# Current Situation of Alumina Industry in China and its Technical Demand

**Yin Zhonglin[1], Fan Dalin[2], Lu Xiaotao[3], Wu Guobao[4]**
1. Professor, Chief Engineer (Alumina)
2. Professor, executive director
3. Engineer
4. Senior Engineer
Zhengzhou Non-ferrous Metals Research Institute Co. Ltd of CHALCO, Zhengzhou, China
Corresponding author: yzlin123@263.net

**Abstract**

In China in 2018 the alumina production capacity was about 83 Mt, and the alumina production output was about 72 Mt. That constitutes more than 50 % of world production. The Chinese bauxite reserves are approximately 1billion ton and the bauxite resource is about 5 billion ton. About 80 Mt of bauxite was imported into China in 2018. Due to the characteristics of the alumina industry and nature of the local bauxite resource in China there is a high demand for efficient alumina production technologies for low grade bauxite, high sulfur bauxite as well as imported bauxite and impurity control technologies.

**Keywords:** Low grade bauxite, high sulfur bauxite, alumina production technology, alumina impurity control, bauxite residue.

## 1. Current Situation of Alumina Industry in China

Alumina production technology in China started from sinter process in Shandong alumina refinery (the former of Shandong Branch, Chalco), and the first alumina refinery was built and put into operation in July 1954.

The second alumina refinery, Zhengzhou Alumina Refinery (the former of Henan Branch, Chalco) was built and put into operation in 1965, the Bayer and Sinter mixed process was adopted for the first time.

China's alumina industry had good progress after decades of efforts. In 2001, China became the world's second largest alumina producer, since 2006 the output was more than 10 million tons, and in 2007 China became the world's largest alumina producer.

The changes of alumina production capacity and output in China in the last ten years are shown in figure 1.

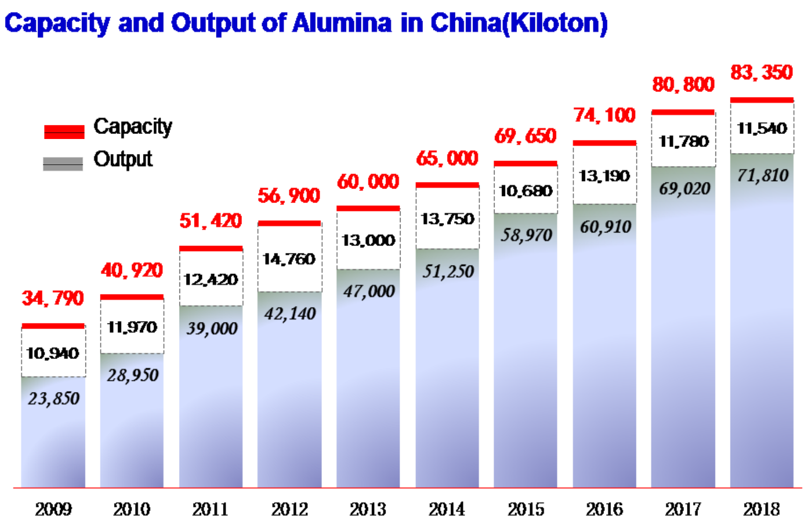


**Figure 1. Alumina production capacity and output in China in the last ten years.**

By the end of 2018, China's alumina production capacity was 83.35 million tons. The alumina output was 71.81 million tons, accounting for about 55 % of the global alumina output of 130 million tons.

Alumina producers in China are mainly located in Shandong, Shanxi, Henan, Guizhou, Guangxi provinces and Chongqing with imported bauxite resources or with local bauxite resources.

Figure 2 shows the distribution of alumina production in China in 2018.

