers the vanadium from the Guinean bauxites. After application in three alumina refineries, the vanadium recovery rate significantly improved.

For scandium, a highly selective extracting process from bauxite residue has been developed, achieving over 85 % scandium leaching rate from bauxite residue. The Na_2O content in the residue is reduced to below 1 % after scandium extraction, making it suitable for use in construction materials, cement, and soil treatment, and enabling large-scale utilization of bauxite residue. Southwest University of Science and Technology proposed a method of "target mineral reconstruction" to enhance the separation and extraction of iron and scandium from bauxite residue [6]. By this technology, bauxite residue with 22.63 % TFe and 0.0056 % Sc_2O_3 yields iron concentrate with 78.54 % TFe and 91.35 % Fe recovery, with scandium leaching reaching 95.63 %, and the process demonstrates high efficiency in the separation and recovery of iron and scandium.

3.5 Intelligent Control Technologies in Alumina Production

In terms of digital intelligence and automation upgrading, several successful implementations have emerged. Guangxi Huasheng New Materials Co., Ltd. has pioneered to launch the AI-powered "Zhisheng Alumina" large model, establishing an industry-leading remote visual central control center. Integrating digital twin technology and AI visual recognition, it has enabled unmanned operation in key links such as materials stockpiling, retrieval and weighing, and low-manpower operation in evaporation and digestion. The automation coverage across the refinery has reached 90 %. SAMI independently developed China's first intelligent roasting optimization control system for alumina production [7]. This system integrates advanced control strategies based on dynamic matrix control and adaptive algorithms, along with intelligent optimization logic. It achieves automatic P04 temperature control accuracy within 2 %, reduces thermal consumption by over 3 %, maintains a system utilization rate of over 95 %, and achieves a 100 % qualified rate in loss on ignition tests. The system is now in operation at Shanxi Xinfa Chemical Co., Ltd. To enable accurate bauxite blending, CHINALCO developed a real-time bauxite composition detection technology and established a corresponding analytical model, achieving a relative error of less than 4 % for Al_2O_3 analysis. Jiangsu Jingjing New Material Co., Ltd. has filed patents for a steady-state detection method in alumina production and evaporation [8], and an advanced process control system for bauxite slurry mill [9], enabling steady-state detection and process control for alumina production.

3.6 Technologies for Comprehensive Utilization of Bauxite Residue

The harmless and resourceful disposal of bauxite residue is a critical indicator of whether the alumina industry is environmentally friendly and green. In 2024, CHINALCO achieved comprehensive utilization of 5.59 million tonnes of bauxite residue, reaching a utilization rate of 20.02 %, far exceeding the global average level. Current pathways for the comprehensive utilization of bauxite residue mainly include iron extraction, construction material preparation, soil improvement, and mine backfilling.

In terms of iron extraction from bauxite residue, CHINALCO, China Weiqiao Group, and others have built and put into operation multiple production lines [10].

Figure 6. A production line of iron recovery from bauxite residue in a Chalco refinery.

In the area of construction material preparation, several Chinese building material companies have established large-scale, high-value production lines utilizing bauxite residue. After treatment, the bauxite residue is a substitute of traditional cement for the improvement of roadbeds and subgrades of highways, consuming nearly 600 000 tonnes of bauxite residue and other industrial solid wastes annually [11].

For soil improvement, CHINALCO has developed an ecological remediation technology for bauxite residue-based soils, addressing challenges such as high alkalinity and easy hardening of bauxite residue. This technology has been applied to an area of 15 ha in total. After restoration, the pH of bauxite residue-based soil decreased from 11.34 to 7.62. Soil fertility indicators exceeded the Grade I standard for dryland soils, and vegetation coverage reached over 95 %.

Figure 7. Application of ecological remediation technology for bauxite residue-based soil.

In terms of mine backfilling, leveraging the synergistic effect of multiple solid wastes enables the activation of aluminosilicate minerals, stabilization and solidification of pollutants, and formation of a polymeric cementitious system. This supports the development of green backfilling technology using bauxite residue, addressing issues such as low bauxite residue content, poor operational performance, and contamination of leached products, thereby achieving large-scale utilization of bauxite residue in mine backfilling.

In addition, some researchers are actively developing alternative bauxite processing technologies, such as calcium-free leaching [12], calcification-carbonation [13], reductive roasting [14], sub-molten salt leaching [15], and ammonium sulphate roasting [16], which may fundamentally reduce bauxite residue generation from the root cause.

