Research on the Sustainable Development of Alumina Industry in China-Based on the Perspective of Environmental Governance

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Abstract: This paper analyzes the main contradictions and challenges in the development of China's alumina industry in terms of resources, production costs and environmental governance, compares the production cost of China's alumina with that of other countries, analyzes the pollutants produced in the production process of alumina, and discusses the related problems. On this basis, this paper puts forward the strategies and suggestions for the sustainable development of China's alumina industry, that is, adopt advanced technology and equipment to solve the problem of bauxite resource shortage; Improve safety protection facilities to prevent accidents and hazards; Solve the problem of deep purification and standard discharge of alumina industrial flue gas; Implement the safe storage and resource utilization of alumina industrial solid waste; Increase the depth recovery efficiency of waste heat in alumina production; Implement all safety management measures and strengthen the ability to prevent accidents. By adopting the above strategies, the sustainable development strategy of China's alumina industry can be realized.

1. Introduction

In 2022, China's alumina reached 81.862 million tons, accounting for 56.61% of the global alumina production. The technological innovation and scientific and technological progress of China's alumina oxide industry have also made remarkable achievements. However, the huge scale of alumina industrial production has led to increasingly prominent resource, energy and environmental issues. Especially in recent years, due to the significant increase in domestic alumina production, environmental protection and other policies, domestic bauxite resources have been difficult to meet the demand, the proportion of imported bauxite resources has increased year by year, and the external dependence of bauxite has exceeded 60%[1]. The output of solid waste is huge and increasing year by year, which has caused great pressure and impact on ecology and environment. The production technology of China's recycled alumina industry is still far behind the level of developed countries.

In view of the serious constraints on resources, energy and the environment, as well as the limits of market development capacity, the development and survival of China's alumina industry has reached a very critical period. Carefully study the production and technology status of China's alumina oxide industry, analyze the main contradictions and challenges facing the development of China's alumina oxide industry, compare and analyze the production cost competitiveness on a global scale, and put forward the strategic development trend of China's alumina oxide industry production and technology. This is of great significance to the strategic research of industrial structure adjustment and high-quality sustainable development of China's alumina industry.

2. Related research literature

2.1. Research on the alumina smelting technology

According to Yin Keting (1996), the production process of alumina in China is complex, the process is long, and the energy consumption is 1-3 times higher than that of foreign countries. Resource extraction is poorly managed and seriously wasted [2]. Liao Zhihua (2020) believes that the disorderly development of alumina industry will lead to overcapacity and vicious competition. The large proportion of bauxite imports and the high concentration of import countries will bring uncertain factors [3]. Ma Lifang(2019) believes that the transformation and management experience of cleaner production of alumina not only effectively solve the environmental protection problem, but also obtain better economic benefits [4]. Zhang Qingxuan(2018) believes that effectively reducing energy consumption in alumina production and realizing sustainable development of energy conservation and environmental protection are issues that alumina production enterprises must attach great importance to [5]. Li Zhuozhi (2017) proposed that the innovation of
alumina smelting technology would play a positive role in improving red mud treatment technology and promote the healthy and sustainable development of China's economy[6]. Xue Shengguo et al. (2017) found that resource utilization and large-scale disposal of red mud in the solidification rate smelting process played a positive role in environmental risk prevention and control management and promoting the healthy development of alumina industry[7]. Yue Ling(2015) believes that China's alumina enterprises should actively explore overseas markets, develop and occupy overseas bauxite resources, and ensure the sustainable and stable development of China's alumina industry [8].

2.2. Research on the sustainable development of alumina industry.

Che Junwen et al.(2018) believe that the alumina industry is a resource, capital and technology-intensive raw material industry. Due to the large amount of tailings and red mud produced in the production process, a certain amount of alkali-containing wastewater is generated in the production process of alumina, resulting in very serious water pollution. Therefore, water pollution in the alumina industry has the most serious environmental impact [9]. Zhou Faxing (2018) found that the most important measure to reduce energy consumption in alumina production is to update and reform production technology, seeking to meet the purpose of energy saving and consumption reduction while improving work efficiency. In addition, the quality of the raw materials used is strictly controlled, and the performance of the finished alumina products is committed to improving, so as to stand out in the same type of goods [10]. Wang Ning (2018) believes that alumina enterprises continue to improve their own production technology, reduce environmental pollution and excessive energy consumption, and achieve harmonious social and economic development [11].

