Dealkalization of Bauxite residue through Acid Neutralization and its Revegetation Potential

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Abstract

Bauxite residue is an alkaline industrial solid waste generated in alumina production process and the high alkalinity has caused serious environmental pollution. In this paper, a fast, high efficiency and low cost de-alkali process was developed, of which bauxite residue was dealkalized by sulfuric acid and calcium-containing compound CAM. And the revegetation potential of de-alkali bauxite residue was also studied. The results showed that the de-alkali rate reached up to 94.31 % when added 18.4 % of sulfuric acid and 2 % of CAM leaching at room temperature for 10 - 30 min. And the filtration speed increased by about 70 times with the addition of CAM up to 4.5 %. Subsequent pot experiment showed that the de-alkali bauxite residue met the growth requirements of plants. SEM analysis showed that the particle size of neutralized bauxite residue was enlarged, accelerating the process of soil formation of bauxite residue. This work provided technical support for ecological restoration of bauxite residue disposal area.

Keywords: bauxite residue; dealkalization; acid neutralization; revegetation; ecological restoration.

1. Introduction

Bauxite residue is an alkaline industrial solid waste generated in alumina production process [1]. Depending on bauxite type, 1 - 1.5 t of bauxite residue is produced when generating 1 t of alumina production [2]. The total amount of bauxite residue globally was about 160 Mt in 2015 [3]. Due to its abundant bauxite resources [4], China has become the largest producer of bauxite residue. The total bauxite residue production of China in 2016 was about 88 Mt [3]. As of 2017, the global reserves of bauxite residue have reached 3.9×10^3 Mt [5], of which China has accumulated more than 350 Mt [6]. However, the average utilization factor of global bauxite residue is only 15 %, and that of China is only 4 % [7].

The traditional disposal method of bauxite residue is building a dam in the open [8]. However, the cost of bauxite residue damming is very high, accounting for about 2 % of the price of alumina [9]. The fine size and strong alkalinity of bauxite residue caused serious air pollution [10], land pollution and water pollution [9]. Owing to the potential environmental risks of the large-scale pile-up of bauxite residue, researches on the ecological restoration of bauxite residue have been conducted worldwide. At present, gypsum [11] and organic matter (e.g., composts, manures, bio solids) [11b] are often used as amendments for the ecological restoration of bauxite residue.

Moreover, bauxite residue contains large amounts of Al, Fe, Ti, and other valuable components [12], all belonging to potential secondary solid resources. Several researchers have extensively investigated the comprehensive utilization of bauxite residue. Bauxite residue are mainly used in the (1) preparation of building materials, such as bricks [13], cement [14] and concretes [15], subgrade materials [16], and ceramics [17]; (2) preparation of adsorbent materials [18] for wastewater processing; and (3) extraction of valuable metals, including aluminum [19], titanium [20], iron [21], gallium [22], and scandium [23].

Among these different uses, making building materials can consume a large amount of bauxite residue [24] and produce lower environmental pollution [3], thus using bauxite residue in building materials is an important means of using it on a large scale. And the sodium content in the raw materials for preparing building materials require to be less than 0.5 %, which prevent the occurrence of "efflorescence" phenomenon affecting production quality [25]. However the sodium content in bauxite residue is 2 % - 10 % [12], which is much higher than the requirements of building materials and the standard salt content of the soil (high salinity soil, salt content > 0.4 % [26]). Thus, sodium in bauxite residue cannot be used directly by soil or to make construction materials. So the dealkalization of bauxite residue is the key factor for its comprehensive utilization.

The conventional methods of bauxite residue dealkalization are water leaching, acid leaching, calcium ion replacement, and wet carbonization [7, 27]. The water leaching method can remove free alkali in bauxite residue and has no agent consumption, but it requires several times of dealkalization and long-term leaching, prolonging the operation time and affecting the subsequent comprehensive utilization of bauxite residue. Acid leaching can significantly improve the de-alkali rate of bauxite residue, but the acid consumption is extremely large in the de-alkali process. After de-alkali, the acidity of bauxite residue are so strong that it is not conducive to dam stacking or to the preparation of building materials and other comprehensive use. Calcium ion replacement method can significantly remove free alkali and structural alkali in bauxite residue, but its agents consumption is larger and de-alkali rate is generally less than 80 %. Wet carbonization can effectively remove free alkali and structural alkali in bauxite residue with no agent consumption, but leaching equipment requirements are more stringent, leaching process conditions are difficult to control and operation is more cumbersome.

In the process of direct acid neutralization, silicon in bauxite residue is easily immersed to form silica gel, seriously affecting the filtration performance of bauxite residue [28]. Additionally, this gelatinous precipitate may blind ore particles from further dissolution and reduce the leaching kinetics significantly [28], making solid-liquid separation harder.

In this paper, a fast, high-efficiency, low-cost de-alkali process of bauxite residue was proposed, which was dealkalized by sulfuric acid and calcium-containing compound CAM. Then the revegetation potential of de-alkali bauxite residue was studied. The flowsheet of bauxite residue treatment is shown in Figure 1.

calcium-containing compound CAM. The revegetation potential of the neutralized residue has also been studied. The main conclusions were drawn as follows:

1) De-alkali rate of bauxite residue could reached up to 94.16 % with 18.4 % of sulfuric acid and 2 % of CAM addition at room temperature for 10 - 30 min; with higher addition rate of CAM, the filtration speed increased by about 70 times without adverse effects on de-alkali rate;
2) SEM analysis indicated that both sulfuric acid and CAM enlarged the size of aggregate particle in bauxite residue, which was conducive to improve the physical structure of substrates, accelerating the process of soil formation;
3) Pot experiment showed that the neutralized residue was suitable for the growth of ryegrass. But the accumulation of organics in plants was less than that grown on soil, indicating that organics should be introduced to bauxite residue during ecological restoration.

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6. References

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