# The Desulfurization Desilication Study on Technology of Low Grade High-Sulfur Bauxite in Western Henan

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**Abstract**

Research and development on desulfurization and desilication technology for low grade, high sulfur bauxite in Western Henan has been undertaken to solve the problem of low mass ratio of alumina to silica (A/S) in concentrate when only desulfurization is performed, and high sulfur content in concentrate when only desilication is performed. Low grade, high sulfur bauxite with a sulphur (S) content of 1.21 %, alumina ($Al_2O_3$) content of 58.09 % and A/S of 4.43, can be improved to produce a bauxite concentrate at a production rate of 76.55 %, with S of 0.15 %, $Al_2O_3$ content of 65.25 %, A/S of 9.02 and a sulphur concentrate with S content of 23.27 %, and yield of 4.60 %. This is achieved by "one roughing, one selection and two sweeping" stages of desulphurizing flotation, that is followed by "one roughing, two selection and one sweeping" stage of desilication flotation. These results demonstrate that effective utilization of low grade, high sulfur bauxite is possible, and that efficient utilization will provide support to the economy.

**Keywords:** Low grade bauxite, High-sulfur bauxite, Desulfurization desilication, Economic support.

## 1. Introduction

With the rapid increase of alumina production capacity in China, domestic bauxite resources are becoming increasingly scarce, and low grade, fine and difficult to process bauxites are becoming increasingly prominent. As a result, new challenges are being faced by bauxite beneficiation technology and beneficiation equipment performance.

With the decrease of bauxite resources and reduction in quality, the particle size of useful minerals are getting finer and finer. In addition, the symbiotic relationship with gangue minerals is becoming more and more complicated, making it difficult to improve the quality of desired minerals while reducing impurities, leading to an increase in production costs and decrease in process index [1-6].

There are a large number of low-grade, high-sulfur bauxite deposits in western Henan. With reserves of more than 60 million tonnes, the typical sulfur content is about 1.2 - 2.0 %, and the ratio of aluminum to silica (A/S) is around 4.5 - 5.0. The use of desulfurization flotation alone cannot deliver a high A/S concentrate, and the sulfur content of the flotation concentrate is above 0.8 % and cannot meet the alumina production requirements. In order to develop and utilize this resource economically and rationally, this paper studies combining desulfurization and desilication technology for use with low-grade and high-sulfur bauxite in western Henan.

## 2. Research on the Properties of Ore

Multi-element analysis, X-diffraction analysis and phase composition analysis of low-grade and high-sulfur bauxite ore from western Henan were carried out to understand the nature of the ore and provide mineralogical guidance for subsequent experiments. The analysis results are shown in Table 1, Figure 1, and Table 2.

According to the analysis results, it can be seen that the $Al_2O_3$ content in the raw ore is 58.09 %, with $SiO_2$ content of 13.10 %, A/S content of 4.43, and the harmful impurity S content of 1.21 %, confirming the sample as low-grade and high-sulfur bauxite ore. The useful minerals in the ore are mainly diaspore, the gangue minerals are mainly illite, kaolinite, chlorite, calcite, etc., and the sulfur-containing minerals are mainly pyrite.

The bauxite ore must be beneficiated before it can be used for alumina smelting. Flotation desulfurization can be used to reduce the content of harmful impurities S, and flotation desilicication to increase the A/S of the ore to meet the requirements of alumina smelting [7-9].

**Table 1. Multi-element analysis results of raw ore (%).**

| $Al_2O_3$ | $SiO_2$ | $Fe_2O_3$ | $TiO_2$ | $K_2O$ | $Na_2O$ | CaO | MgO | S | C | LOI |
|---|---|---|---|---|---|---|---|---|---|---|
| 58.09 | 13.10 | 7.05 | 2.76 | 1.88 | 0.05 | 0.67 | 0.37 | 1.21 | 1.19 | 14.73 |

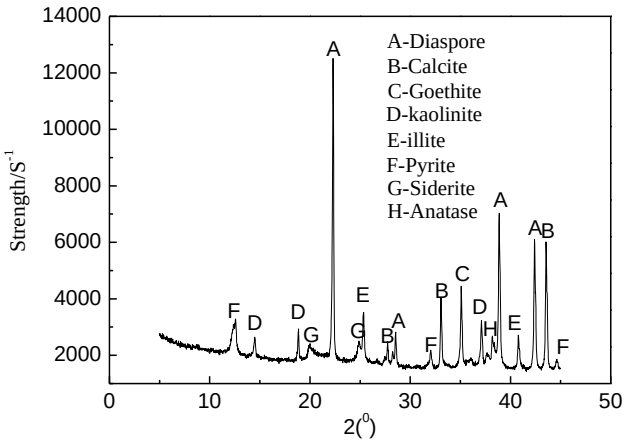


**Figure 1. XRD pattern of raw ore.**

**Table 2 The original mineral phase analysis results (%).**

| **Mineral** | **Diaspore** | **llite** | **Kaolinite** | **Chlorite** | **Pyrite** | **Anatase** |
|---|---|---|---|---|---|---|
| Content | 54.50 | 18.00 | 10.63 | 6.58 | 2.20 | 2.23 |
| **Mineral** | **Rutile** | **Calcite** | **Siderite** | **Dolomite** | **Quartz** | **Gypsum** |
| Content | 0.50 | 1.00 | 0.75 | 0.23 | 0.10 | 0.10 |