Shao Ke (2023) believes that the improvement of resource utilization efficiency can not only reduce manufacturing costs and improve production efficiency, but also reduce the dependence on limited resources, reduce the impact on the environment, and promote the sustainable development of industrial economy[12]. Zhan Jianren (2023) believes that in the practice of industrial economic development, in order to further promote the economic development of the region, it is of significant value for regional development to think deeply about the sustainable development strategy of industrial economy under the new situation[13]. Huo Zhihong et al. (2022) believe that the standardization and mobility of low-carbon technology can promote the transfer and sharing of carbon reduction technology, and its upgrading process will promote the transformation of regional industrial economy to the low-carbon sustainable development path of "deindustrialization" and "modernization" [14].

2.3. Research on the noise and corrosion during alumina production.

In the process of alumina production, many equipment are noise sources, which are easy to cause human anxiety and irritability, and seriously affect the physical and mental health of production personnel [15]. In addition, equipment will be corroded due to the perforation effect, resulting in the loss of slurry medium and the termination of production equipment. At the same time, such corrosion is irreversible and difficult to repair once it occurs [16]. In the production of alumina, it is necessary to analyze the risk factors in the whole process of production, carefully identify the danger sources, and formulate corresponding measures for them [17]. In terms of environmental protection, affected by the production process of alumina, red mud has strong alkalinity and belongs to Class II general industrial solid waste [18]. In the industrial production process, corrosion of equipment has a very obvious impact on production [19]. The discharge of solid waste may also pose a threat to people's health [20].

2.4. Research on environmental protection.

Hart(1995) proposed that environmental strategy mainly includes three aspects: pollution prevention, product management and sustainable development [21]. Polas et al(2021). pointed out that enterprise managers' awareness of the environment can not only identify potential opportunities in the external environment, but also improve the enterprise's ability to innovate in environmental protection, thus improving the sustainability of environmental governance [22]. Wastewater has caused damage to groundwater resources and aquatic ecological environment, affecting people's life and health [23]. In the process of environmental management, enterprises can seize any opportunity to carry out continuous innovation and improve their capabilities in the process of continuous innovation and transformation [24].

3. Analysis of the production and resource status of alumina industry in China

3.1 Production status of the alumina industry in China

Since 1954, China's alumina production began, but it was not until 2005 that China's alumina production increased rapidly, mainly because the high-temperature Bayer process technology for the treatment of diaspore ore has been fully promoted and applied. See Figure.1.
Most alumina production enterprises are located in the regions of China with rich bauxite reserves, namely Shanxi, Henan, Guangxi and Guizhou. Alumina enterprises in Shandong Province, due to its proximity to the coast, mainly rely on imports of bauxite to produce alumina.

### 3.2. Analysis of the bauxite resources

According to the report on China's mineral resources released by the Ministry of Natural Resources in 2019 [25], in 2018, China's bauxite resources amounted to 5.17 billion tons, but its proven reserves were only 1 billion tons, accounting for only 3.3% of the world's reserves, which is far lower than Guinea, Australia, Brazil, Vietnam and Jamaica [26]. See Figure 2.

Therefore, in the world, China's bauxite reserves are relatively small, and the bauxite that can be economically utilized is all refractory diaspore ore, and the grade is low. Shanxi, Henan and other regions in northern China have a large number of large-scale aluminum oxide plants, and the distribution is concentrated. Due to decades of excessive mining, the local bauxite mining grade decline, serious depletion, and even depletion, the current supply of aluminum silicon ratio(A/S) is basically 3.5~5.5, resulting in high ore consumption and alkali consumption in alumina production and lack of competitiveness, has been difficult to support the local large-scale alumina industry. To this end, China's bauxite imports in recent years has shown an increasing trend year by year.

### 3.3. Analysis of alumina production cost ratio in China

Taking 2019 as an example, the comparison of alumina production and operation cost composition between China and other countries is shown in Figure 3.

It can be seen from Figure 3, The biggest difference in alumina production costs between China and other countries is the cost of bauxite. China's bauxite resources are poor and the ore price is high, so bauxite accounts for 41% of the production cost, while foreign countries only account for 24%. However, China's share of other alumina costs is relatively low, mainly because of China's lower labor and maintenance costs.
4. The Main environmental problems in alumina production process.

In the process of alumina production, the main harm in the process of ore treatment is the dust generated in the process of crushing and conveying. Natural gas, coal gas, heavy oil, diesel oil and other fuels are flammable and explosive, and natural gas and gas are easy to cause poisoning. Lime has strong alkalinity, irritating and corrosive effect; Alkali has strong corrosion, easy to cause chemical burns; Molten salt is an oxidizing agent, toxic, carcinogenic and corrosive.

Alumina dust with air inhalation damage respiratory tract, lung; High temperature and high pressure water steam is prone to high temperature scald and physical explosion injury of steam pressure pipes and vessels. There is a danger of explosion of compressed air. The environmental influencing factors and hazards in alumina production are shown in Table 1.