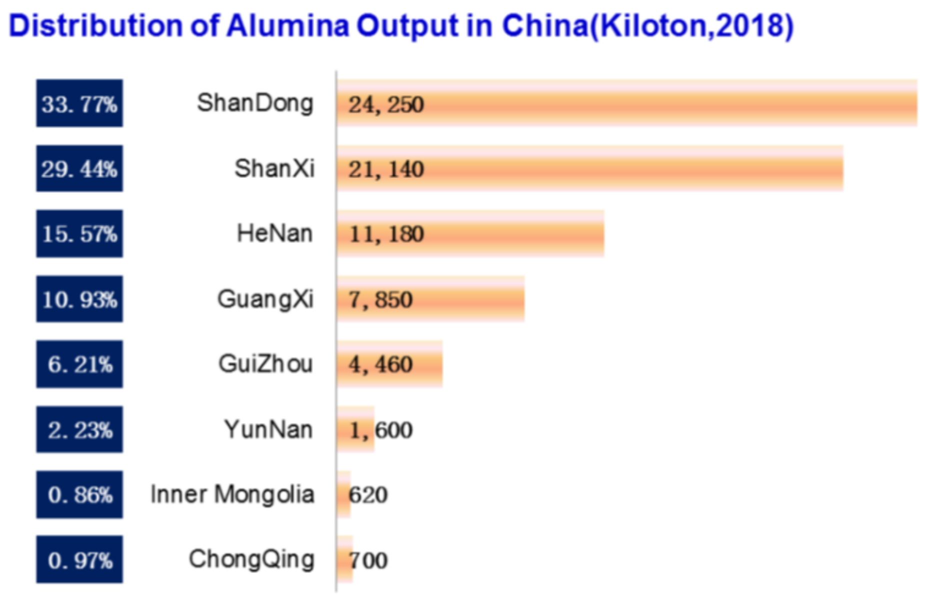


**Figure 2. Distribution of alumina production in China in 2018.**

It can be seen from figure 2 that Shandong province is the largest alumina producer in China, with annual alumina output of 24.25 million tons in 2018, accounting for 33.77 % of the national alumina output. The Bauxite used in Shandong is almost exclusively imported bauxite. More than a third of China's alumina production was produced from imported bauxite in 2018. By April 2019, China's complete alumina production capacity, which mainly relies on imported bauxite, had increased to 40.5 million tons, and its operating capacity to 30.77 million tons.

Shanxi and Henan provinces produced 32.32 million tons of alumina, accounting for 45 percent of the total in China. Currently, the bauxite used in Shanxi and Henan provinces is mainly the domestic and local low-grade bauxite, and the bauxite $Al_2O_3$-$SiO_2$ ratio is generally around 4.0-4.5. The alumina produced from low-grade bauxite accounted for about 50 % of the total output in 2018 in China.

## 2. Bauxite Resources in China

### 2.1. Reserves and Distribution of Bauxite in China

China is the world leader in terms of alumina production capacity and output, however, the bauxite resources are relatively insufficient. According to the latest data released by the US geological survey (USGS), the global bauxite resources are about 55 - 75 billion tons, and the global bauxite reserves are 30 billion tons, while China's bauxite reserves are about 1 billion tons [1]. In recent years, with the rapid development of the alumina industry in China, the grade of bauxite used for alumina production has dropped sharply. The grade of some of the bauxites has decreased to such an extent that the $Al_2O_3$-$SiO_2$ ratio is > 4.

By the end of 2017 the reserves & resources of bauxite in China were 5.089 billion tons according to the data published by the Ministry of Natural Resources of People's Republic of China [2].

Bauxite reserves & resources in China are mainly distributed in Shanxi, Henan, Guangxi and Guizhou provinces, among which Shanxi accounts for 30 %, Henan 22 %, Guangxi 20 % and Guizhou 20 %. The total bauxite reserves & resources in Shanxi, Henan, Guangxi and Guizhou provinces are 4.682 billion tons, accounting for 92 percent of the national reserves & resources. In addition, 15 provinces and cities, including Chongqing, Shandong, Yunnan, Hebei, Sichuan and Hainan, also have certain reserves & resources, but their total amount only accounts for about 8% of the total in China.

**Table 1. Bauxite reserves & resources in China (billion tons).**

| Province | Reserves & Resources | % |
|---|---|---|
| Shanxi | 1.53 | 30 |
| Henan | 1.12 | 22 |
| Guangxi | 1.02 | 20 |
| Guizhou | 1.02 | 20 |
| Chongqing | 0.10 | 2 |
| Others | 0.31 | 6 |
| Total | 5.09 | 100 |

### 2.2. China's Bauxite Imports

More than a third of China's alumina production is now made from imported bauxite. China's bauxite imports in the past decade are shown in figure 3. The proportion of bauxite imported by source country in 2018 is shown in figure 4. Figure 3 and figure 4 show that China imported 82.43 million tons of bauxite in 2018. Bauxite is mainly imported from 15 countries including Guinea, Australia and Indonesia.