3.7 Trends in Alumina Production Technologies

In 2025, the Ministry of Industry and Information Technology of China, together with the National Development and Reform Commission and other departments, issued the *Implementation Plan for High-Quality Development of the Aluminium Industry (2025–2027)* and the *Action Plan for Comprehensive Utilization of Bauxite Residue*, which set new l requirements for the development of alumina production technologies. In terms of energy consumption, the energy efficiency of the newly renovated and expanded alumina projects must meet the advanced level specified in the mandatory energy consumption limit standards, while the environmental performance must achieve the A-level standard. Enterprises are encouraged to participate in the development and utilization of renewable energy sources, such as photovoltaic power, wind power, hydrogen energy, and energy storage systems. Clean energy substitution for alumina hydrate calcination is also promoted. Regarding the comprehensive utilization of bauxite residue, it is stipulated that the new projects must achieve a comprehensive utilization rate of over 15 %. Furthermore, newly built or expanded alumina projects must be equipped with the necessary capacity for comprehensive bauxite residue utilization. In terms of digital transformation, the industry is encouraged to develop a panoramic digital transformation roadmap across the aluminium industrial chain, promoting in-depth application of digital intelligence technologies in bauxite mining, refining, and processing. Comprehensive utilization of mineral resources is also emphasized, with increased evaluation and recovery of associated resources such as gallium during alumina production. Strengthen the comprehensive utilization of associated resources such as iron ore in bauxite deposits, and improve the resource mining and recovery rate, beneficiation recovery rate, and overall utilization efficiency. In accordance with the guiding requirements of policies and regulations, the trends in the development of China's alumina production technology have been summarized and mainly include the following aspects.

3.8 Efficient Utilization of Low-Grade Bauxite

Low-grade bauxite constitutes a significant portion of bauxite resources, yet there remains a lack of economically viable and efficient utilization technologies. Therefore, it is imperative to intensify efforts in technological research and development, with a focus on source-level technologies for blocking harmful impurities in bauxite. Additionally, priority should be given to the development of low-cost, short-process technologies aimed at enhancing quality and removing impurities, along with the corresponding equipment. These measures will help address the current challenges of complex desilication processes and high production costs. In the case of coal-bed bauxite, targeted research should be conducted on desulphurization and decarbonization technologies to overcome issues such as the difficulty in dissociating sulphur minerals and achieving simultaneous desulphurization and decarbonization. This will facilitate the comprehensive utilization of coal-bed bauxite resources and ensure the supply of high-quality raw materials for the aluminium industry.

3.9 Development of Alumina-Bearing Resources Beyond Bauxite

Accelerating the development of non-bauxite alumina-bearing resources, such as coal fly ash and nepheline, is a critical pathway to alleviate bauxite shortages and facilitate the green transition of the aluminium industry. Future efforts should focus on enhancing technological research and advancing industrial applications. Through fundamental theoretical studies, key breakthroughs must be achieved in high-value utilization technologies for aluminium resources contained in non-bauxite materials, aiming at the efficient extraction of alumina or the direct production of aluminium-silicon alloys. Furthermore, it is essential to strengthen industrial chain coordination and optimize regional layouts. By developing integrated technologies across the coal-electricity-aluminium industrial chain, a circular economy system, such as "high-alumina coal power generation – alumina extraction from fly ash – electrolytic aluminium production", should be established, to facilitate local resource conversion and efficient, coordinated energy utilization.

3.10 Development of Green Roasting Technologies

Driven by the "dual carbon" objective, green roasting technologies for alumina production, utilizing green electricity or green hydrogen as substitutes for fossil fuels, are emerging as a critical focus for industrial technological innovation. Currently, zero-carbon technologies such as electric roasting, hydrogen roasting, and green steam generation have demonstrated energy-saving potential in laboratory settings; however, numerous technical and operational challenges remain to be addressed before large-scale deployment can be realized. Future research should prioritize advancements in materials development, process optimization, and system integration. Furthermore, intensified efforts are required to develop synergistic technologies that integrate renewable energy sources, such as wind and solar power, with the alumina production process. To achieve energy efficiency and carbon reduction goals in the future development of the aluminium industry, it will be essential to incorporate wind, solar, and energy storage resources across the entire value chain, from bauxite mining to electrolytic aluminium production, accelerate the commercialization of relevant technologies, strengthen collaboration across the industrial supply chain, and align with the global objective of carbon neutrality.

