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A facile disposal of Bayer red mud based on selective flocculation desliming with organic humics

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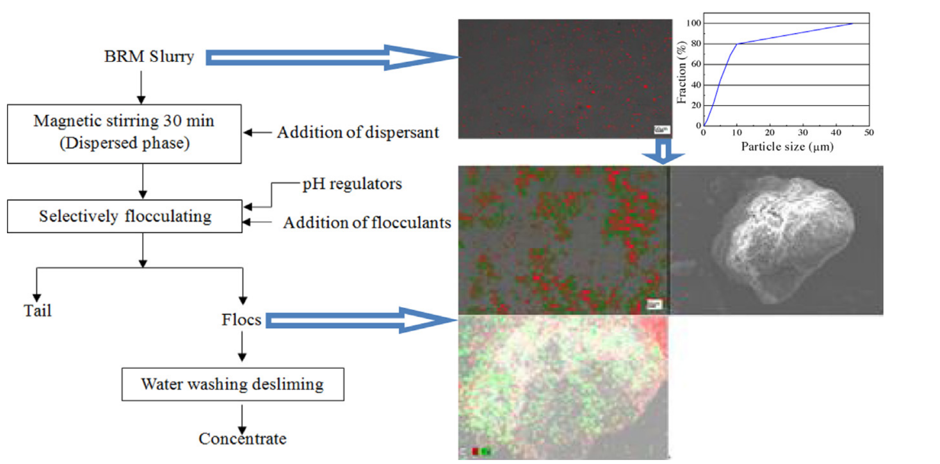
HIGHLIGHTS

- A feasible process for red mud disposal was proposed.
- Humics were used as flocculant in the selective flocculation desliming process.
- Iron grade, recovery and the separation index were enhanced.
- Bridging mechanism controls selectively humics flocculating the iron minerals.

GRAPHICAL ABSTRACT



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ABSTRACT

Humics flocculant was applied in the disposal of Bayer red mud based on selective flocculation desliming process. The parameters affecting selective flocculation behavior such as flocculant dosage, slurry pH and agitation intensity were studied. For flocculating mechanism analysis, the iron mineral and the flocs product were characterized by ζ-potential testing, settling experiments, optical microscope and SEM imaging. The results show that humics exhibits a good selective flocculation performance in the high alkaline pH range. With an optimal condition of 2% solid density, flocculant dosage 30 mg L^{-1}, Na_2SiO_3 dosage 200 mg L^{-1}, slurry pH 10.0 and agitation speed 1000 rpm, the recovery of iron minerals of $86.25 \pm 1.31\%$, the iron grade of concentrate of $61.12 \pm 0.10\%$, the separation index of 0.69 ± 0.02 can be obtained in the selective flocculation. It is found that the adsorption bridging of humics polymer dominates the selectively flocculating the iron minerals. Large flocs or aggregates with a better settling capacity are generated because of humics occurring. The maximum settling velocity of 38.23 ± 1.51 m h^{-1} is reached at pH 10. This work brings the easiness in directly recovering fine particle size of iron-bearing minerals from red mud.

1. Introduction

Bayer red mud (BRM), also called as bauxite residue, is a hazardous solid waste generated during the Bayer alumina extracting

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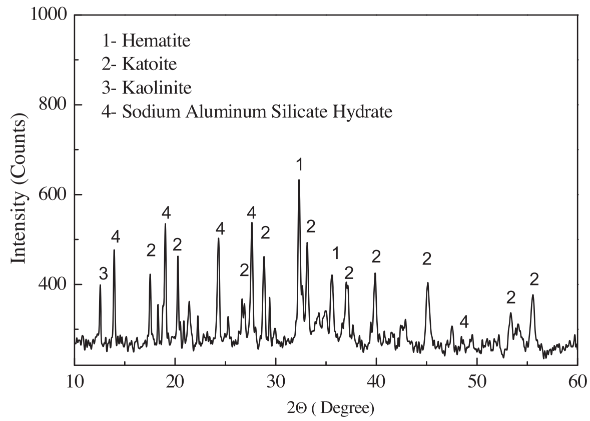

Fig. 1. XRD pattern of the BRM sample.

from bauxite ore [1,2]. About 1.0–1.5 t of BRM is generated for per ton of Al_2O_3 extracted. With the increasing demand for alumina worldwide, the global annual generation of BRM is around 120 million tons and approximately 2.7 billion tons of this waste has already been stockpiled by 2015 [3,4]. China is the greatest producer of red mud in the world, it is estimated that the amount of stored BRM has reached to 350 Mt in China [5,6]. The disposal of BRM is a serious environmental issue and a major headache for the government because of its high alkalinity, the massive volumes generated and the harmful impacts resulting from its disposal [5,7,8]. In order to finding a way for disposal and utilization of red mud, a worldwide study has been carried out. Thus the study of BRM treatment and utilization is very important and challenging.