## 3. Laboratory Testing

### 3.1 Grinding Fineness Test

According to the study of ore properties, the ore sample belongs to low-grade and high-sulfur bauxite with diaspore-type alumina mineralogy. Desulfurization by reverse flotation is planned to reduce the sulfur content in bauxite concentrate products, and desilication by positive flotation is planned to achieve effective improvement of A/S in the bauxite concentrate.

Reasonable grinding fineness not only plays an important role in influencing bauxite beneficiation technology and indicators, but it also affects the subsequent dissolution performance of bauxite concentrate products [10]. In order to obtain the best flotation desulfurization and desilication index, the grinding fineness test was carried out according to the process shown in Figure 2, and the test results are shown in Figure 3.

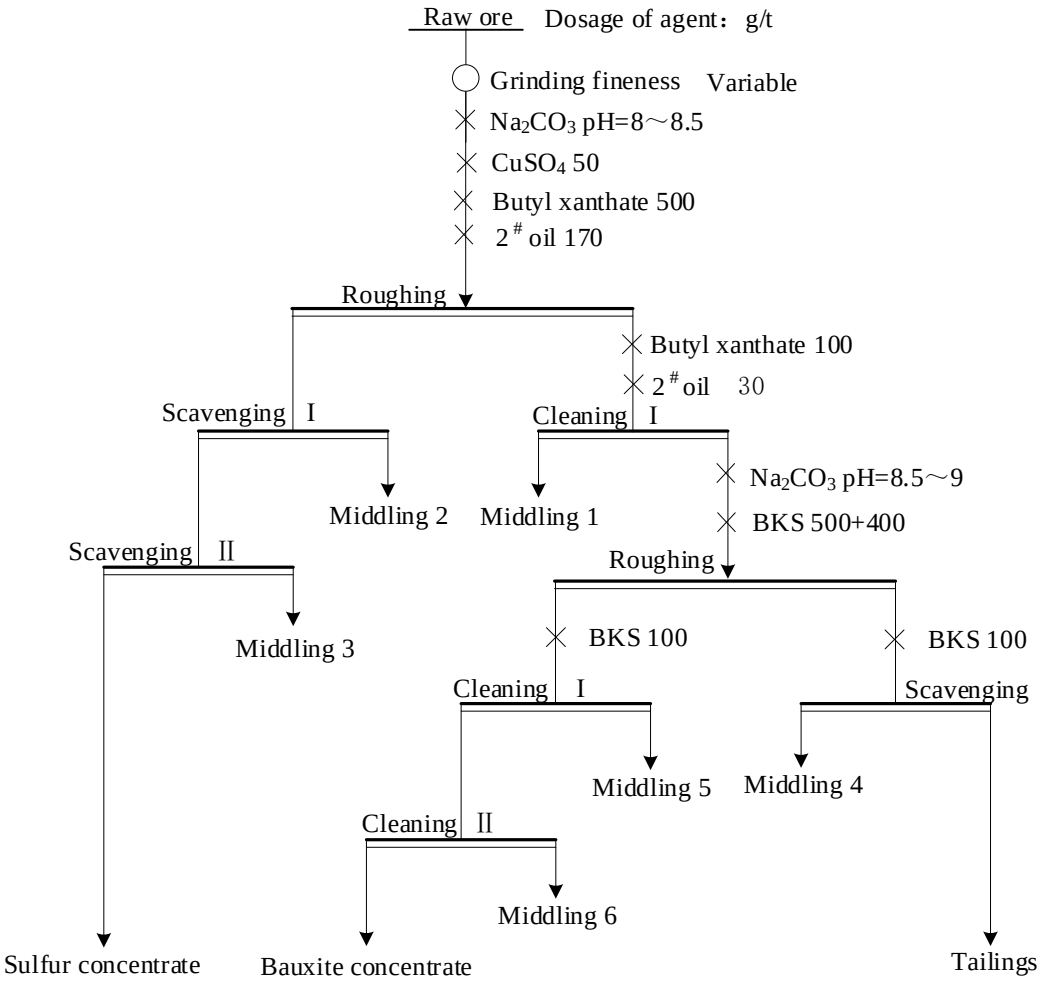


**Figure 2. Flow chart of grinding fineness test.**

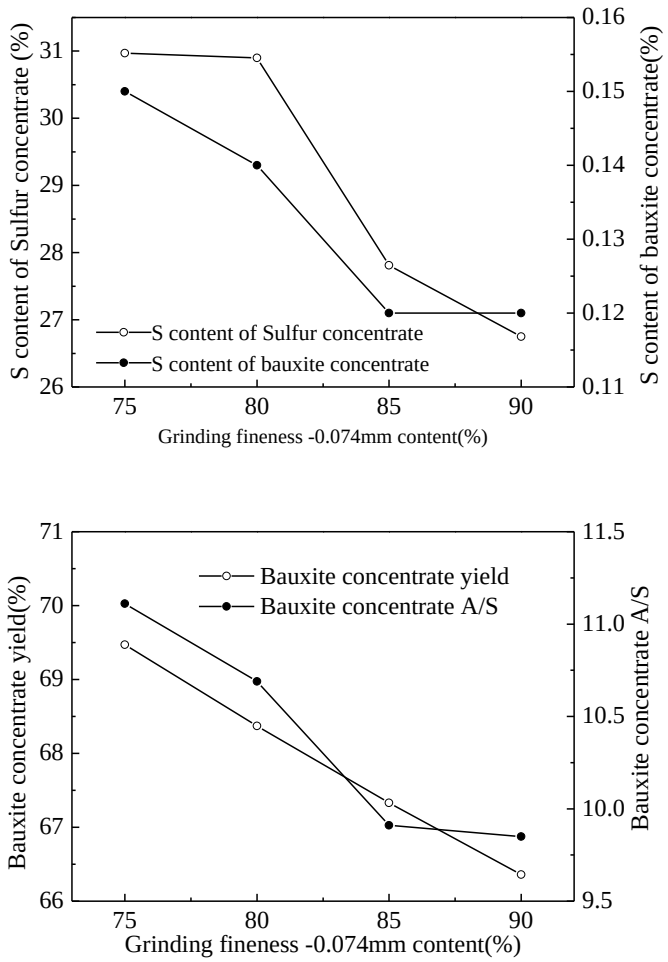


**Figure 3. Test results of grinding fineness**.

It can be seen from the test results in Figure 3 that:

- the coarser the grinding fineness, the higher the S content of sulfur concentrate
- the S content and yield of the bauxite concentrate decrease with the reduction of the grinding fineness
- the A/ S and yield continue to decrease with the reduction of grinding fineness.

Considering the bauxite concentrate index and the sulfur concentrate index comprehensively, when the grinding fineness of -74μm accounts for 85.00 %:

- the comprehensive effect of flotation desulfurization and desilication is better
- a bauxite concentrate with a yield of 67.33 %, an S content of 0.12 %, and A/S of 9.91 can be obtained
- a sulfur concentrate with a yield of 3.44 % and a sulfur content of 27.81 % can be obtained.

### 3.2 Type Test of Desulfurization Collector

Under the condition that the content of ore with fineness of -74μm accounted for 85.00 %, the effect of desulfurization collector types on flotation desulfurization was studied according to the process shown in Figure 4, and the test results are shown in Figure 5.