3.11 High-Value Utilization of Dissipated Metals

Bauxite is rich in valuable metal resources such as lithium, vanadium, and scandium, and serves as a potential source for the "three rare metals". Numerous researchers have investigated the extraction and utilization of valuable elements from both the spent liquor and bauxite residue from various perspectives. While lithium and vanadium have achieved industrial-scale recovery, the extraction of scandium, zirconium, titanium, and other valuable metals still requires further in-depth research. Moreover, most existing technologies focus on the recovery of individual elements, resulting in low overall recovery rates and limited economic benefits. Additionally, these processes often generate wastewater and residues, leading to secondary environmental pollution [17]. In the future, guided by the principles of "systematization and zero emissions," it is essential to continue developing innovative physical, chemical, and biological separation technologies tailored to the complex coexistence of dissipated metals and the primary alumina component in bauxite. Efforts should also focus on optimizing current processes and advancing the deep processing of dissipated metals, as well as the development of high-value end products, to foster the emergence of new productive forces.

3.12 Full-Process Digitalization and Intelligentizing

Accelerating the technological transformation of traditional industries and gradually advancing large-scale, intelligent, and digitally controlled production is a key development trend in modern industry. It is essential to comprehensively promote the application of cutting-edge technologies, such as big data, artificial intelligence, 5G, and virtual reality, within the alumina industry. Furthermore, technologies for real-time monitoring and optimization of critical process parameters during production should be developed, along with big data analytics and digital twin technologies tailored for alumina production. The automation control framework and production operation systems of alumina refineries should be upgraded, and an integrated internal communication network should be established throughout the refinery to eliminate information silos. This will enable seamless integration and high-level coordination across various operational units, including enterprise resource planning, operational management, process control, quality assurance, and inventory logistics. Additionally, a unified, lifecycle-wide data platform should be constructed across the aluminium industry chain to support the realization of fully intelligent manufacturing facilities.

3.13 Large-Scale Utilization of Bauxite Residue

The large-scale utilization of bauxite residue is a key pathway to addressing the problems of environmental pollution and resource waste in the alumina industry. Although certain progress has been made, the global utilization rate of bauxite residue remains below 10 %. To significantly reduce bauxite residue production and promote its ecological treatment during alumina production, it is necessary to break through existing technological frameworks and integrate reduction of bauxite residue production from the process end with the treatment at storage end. Efforts should be made to strengthen source control, reduce bauxite residue generation, and stabilize its composition to create better conditions for its application. It is also crucial to accelerate the development of technologies for extracting valuable elements from bauxite residue in synergy with its modification, and to advance the industrial application of techniques such as bauxite residue-based soil reclamation and mine backfilling. These efforts will enable the large-scale utilization of bauxite residue and promote the green transformation and development of the alumina industry.

4. Conclusions

At present, China's alumina industry is undergoing a profound transformation from scale expansion to high-quality development. Faced with risks in resource supply, increasing demands for energy conservation and carbon reduction, pressures from environmental protection regulations, and challenges in digital transformation, the alumina industry has made significant breakthroughs through technological innovation and strategic adjustments. The dissemination and application of these achievements have played a crucial role in advancing the development of the alumina industry, thereby enhancing its economic and social benefits.

The future development of the alumina industry should focus on establishing a multi-dimensional innovation system. First, it is essential to enhance research on the efficient utilization of resources by developing technologies for the use of low-grade bauxite and other alumina-containing materials derived from non-traditional sources. Second, the industry must accelerate the upgrading of green production processes by developing energy-efficient and environmentally friendly technologies and equipment for alumina production, as well as exploring low-carbon alternatives such as hydrogen and electric combustion technologies. Concurrently, efforts should be made to expand the range of high-value-added products, deepen the extraction and utilization of dissipated metals from bauxite, and promote the digitalization and intelligent transformation of the entire production chain by constructing smart manufacturing facilities. Furthermore, a circular system integrating mining, refining, and recycling should be established to improve the utilization efficiency of bauxite residue. It is recommended that collaborative innovation be strengthened among government entities, industry players, academic institutions, research organizations, and enterprises through the formation of technological alliances, thereby accelerating the promotion and application of advanced technologies and supporting the sustainable growth of the alumina industry.

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