<table>
<thead>
<tr>
<th>Pollutant name</th>
<th>Hazard type</th>
<th>impact to environmental</th>
<th>effects to Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore</td>
<td>dust</td>
<td>To Pollute air</td>
<td>Inhalation of high concentrations of gas is harmful to human health</td>
</tr>
<tr>
<td>Caustic alkali</td>
<td>corrosivity</td>
<td>To Pollute water</td>
<td>It burns the human skin and eyes, causes damage to the human respiratory system after inhalation, and can lead to death if accidentally taken</td>
</tr>
<tr>
<td>coal gas</td>
<td>explosion hazard</td>
<td>To Pollute air</td>
<td>Inhaling high concentrations of the gas can cause dizziness, poisoning, and nausea</td>
</tr>
<tr>
<td>lime</td>
<td>irritability</td>
<td>To Contaminate water</td>
<td>It irritates the eyes, burns the skin, and is harmful to human health when inhaled</td>
</tr>
<tr>
<td>flocculant</td>
<td>Corrosiveness and instability</td>
<td>Spills can be harmful to plants and animals</td>
<td>to sear the eyes, irritates the skin, and affects the human respiratory system</td>
</tr>
<tr>
<td>Concentrated sulfuric acid</td>
<td>corrosivity</td>
<td>Slight hazard to aquatic life</td>
<td>to sear the skin, irritates the human respiratory system, and causes stomach damage after ingestion</td>
</tr>
<tr>
<td>Alkali liquid</td>
<td>corrosivity</td>
<td>To Contaminate water</td>
<td>It burns human skin and eyes and causes harm to human health after inhalation</td>
</tr>
<tr>
<td>Aluminium oxide</td>
<td>irritability</td>
<td>Contamination by residue</td>
<td>Cause irritation to the skin and eyes</td>
</tr>
<tr>
<td>Aluminium hydroxide</td>
<td>irritability</td>
<td>aquatic plants and animals, and then creates acidic soil</td>
<td>Irritation of the skin, eyes and respiratory system</td>
</tr>
<tr>
<td>Red mud with liquid</td>
<td>corrosivity</td>
<td>To Contaminate water</td>
<td>to sear human skin, eyes, if accidentally inhaled can cause human injury</td>
</tr>
</tbody>
</table>

4.1 Alumina industrial waste gas purification and standard discharge problems.

The waste gas of alumina industry mainly includes the flue gas of aluminum electrolysis, the flue gas of aluminum carbon production, the flue gas of alumina production, and the flue gas of boiler containing a variety of pollution sources, among which the main pollutants are SO2, NOx, CO, CO2, polyfluoride, asphalt and volatile organic compounds, etc., which cause harm to the environment and human body.

The pollution control of various flue gases includes the implementation of cleaner production, the reduction of harmful gas emissions, the classification, purification or removal of discharged flue gases, and the realization of emission standards. Therefore, the emission reduction of alumina industry contains two types of technologies to be developed: the production process to develop low-emission clean production technology and exhaust gas purification technology.

4.2 Alumina industry solid waste treatment problem.

The pollutants in the alumina industry are mainly solid waste, of which the solid residue produced by the alumina industry is red mud, and the solid waste of aluminum electrolysis is basically dangerous solid waste, that is, aluminum ash, waste cathode carbon block, waste side lining, waste refractory material (backing) and carbon anode waste residue (carbon residue). The annual output of red mud in China is about 100 million tons, which is distributed around each aluminum oxide plant. Because the red mud contains 2~5g/L of attached alkali (in attached water) and the mass fraction of 3%~12% of combined alkali (in solid waste residue), it causes pollution to the atmosphere, soil and groundwater. Because of the rapid increase of red mud accumulation in the storage yard and the danger of dam break, it is urgent to solve the problem of safe storage, harmless disposal and large-scale resource utilization of red mud.

5. Results & Discussion.

The problems in the development of China's aluminum industry are as follows.

First of all, the shortage of bauxite resources, low S/A, low grade, is a water bauxite, not easy to dissolve, greatly increasing the cost of production.

Secondly, China's aluminum industry in the
production process, will cause serious pollution to the surrounding environment; At the same time, the alumina industry also has great difficulties in environmental governance and less investment in environmental protection. Third, China's alumina production comprehensive energy consumption is high, energy efficiency is low.

Finally, the production cost of alumina is high: the problem of increasing energy consumption and material consumption due to the decline in bauxite grade and rising costs must be solved.