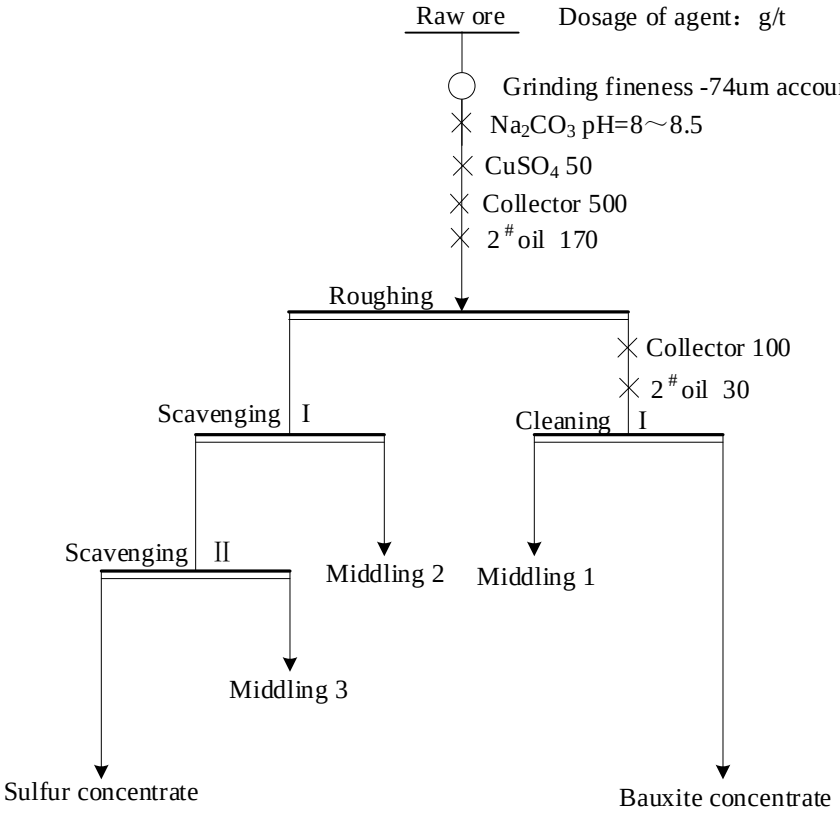


**Figure 4. Flow chart of desulfurization condition test.**

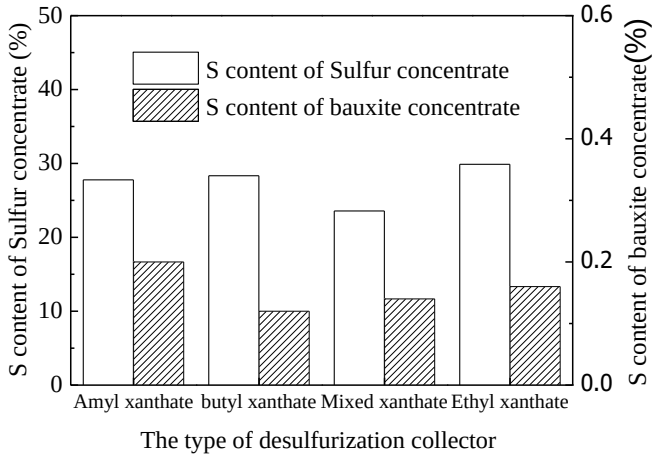


**Figure 5. Test results of types of desulfurization collectors.**

It can be seen from the test results in Figure 5 that the S content in the bauxite concentrate obtained by using amyl xanthate is higher than that of other desulfurization agents. Butyl xanthate has a strong ability to collect pyrite in the ore and the selectivity is also relatively good, enabling a

bauxite concentrate with the lowest S content to be obtained. Comprehensively comparing the S content of bauxite concentrate and sulfur concentrate, the butyl xanthate provides the best results as the desulfurization collector.

### 3.3 Desulfurization Collector Dosage Test

The main function of the collector is to make the surface of the target mineral hydrophobic and increase the floatability. Consequently, the amount of the collector has an extremely important influence on the flotation process performance. When the dosage of foaming agent and desulfurization collector is 3:1, the effect of the amount of butyl xanthate on the flotation desulfurization index was tested. The results are shown in Figure 6 with:

- A – 150 g/t for rough selection and 100 g/t for cleaning
- B – 200 g/t for rough selection and 100 g/t for cleaning
- C – 300 g/t for rough selection and 100 g/t for cleaning
- D – 400 g/t for rough selection and 100 g/t for cleaning
- E – 500 g/t for rough selection and 100 g/t for cleaning

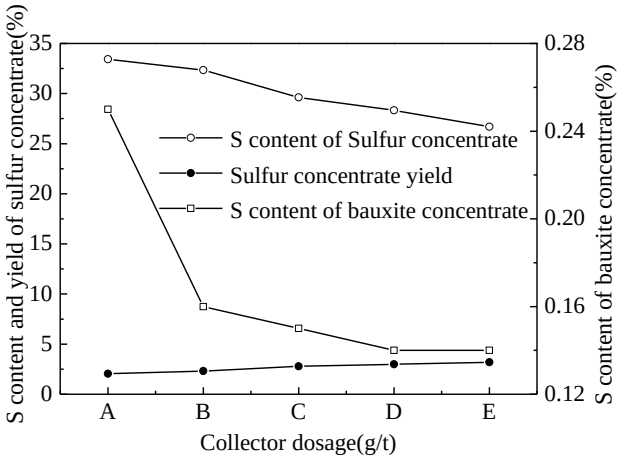


**Figure 6. Test results of desulfurization collector dosage.**

It can be seen from the test results in Figure 6 that by increasing the amount of desulfurization collector:

- the S content of the flotation desulfurized bauxite concentrate, and the S content of the sulfide concentrate are gradually reduced, and the yield of the sulfide concentrate is gradually increased.
- When the dosage of butyl xanthate is B, the comprehensive flotation effect is better.
- When the total dosage of medicament is lower than B, the sulfur content in the bauxite concentrate is too high.

The reduction effect of the S content in the concentrate is not obvious, so comprehensively considering the economic benefits and the flotation desulfurization index, the preferred dosage of butyl xanthate is determined to be B - 200 g/t for rough selection and 100 g/t for cleaning.

### 3.4 Activator Type Test

In order to strengthen the desulfurization effect of flotation, pyrite needs to be activated. The influence of activator types on the desulfurization index was investigated according to the process shown in Figure 4 with test results are shown in Figure 7 for:

- a total dosage of butyl xanthate of 200 g/t for rough selection and 100 g/t for cleaning
- the amount of foaming agent of 70 g/t for rough selection and 30 g/t for cleaning