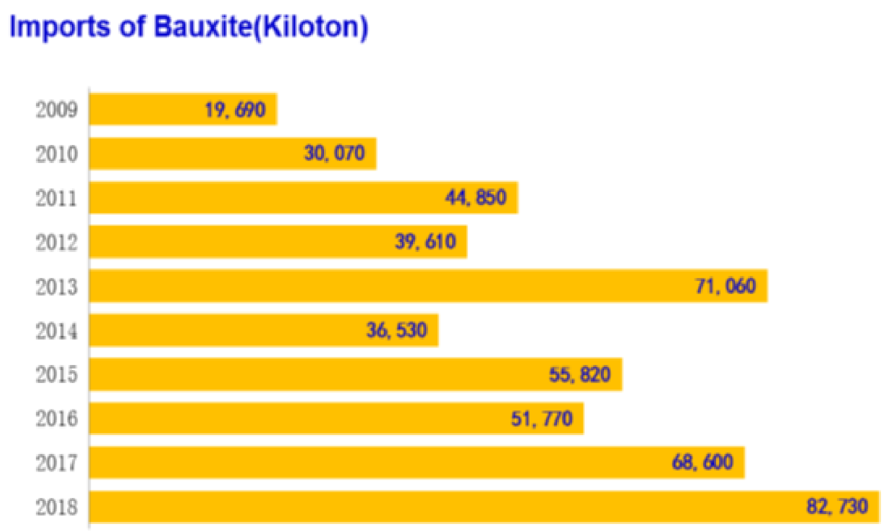


**Figure 3. The amount of China's imported Bauxite in the last ten years.**

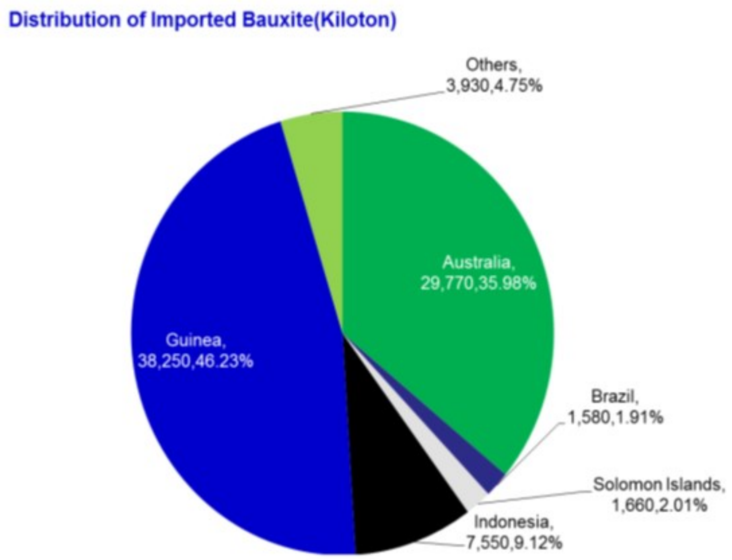


**Figure 4. The proportion of bauxite imported by country in 2018.**

## 3. The main Technical requirements of the Alumina Industry in China

### 3.1. Major Technological Challenges for China's Alumina Industry

In summary, the biggest challenge that China's alumina industry will be faced with is still the imbalance between the rapid growth of production capacity and the quality of the domestic bauxite reserves. Compared with the increasing trend of China's alumina production capacity, domestic bauxite reserves are seriously inadequate or the long term sustainability of the industry, and the bauxite grade decrease trend is a serious threat. The current situation that China's alumina is produced both from domestic and imported bauxite is expected to continue for a long time.

Therefore, the major technical challenges China's alumina industry faced with are to solve the problem of how to continuously optimize the technical and economic indicators of alumina production from domestic bauxite, especially that of low-grade bauxite, and to solve the problem of how to utilize imported bauxite more economically and efficiently at the same time.

