Bauxite Residue Flotation as an Alternative for Iron Concentration and Sodalite Removal

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Abstract

Bauxite residue (BR) is a byproduct of the alumina production by Bayer process. BR generated from gibbsitic bauxite usually presents iron as major element associated with hematite and goethite phases (40.8 % Fe_2O_3). The other typical phases found are sodalite, gibbsite, anatase and quartz. In general, gibbsitic bauxite generates a BR with particle size distribution typical of silt and clay ranges. Such fine distribution normally makes physical separation process unfeasible for a specific mineralogical phase concentration. It is well known that conventional flotation process is limited by particle size, however, considering the surface charge difference mainly between hematite and sodalite, it is worthwhile to investigate if this differentiability property could enhance flotation efficiency. Desliming and reverse cationic flotation operations were carried at under bench scale for hematite concentration from BR by removing sodalite as floated. The results were promising. The mass recovery of BR reported as concentrate was 20 %, the iron and sodium contents were 58.22 % Fe_2O_3 and 0.60 % Na_2O, in addition, sodalite was not detected by X-ray diffraction and SEM, resulting in a final pH of 6.6 on this stream.

Keywords: Bauxite residue valorization, Circular economy, Elutriation, Flotation, Sodalite.

1. Introduction

Bauxite residue (BR) is the solid mixture remaining after aluminium phases lixiviation from bauxite added to compounds formed during other steps of the Bayer process. Based on 2020 alumina production data, it is estimated that 170 million tonnes per year of dry bauxite residue are generated and only about four million is used productively [1]. The variability in BR properties makes it a very challenging material for broad use or individual element concentration. Since iron is one of the main constitutes of BR, it is one of most promising elements for reducing BR inventory [1, 2]. However, BR is not considered a competitive raw material for iron-making process due to its low Fe_2O_3 content (27–47 %) comparing to the conventional iron ores (>60 %) [3], so operations for iron concentration should be investigated.

Considering BR as a potential "mine" for iron extraction, the feasibility of iron concentration needs to be evaluated from the perspective of mineral concentration. The requisites for mineral concentration can be summarized in three topics: (i) mineral liberation, (ii) differentiability and

(iii) dynamic separability [4]. The first two topics are related to the mineral, i.e., if the target phase is present as free particles (liberated) and if the mineral has properties that can be handled to allow its concentration. The last subject concerns equipment technology, meaning that the equipment should be able to achieve the conditions that will result in the concentration of the target phase [4].

In terms of liberation, as a rule of thumb, mineral liberation is lower in coarser size ranges, and it increases in finer size ranges [4]. BR studied in this work presents fine particle size distribution, where more than 80 % is smaller than 38 µm [5]. For the purpose of this study and due to insufficient data, one will assume that the main constituents of the BR, such as iron oxides (hematite and goethite), aluminous compounds (gibbsite), silicon compounds (sodalite and quartz), titanium oxides (anatase) [1, 5, 6] exist as individual particle and are able to be handled in a concentration process. Regarding to differentiability, properties such as broader size range, pronounced differences of properties as density and magnetic susceptibility do not occur among the solids present in BR. However, surface charge may be a potential property to be explored. Both pH-dependent surface charge (variable) and pH-independent surface charge (permanent) exist in BR [6, 7]. Sodalite is the only pH-independent charge, being permanently negative, while the other solids present in BR have a pH-dependent charge [6]. Based on that, charge development in mineral-solution phases regulates, for instance, adsorption reactions of ions at the mineral-water interface; the hydrophobic/hydrophilic character induced or modified by the adsorption of reagents can be very opportune and may result in substantial differentiation property between the various solids. Furthermore, the principle of concentration by flotation is related to the difference between the wettability of a specific mineral or its hydrophobic/hydrophilic character [4]. Flotation is about dynamics of liquid, solid and gas phases. Reagents are used to modify the wettability of a specific mineral, changing selectively its hydrophobic/hydrophilic character. Hydrophilic particles have a strong affinity to water while hydrophobic particles combine with bubbles, so they float [4].

In terms of the dynamic separability, the third and last topic mentioned above and related to the requisites of mineral concentration, handling very fine particle is an issue for mineral processing. Flotation of fine particles is being studied specially because of the declining of mineral grades, which results in comminution until finer sizes to improve liberation, and also, as a potential concentration process to recover minerals from tailings, such as recovery of iron from iron slimes [8, 9, 10]. Therefore, development of flotation equipment for small size particles can be a solution for dynamic separability issues related to handling fine material such as BR [5, 11]. For the moment, a deep discussion about equipment dynamic improvement is out of the scope of this work since the aim is a first exploratory assessment of how the solids present in BR will answer to a conventional flotation cell at bench scale.

Flotation is a well-known process in iron ore mining; in particular, cationic reverse flotation route is very effective in separating quartz from hematite [12]. BR holds similarities to iron slimes generated after iron ore beneficiation. Iron slimes has hematite as the main iron host phase (35 – 45 % Fe), a fine particle size distribution (99 % < 45 µm), and silicate gangue minerals (quartz and kaolinite) [13]. Several researches remark that development in flotation may be a possible alternative for iron concentration from slimes [13, 14, 15]. Therefore, in the present work, a BR sample from a gibbsitic bauxite processing was tested to investigate conventional flotation for iron oxides concentration. The reagents, process conditions and parameters were similar to those used in iron ore processing.

concentrate does not contain sodalite, it is possible to confirm that sodalite is the only responsible for the BR alkalinity: without sodalite, there is no caustic adsorbed on the other solids present in BR.

4. Conclusions

Flotation is a concentration operation based on the wettability as the differentiability property. Reagents are used to change or enhance the hydrophilicity or hydrophobicity characteristics of the particle surface, so each solid will combine to liquid or to gas phase (bubbles), allowing a proper material split and its concentration.

As a first and exploratory trial, BR from a gibbsitic bauxite processing was submitted to the reverse cationic flotation where the reagents and process conditions were similar as usually applied during iron ore beneficiation. An attrition scrubber, an elutriator and a conventional flotation cell were used for desliming and flotation tests. The chemical analyses for the final product (concentrate), showed an Fe_2O_3 concentration of 58.22 % while one of the major contaminants, Na_2O, decreased to 0.60 %, suggesting the absence of sodalite. XRD diffractograms confirmed that sodalite was removed from the concentrate stream, which presents strong evidence that charge surface may be a strong property to be manipulated for solids concentration from BR. In addition, since a stream from BR without sodalite was obtained and lead to the measurement of a neutral pH (6.60 and 7.9), it confirmed that DSP is responsible for the alkalinity of the BR in study.

It is also important to note that, evaluating the iron concentration from BR under the perspective of mineral concentration (liberation, differentiability, and dynamic separability), the main bottlenecks may stand clearly. The liberation degree of the solids present in BR needs to be determined, so a complete assessment about the limits of concentration potential would be known. This work has shown that surface charge of the BR solids can be explored for concentration proposes. As for dynamic separability, handling particle of small size is a major concern everywhere, and developments are being made, especially in operations such as flotation.

5. References

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