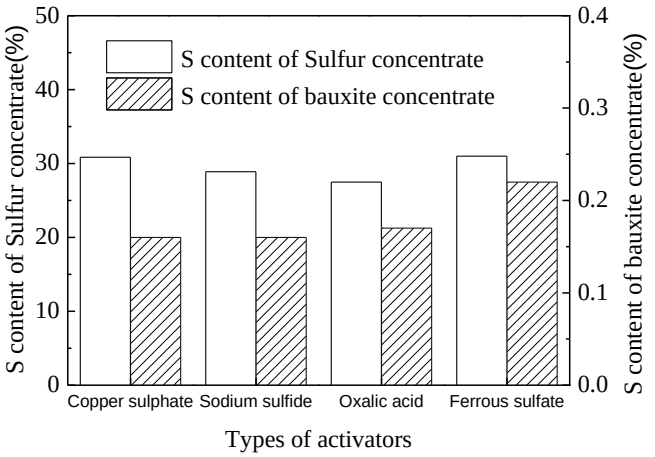


**Figure 7. Test results of desulfurization activator types.**

It can be seen from the test results in Figure 7 that when the dosage of the four activators are the same, the minimum S content of 0.16 % in the bauxite concentrate was obtained with copper sulfate as the activator, and the S content in the pyrite concentrate is 30.84 %, which is second only to ferrous sulfate 30.99 %. Copper sulfate is selected as the activator for flotation desulfurization.

### 3.5 Activator Dosage Test

For the original ore, with grinding fineness of -74μm accounting for 85.00 %, and a total dosage of butyl desulfurization collector of B of 200 g/t for rough selection and 100 g/t for scavenging, combined with foaming agent dosage of 70 g/t for rough selection and 30 g/t for cleaning, the influence of the dosage of desulfurizing activator (copper sulfate) on flotation desulfurization was investigated according to the process shown in Figure 4. The test results are shown in Figure 8.

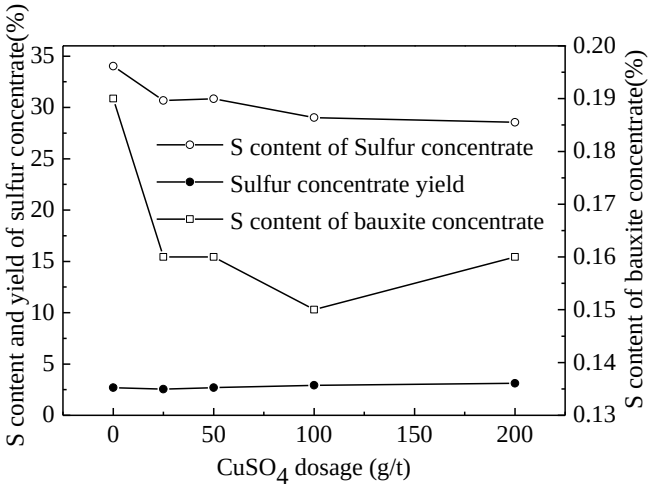


**Figure 8. Test results of desulfurization activator dosage.**

It can be seen from Figure 8 that with the increase in the amount of copper sulphate as desulfurization activator the S content of the flotation:

- desulfurized bauxite concentrate firstly decreases and then increases
- sulfide concentrate gradually decreases and then suddenly increases.

When the amount of copper sulfate is 25 g/t, the comprehensive flotation desulfurization effect is better. For this dosage, the S content of the flotation desulfurized bauxite concentrate is 0.16 %, and the sulfur content of the flotation sulphur concentrate is 30.67 %.

### 3.6 Foaming Agent Dosage Test

For the original ore, with grinding fineness of -74μm accounting for 85.00 %, and the total amount of butyl desulfurization collector is 300g/t (as 200 g/t for rough selection and 100 g/t for scavenging), and the activator copper sulfate dosage is 25 g/t, the influence of the dosage of desulfurizing foaming agent 2# oil on flotation desulfurization was investigated according to the process shown in Figure 4. The experimental results are shown in Figure 9 for the dosage rates tested:

- A – 40 g/t for rough selection and 20 g/t for cleaning
- B – 50 g/t for rough selection and 30 g/t for cleaning
- C – 70 g/t for rough selection and 30 g/t for cleaning
- D – 100 g/t for rough selection and 50 g/t for cleaning.

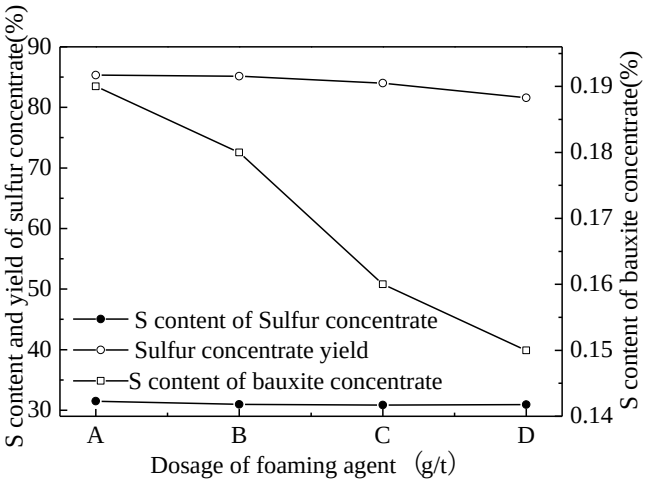


**Figure 9. Test results of foaming agent dosage.**

It can be seen from Figure 9 that with the increase of total amount of desulfurization foaming agent:

- the yield and S content of the flotation desulfurized alumina concentrate gradually decreases
- when the total amount of foaming agent exceeds C, the yield of bauxite concentrate drops sharply, which is caused by the excessive amount of foaming agent.