## 3.2. The main Technical Requirements for the Alumina Industry in China

### 3.2.1. Technologies of Producing Alumina from Low-grade Bauxite

The production technology of alumina from low-grade diasporic bauxite more economically and more efficiently has been the focus and challenge for China's technological research and development field for the alumina industry. The developments of technologies for the production of alumina from China' low-grade diasporic bauxite had been reviewed at the ICSOBA 2017 Conference in Hamburg in October by the author of this paper [3]. A lot of research on the production of alumina from China's low-grade bauxite has been carried out systematically for a long time, and some progresses have been made. But only the Lime Bayer Process, Series Process and Floatation Bayer Process have been used in the commercial production of alumina.

The Lime Bayer process is suitable for treating medium and low grade bauxite [4]. The form of desilication products is changed by adding appropriate amounts of excess lime in the Bayer Process. The form of desilication products is changed from sodium aluminosilicate hydrate with high alkali content, to hydrogarnet with no alkali content (see the following reaction):

$$Na_2O\cdot Al_2O_3\cdot 1.7SiO_2\cdot nH_2O+CaO\rightarrow 3CaO\cdot Al_2O_3\cdot xSiO_2\cdot (6-2x)H_2O+NaOH \quad (1)$$

The Lime Bayer Process is simple, and does not require too much investment in process equipment. The energy consumption is low and as is the alkali consumption in the Lime Bayer Process. However, the lime consumption, material flow and bauxite residue amounts are high, and also the alumina recovery is relatively low in the Lime Bayer Process. More and more alumina refineries continue to use this technology because of its low energy consumption and simple process. Now the lime addition is more than 10 % of the bauxite in processing of diasporic bauxite in China using this method.

Significant progress has also been made in the Floatation Bayer process. The lowest ratio of alumina to silica in the bauxite treated by the Floatation Bayer process has been about 2.2.

### 3.2.2. Technologies of Producing Alumina from High Sulphur Bauxite

China's high sulphur bauxite reserves & resources are about 1 billion tons, most of which are concentrated in Guizhou, Chongqing and Western Henan. The main sulfide minerals in high-sulphur bauxite are pyrite ($FeS_2$), colloidal pyrite and sulfates such as gypsum $CaSO_4$, etc. Sulphur element in the bauxite first enters the solution in the main form of $S^{2-}$, which is then gradually oxidized to various forms of sulfur anion, such as $S_2O_3^{2-}$, $SO_3^{2-}$, $SO_4^{2-}$ during the Bayer process of alumina production.

Sulphur contained in bauxite enters into the digested solution during the digestion process and then accumulates continuously in the process. When the sulfur content in Bayer solution reaches a certain level, it will bring a series of negative effects to the production [5].

The harms of sulphur to alumina production process are mainly manifested in the following aspects:
① Corrosion preheating pipes, digestion reactors and evaporators,
② Increasing the iron content in the product alumina to exceed the standard, and causing the product quality to drop in general,
③ Formation of $Na_2CO_3\times 2Na_2SO_4$ in the evaporation process aggravates the burden of desalination and causticization process, and causes alkali loss,

④ Poorer bauxite residue settling performance, and causing the solid content in the in over flow from the settling tank to exceed the limit.

A lot of research works on desulfurization of high-sulfur bauxite have been carried out in China. Among them, the main desulfurization methods involved are desulfurization by flotation or by roasting desulfurization before the bauxite entering the alumina production process, desulfurization by adding precipitation agent or by adding oxidative agent during the alumina production process, etc. Zhengzhou Research Institute of Chalco has carried out a series of systematic studies on the desulfurization by flotation and deep oxidation desulfurization. The desulfurization by flotation and other technologies have been used in the commercial production of alumina, and have been highly appraised by China Nonferrous Metals Industry Association.

#### 3.2.3. Purification Technology of Sodium Aluminate Solution

There are some impurity minerals, such as lithium, potassium, zinc, etc. in diasporic bauxite in China. These minerals will react in the high temperature digestion process and dissolve into sodium aluminate solution, which can be precipitated into aluminum hydroxide and then affect the quality of the product [6, 7, 8]. Therefore, it has become an important technical requirement for the alumina industry in China to remove these impurities in the Bayer process and to purify the sodium aluminate solution to ensure alumina quality meeting the requirements for aluminum electrolysis.