6. Strategies and suggestions for the sustainable development of alumina industry in China.

6.1 The advanced technology and equipment should be used to fundamentally eliminate and weaken risks.

At present, the more mature advanced technology in China is: lime Bayer process of alumina production process, pipeline dissolution technology, positive flotation flotation Bayer process, enriched ore strengthening sintering process, crude liquid desilication technology, red mud dry storage process. Commonly used advanced equipment and facilities with a relatively high degree of safety guarantee are: efficient sedimentation tank, flash baking furnace, vertical plate filter, flame retardant and high temperature resistant cable. There are also many advanced process technologies and equipment being developed and tested. The use of advanced technology and equipment can fundamentally overcome the inherent and difficult to eliminate the original process of fire, explosion, high temperature, dust, smoke and other dangerous sources, and can reduce labor intensity, improve operation stability, so that safety and health conditions have been fundamentally improved.

6.2 The poor bauxite resources need to be solved as soon as possible.

To solve the problem of shortage of bauxite resources in China as soon as possible, two approaches need to be taken, one is to speed up the development of efficient utilization technology of domestic complex components of bauxite, the other is to broaden the import channels of foreign high-quality bauxite and efficiently deal with it, or to encourage the construction of factories in the Belt and Road region rich in bauxite resources and energy and politically stable. That is, domestic and foreign resources together.

The domestic complex composition of the monohydrate duralumite mine needs to develop as soon as possible to economically treat the production of alumina technology, need to make a breakthrough in recent years, the focus is on the development of light burning desulfurization technology to treat high-sulfur bauxite, the development of wet series technology to treat high-silicon bauxite, and try to produce alumina at a lower operating cost than the imported mine.

6.3 Improve safety protection facilities to prevent accidents and hazards.

For dust sources and gas, acid, alkali and other toxic sources, adopt water spraying, sealing, setting up dust collectors and ventilation measures; For noisy equipment such as air compressors, set up an independent foundation and an independent machine room to reduce the spread of noise and vibration, and set up isolation operation room, sound proof duty room, control room, using double-glazed Windows, double-walled doors and other measures; Install permanent or temporary shielding and on-site warning measures for radioactive sources.

6.4 The problem of deep purification and standard discharge of alumina industrial flue gas need to be solved.

The flue gas treatment of China's alumina industry mainly includes dust reduction, desulfurization and removal of organic matter, which need to implement two methods: clean production and deep purification of emission flue gas. The technology is developed to strictly control the process conditions and reduce emissions in the production process, and for other harmful substances in the flue gas, the corresponding dust reduction and desulfurization technology is used to ensure that the exhaust gas is discharged to the standard.

6.5 The safe storage and resource reuse of alumina industrial solid waste should be implemented.

It should be vigorously developed safe storage and large-scale low-cost resource utilization technology of red mud. Accelerate the development of technology that can use red mud in large quantities, and produce raw materials and auxiliary additives that can be used in building materials industry, metallurgical industry, chemical industry and environmental industry.

6.6 The deep recovery efficiency of waste heat utilization in alumina production should be increased.

Considering that in the aluminum oxide production process, the energy consumption of roasting accounts for about 25% to 30% of the comprehensive energy consumption of aluminum oxide, under normal circumstances, the flue gas temperature of the aluminum hydroxide baking furnace can reach up to 200℃, and the high-temperature baking furnace flue gas will inevitably take away part of the aluminum oxide. At the same time, due to the waste heat of baking furnace flue gas, a lot of heat and water loss, which has a very bad impact on the environment. Partial sensible heat of baking furnace flue gas is used to achieve deep recovery of residual heat of flue gas. Direct heat exchange between low temperature
water and baking furnace flue gas is adopted by spraying method, and the sensible heat of high temperature flue gas is directly transferred to low temperature water, and the latent heat of water steam is also guaranteed to enter the low temperature circulating water. The waste heat of roaster flue gas is used to preconcentrate the evaporated liquid of the alumina plant, reduce the evaporation water of the evaporation station, thus reducing the evaporation steam consumption, and further achieve the purpose of reducing the energy consumption of alumina production.

6.7 Implement all safety management measures and strengthen the ability to prevent accidents.

In the alumina production process, various safety management measures need to be implemented in order to better prevent all kinds of accidents. The main safety management measures include: improve the safety management rules and regulations, and strictly implement; Establish a safety management organization and implement the safety production responsibility system; Carry out targeted safety education and training and safety inspection; Ensure safe input; Be equipped with labor protective articles to strengthen individual protection; To set up rescue organization and make accident emergency plan; Strengthen the safety monitoring of major hazards and the implementation of safety management measures for maintenance operations.

7. Conclusion

To sum up, the path of sustainable development of China's alumina industry is: first, strictly control the disorderly expansion of production capacity; The second is to solve the problem of bauxite resource depletion; Third, we will implement the development strategy of high quality, energy conservation and low consumption. The fourth is to solve the problem of alumina industrial waste discharge and solid waste safety storage; Fifth, implement safety management measures to enhance accident prevention capabilities. By adopting the above strategies, the stable, healthy, green and sustainable development of China's alumina industry can be achieved.

References