Foaming agent dosage C (70 g/t for rough selection and 30 g/t for cleaning ) is preferred as the comprehensive flotation effect is better, given that a bauxite concentrate yield of 84.47 %, S content of 0.16 % and sulfur concentrate with S content of 30.67 % can be obtained.

### 3.7 Type Test of Desilication Collector

The influence of desilication collector types on the flotation desilication index was investigated according to the process shown in Figure 11. The test results are shown in Figure 10.

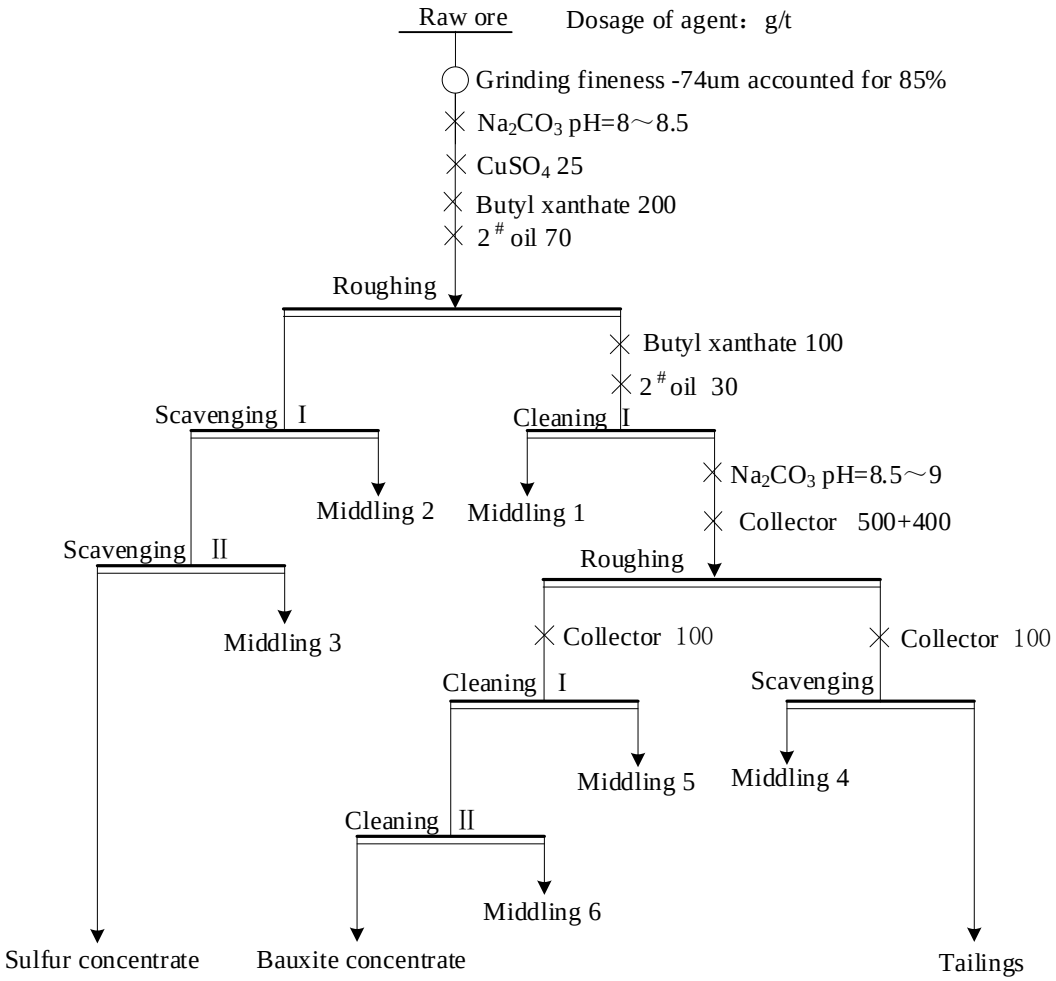


**Figure 10. Flow chart of desiliconization condition test.**

From the test results in Figure 11, it can be seen that among the four desilication collectors that SW has the worst desilication effect, and the self-made collector BKS has the highest bauxite concentrate yield when the other three have the same A/S difference. Review of the comprehensive results confirms that the self-made BKS collector is preferred as the desilication collector.