As a typical industrial waste, many technologies and attempts have been proposed to find an environmentally friendly and cost-effective method to dispose or utilize BRM. BRM can be used as adsorbents for pollutant removal, building materials (brick, cement, glasses and concrete blocks), filling materials in mining and reagents for neutralizing acidic wastes [9–13]. However, all these above solutions can only accommodate a small fraction (less than 40%) of red mud generated. BRM can be considered as a secondary resource for the recovery of valuable elements. These metals are mainly iron, aluminum and titanium as well as some minor or trace components of rare earth elements [14–17]. Since iron minerals usually accounts for about half of BRM, even as high as over 60 wt.%, the recovery of iron is one of the most attractive strategies [18,19]. As a conservative estimate, more than 12 Mt/year of iron are disposed along in BRM. If both Al and Fe can be extracted, there is a considerable economic advantage for the Bayer process.

The recovery of iron from BRM has been studied by many researchers. Iron in bauxite ore or resulting BRM is mainly in the forms of oxides\hydroxide including hematite, goethite and magnetite minerals. Many techniques have been intensively studied for physical–chemical routes such as direct magnetic separation, acid leaching, smelting in a blast furnace and solid state reduction–magnetic separation [20–25]. Considering the above routes, low-level recovery, high energy consumption, long process and secondary pollution are the main reasons for the limitation of large-scale industrial applications. The alternative methods for iron recovery from red mud have been desired and explored.

Selective flocculation is one of the alternative methods available for effective beneficiation of fine particles (−45 μm), which is a solid–solid separation process where targeted minerals are selectively flocculated and undesired minerals remains in dispersed suspension [26,27]. Selective flocculation process has been applied to beneficiation of fine iron particles from hematite-quartz system [28,29]. However, very limited studies were carried out for enrichment of iron minerals by selective flocculation from BRM.

The fine particle size of iron-bearing minerals and the alkalinity bring the difficulty in directly recovering iron from BRM. Humics is the most abundant natural organic matter, which was preliminarily observed to be a more selective interacting with iron oxides in our flotation experiments. Humics possess many acidic functional groups including phenolic hydroxyl and carboxyl groups [30]. And they work well at a pH value of 10 or above, with having a potential for neutralizing the alkaline BRM. This work focuses on the recovery of iron and proposes a facile, environmentally and economically feasible process for the beneficial utilization of BRM. A variety of humics were tested to understand their ability to function as flocculants in the selective flocculation desliming for iron-bearing minerals. The enriched iron-bearing minerals can be used as iron concentrates for iron-making.

2. Experimental

2.1. Materials

The BRM sample studied in this work was collected from Henan province, China. It was obtained from alumina refinery after dewatering by filter presses and room temperature drying. The sample was further dried at 105 °C for 24 h. The metal element content of BRM sample was analyzed following ISO/TS 16.965 by Inductively Coupled Plasma Mass Spectrometry (ICP-MS, Agilent 7500cx, America). The Si content of sample was measured in accordance with ISO 3262-20. The BRM sample for subsequent determination needs to be dissolved in acid mixture as follows: 0.2000 g of dry sample was introduced into a boiling flask and dissolved with 6 mL of H_2SO_4, 18 mL of H_3PO_4; the flask was then heated for 2 h at 200 °C. The chemical compositions of BRM sample are listed in Table 1. Table 1 shows that hematite is the major chemical composition in red mud. XRD pattern of the BRM sample is given in Fig. 1, showing that it mainly consists of hematite, katoite, kaolinite and sodium aluminum silicate hydrate.

Particle distribution of the ultrasonic dispersed BRM sample in aqueous solution was observed and analyzed by using the optical microscope software (ZEISS Axio Scope.A1, Germany). The sample was pre-dispersed in deionized water with an ultrasonic cleaner. Particle distribution and cumulative particle size fraction of the BRM sample is respectively given in Figs. 2 and 3. It is indicated that 100% of the BRM particles are smaller than 45 μm and 80% of the particles are smaller than 10 μm. Those fine particles with diam-

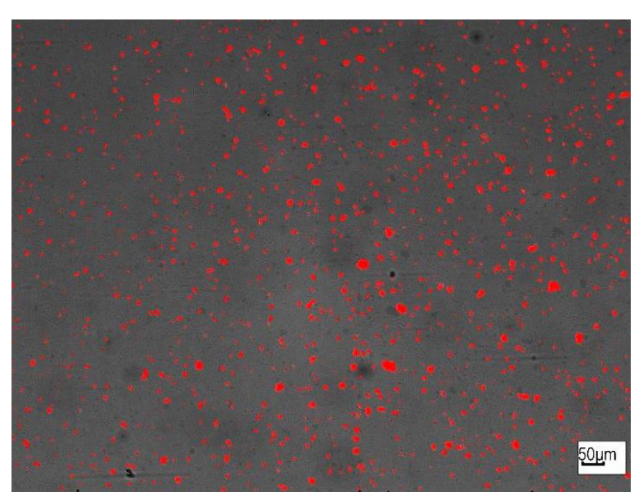

Fig. 2. Particle distribution of the ultrasonic dispersed BRM sample in aqueous solution (red-BRM particles).