Lithium, potassium and zinc are all brought into sodium aluminate solution from bauxite.

The average content of lithium in non-Chinese (imported) bauxites is 0.0030 %, while the lithium content of most bauxite in China is between 0.016 % and 0.030 %, and the lithium content of some bauxite is as high as 0.068 %. However, the exact composition of the lithium minerals in the Chinese bauxites has not been determined so far.

During the digestion process in the Bayer process, lithium compounds react with caustic soda to form soluble lithium aluminate which enters into the sodium aluminate solution. During the precipitation process, some of the lithium precipitates out in the form of a lithium compound, thus affecting the quality of the alumina.

Illite is the main potassium-containing mineral in diasporic bauxite in China. Illite can be dissolved by sodium aluminate solution at a higher digestion temperature (above 180 °C), and $K^+$ enters the solution which is then gradually enriched. When the concentration reaches a certain level, it will enter aluminum hydroxide in the precipitation process, thus affecting the quality of the alumina products [9].

The research results show that zinc exists in the bauxite in the form of blende (ZnS), smithsonite ($ZnCO_3$) and Calamine ($Zn_4(OH)_2Si_2O_7H_2O$), etc. Zn-containing compounds in the bauxite will react with NaOH in the digestion process and then exist in sodium aluminate solution in the form of sodium zincate, which will be absorbed by aluminum hydroxide in the subsequent seeded precipitation process, and enter into the alumina products, resulting in low purity of alumina products and finally affecting the electrolysis of alumina and metal grades.

#### 3.2.4. Improvement of Alumina Production Process Technology

To improve the Bayer process and improve the efficiency has also become an important technical requirement for the alumina industry in China.

**Increasing the precipitation efficiency and reducing inefficient recycle of alumina in the process.** The precipitation efficiency in the Bayer process is only about 50 %. As a result, about half of the alumina goes back to the digestion process and is thus a direct process inefficiency (recycle stream). The ineffective recycle stream greatly reduces the efficiency and increases the energy consumption and power consumption of the whole system. Therefore, improving the precipitation efficiency is an important prerequisite for the Bayer process to achieve substantial energy saving.

**Recycling waste heat in alumina production system.** In the Bayer process, there are heating, cooling, evaporation, dilution and other processes, as well as a large amount of high temperature waste gas, high temperature materials and waste steam to discharge heat into the environment. It is one of the key areas for potential energy saving in alumina production system to improve the utilization rate of waste heat as far as possible.

**Reducing new water consumption.** The study of water balance in alumina production process shows that the added new water is mainly used for the washing of aluminum hydroxide, bauxite residue and cooling purposes. The main channels of removing moisture are calcining of aluminum hydroxide, discharge of bauxite residue and steam. So the main way to reduce the consumption of water is to reduce the amount new water added, recycle the water contained in the discharge of flue gases, steam and bauxite residue, and achieve the water balance in the production system.

**Reducing alkali consumption technology.** The alkali consumption increases with decreasing ratio of $Al_2O_3$ to $SiO_2$ in the bauxite, which results in higher production costs. How to reduce the alkali consumption in alumina production is a problem urgently needed to be solved. Generally, there are three ways to reduce the alkali consumption of alumina production: the first way is to carry out pre-desilication of the bauxite to reduce the silica going into the alumina production process from the source, the second way is to adjust and optimize the dissolution conditions to change the mineral composition of bauxite residue, and the third way is to deal with the bauxite residue by dealkalizing.

### 3.2.5. High Efficient Utilization Technology of Imported Bauxite

As mentioned above, about 30 million tons of China's alumina output in 2018 was produced by using imported bauxite, accounting for 41.78 % of the total alumina output in China. According to the current situation, domestic bauxite grade are declining significantly, and as environmental policies become more and more stringent, domestic bauxite prices remain high, the cost of alumina production mainly in Shanxi and Henan increases significantly, more and more refineries have to consider using imported bauxite.

There are four main technical routes for inland refineries to use imported bauxite: sweetening process, high temperature Bayer process, low temperature Bayer process and high temperature Bayer process for mixing imported bauxite with domestic bauxite.

How to choose and optimize the appropriate technical route according to the characteristics of imported and local bauxite is the necessary premise for the inland refineries to maximize the economic benefits.