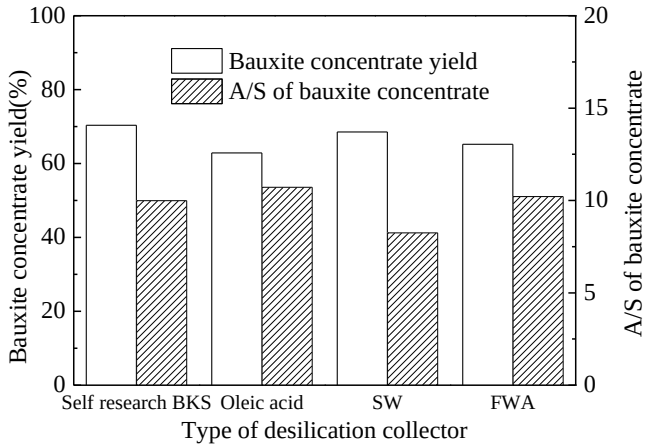


**Figure 11. Test results of desiliconization collector types**

### 3.8 Desilication Collector Dosage Test

The influence of the amount of desilication collector on the flotation desilication index was investigated according to the process shown in Figure 10, using the self-made BKS as the collector. The experimental results are shown in Figure 12 for the dosage rates tested:

- A – 700 g/t for rough selection, 100 g/t for scavenging and 100 g/t for cleaning i
- B – 800 g/t for rough selection, 100 g/t for scavenging and 100 g/t for cleaning i
- C – 900 g/t for rough selection, 100 g/t for scavenging and 100 g/t for cleaning i
- D – 1000 g/t for rough selection, 100 g/t for scavenging and 100 g/t for cleaning i.

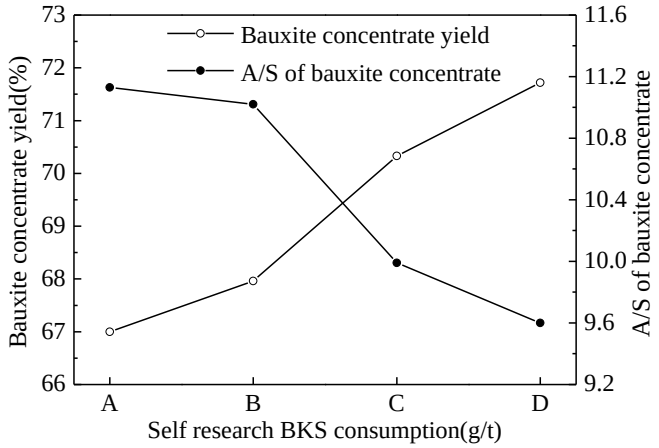


**Figure 12. Test results of the amount of desiliconization collector.**

According to the test results in Figure 12,

- the higher the total amount of BKS desilication collector, the higher the percentage of alumina concentrate, and the lower the A/S.
- when the total amount of desilication collector is C (900 g/t for rough selection, 100 g/t for scavenging and 100 g/t for cleaning i), the bauxite concentrate yield reached 70.33 %, and the A/S was 9.99
- when the total amount reaches D, the incremental increase in the production rate of bauxite concentrate declines, with yield reaching 71.72%, with an A/S of 9.6

Considering reagent dosage, flotation effect and reagent cost comprehensively, the suitable total amount of desilication reagent was determined to be dose rate C.

### 3.9 Full-Process Closed Circuit Test

A closed-circuit flotation test was performed according to the process shown in Figure 14 in order to investigate the reliability and feasibility of the overall desulfurization and desilication process using the preferred test conditions identified through the earlier tests. The test results are shown in Table 4.

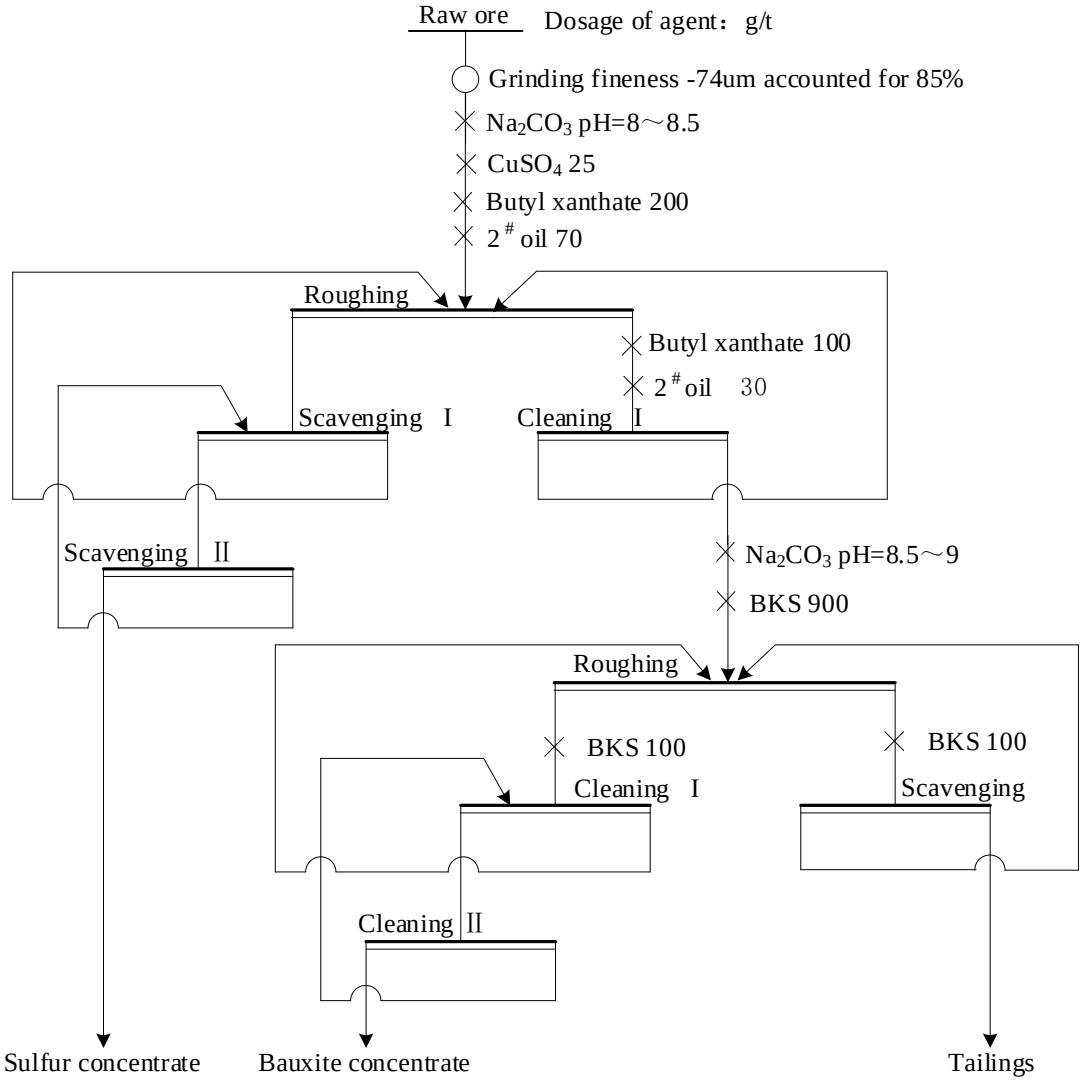


**Figure 13. Flow chart of the whole process closed circuit test.**

**Table 4. Closed circuit test results of the whole process.**

| Name | Yield (%) | $Al_2O_3$ (%) | $SiO_2$ (%) | A/S | S (%) |
|---|---|---|---|---|---|
| Sulphur concentrate | 4.60 | 29.01 | 9.01 | 3.22 | 23.27 |
| Bauxite concentrate | 76.55 | 65.25 | 7.23 | 9.02 | 0.15 |
| Tailings | 18.85 | 36.11 | 37.94 | 0.95 | 0.13 |
| Raw ore | 100.00 | 58.09 | 13.10 | 4.43 | 1.21 |

According to the results in Table 4 for the closed circuit test of the complete process, the raw ore is desulfurized by flotation using "one roughing, one selection and two sweeping" stages. The desulfurized concentrate is desilicated by flotation using "one roughing, two selection and one sweeping" stage. After treatment, bauxite concentrate with a yield of 76.55 %, S content of 0.15 %, $Al_2O_3$ content of 65.25 %, A/S of 9.02 and sulfur concentrate with S content of 23.27 % and yield of 4.60 % were obtained. The results indicated that improved flotation indexes could be obtained, and the S content of bauxite concentrate is able to meet the requirements of alumina smelting.

## 4. Conclusion

1. According to the study of the nature of the raw ore sourced from western Henan, the $Al_2O_3$ content was 58.09 %, the $SiO_2$ content was 13.10 %, A/S of 4.43, and the harmful S content of 1.21 %. This is classified as a medium-low grade and high-sulfur bauxite. The useful minerals in the ore are mainly diasporic alumina mineralogy which is accompanied by sulfur-bearing minerals that are mainly pyrite.
2. The bauxite must be beneficiated before it can be used for alumina smelting. Flotation desulfurization can reduce S content which is a harmful process impurity and flotation desilication can increase ore A/S, and when combined can meet the ore quality requirements of alumina smelting.
3. Through comparison tests for the types of desiliconization collectors, it was found that the self-made desilication collector, BKS has strong collecting ability and selectivity.
4. Closed circuit testing using preferred test conditions confirmed the low-grade and high-sulfur bauxite in western Henan may be desulfurized by "one roughing, one selection and two sweeping" stages of flotation, and the desulfurized bauxite concentrate may be desilicated through "one roughing, two selection and one sweeping" flotation stages.
5. Closed circuit test results indicated that the ore can be improved such that a bauxite concentrate with yield of 76.55 %, S content of 0.14 %, $Al_2O_3$ content of 64.25 %, A/S of 8.02 can be generated alongside a sulfur concentrate with S content of 23.27 %, yield of 4.60 %. Better flotation indexes were obtained, which provided technical reference for economic and efficient utilization of low-grade and high-sulfur bauxite resources.

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