### 3.2.6. Organic Control Technology

How to control and remove organics in the alumina production process becomes more and more important with the increasing operational time of the refineries using domestic bauxite resources and the increasing capacity of producing alumina using imported bauxite in China. Some technologies used in foreign refineries such as seawater neutralization can not fully adapt to China's conditions.

The wet deep oxidation technology successfully developed by Zhengzhou Research Institute of CHALCO can control the organics effectively in the high temperature Bayer process. However, it is necessary to develop the control technologies for organics in the low temperature Bayer process using imported bauxite according to the characteristics of the bauxite and alumina production technologies.

### 3.2.7. Bauxite Residue Treatment Technology

Large-scale economic comprehensive utilization of bauxite residue is still a worldwide problem. There is significant research efforts on the comprehensive utilization of bauxite residue at home and abroad, but none of them can deal with and utilize the bauxite residue economically and effectively so as to solve the problems of safety and environmental protection brought by bauxite residue effectively. Industrial application in recovering iron from high iron bauxite residue has been achieved in China [10].

The technical route of large-scale comprehensive utilization of bauxite residue economically mainly includes: using the bauxite residue to produce various kinds of building materials after removing alkali, using the bauxite residue for road building materials after solving alkali seepage and bauxite residue denaturation, using the bauxite residue as filler in composite materials, using the bauxite residue as acidic soil improver, using the bauxite residue to treat acid sewage and waste residue, using the bauxite residue for extracting valuable elements (such as iron, titanium, rare earth elements, etc.).

## 4. Conclusions

The development trends of the Chinese alumina industry science and technology are determined by the nature of the bauxite resources, the characteristics of the alumina production process and environmental protection policies in China. It is expected that the production of alumina by both domestic and by imported bauxite will coexist in China for a long time.

Two major technical challenges for China's alumina industry are how to improve the technical and economic indicators of alumina production from bauxite in China on the premise of clarifying the development strategy of the alumina industry in China, and how to use the imported bauxite with high efficiency and economically.

The main technical requirements for high efficiency utilization of bauxite in China include efficient technology for processing of low-grade diasporic bauxite and high sulfur bauxite, and organic control technology in the alumina production process.

The main technical requirements in the efficient and economic utilization of imported bauxite also include the selection of efficient production technologies and the control strategy for organics in the alumina production process.

## 5. References

1. https://minerals.usgs.gov/minerals/pubs/commodity/bauxite/mcs-2014-bauxi.pdf
2. http://www.mnr.gov.cn/sj/sjfw/kc_19263/zgkczybg/201811/t20181116_2366032.html
3. Yin Zhonglin et al, Progress in Research and Development of Alumina Production Technology for Low Grade Bauxite in China. Hamburg, Germany, 2-5 October 2017 ICSOBA.

4. Yin Zhonglin, Li Xinhua, Fan Weidong, Lime Bayer process and its application prospect. Proceedings of the fourth national conference on light metal metallurgy. 2001. 150-153
5. YANG Quan-ping, LV Xian-cui, The industrial practice of producing metallurgical grade alumina from high sulfur bauxite. Light Metals (in Chinese), 2012 (7), 10-12
6. Huang-haibo, Qiu-shilin. Effect of rich lithium alumina on aluminum electrolysis production[J]. Light Metals, 2014, 8: 26-28
7. Zhang Qing-xiang, Yang Jian-hong, Li Qing-yu,et al. Behavior and Elimination of Zinc in Alumina Production[J].J.CENT.SOUTH UNIV.TECHNOL,1999,12:589-591
8. Shi Ying-jie, Li Rong-xing, Yu Xiao-hua, et al. Study on Zinc Removal by Sodium Sulfide in Bayer Alumina Production[J]. Journal of Kunming University of Science and Technology (Natural Science Edition), 2016, 12: 1-6
9. Gu Songqing,Yin Zhonglin, et al. Behaviuor of illite in the Bayer digestion process of diasporic bauxite. Light Metals 1992.
10. LI Jianwei，ZHANG Jiangbin，LI Qiumei. Recovery of Iron from Bayer Red Mud. Hydrometallurgy of China. Vol.33 No.3(Sum.135) June 2014.