Journal of Hazardous Materials 286 (2015) 85–91

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

An active dealkalization of red mud with roasting and water leaching

Xiaobo Zhu [a,b,*], Wang Li [a,b], Xuemao Guan [a,b]

[a] School of Materials Science and Engineering, Henan Polytechnic University, Jiaozuo, Henan 454000, China
[b] Henan Key Discipline Open Laboratory of Mining Engineering Materials, Henan 454000, China

HIGHLIGHTS

- The dealkalization of active roasting and water leaching from red mud was put forward.
- The main factors on dealkalization during active roasting and water leaching were investigated.
- The mechanism of dealkalization from red mud was in-depth studied in the process.

ARTICLE INFO

Article history:
Received 4 September 2014
Received in revised form
21 December 2014
Accepted 24 December 2014
Available online 27 December 2014

Keywords:
Red mud
Dealkalization
Active roasting
Water leaching
Leaching kinetic

ABSTRACT

The research has focused on the dealkalization of red mud after active roasting and water leaching, which is obtained from bauxite during alumina production. The main factors such as roasting temperature, roasting time, water leaching stage, leaching temperature, leaching reaction time and liquid to solid ratio were investigated. The mechanism of dealkalization was in-depth studied by using ICP–AES, XRD, TG-DSC, SEM–EDS and leaching kinetic. The results show that the dealkalization rate reached 82% under the condition of roasting temperature of 700 °C, roasting time of 30 min, four stage water leaching, liquid to solid ratio of 7 mL/g, leaching temperature of 90 °C and reaction time of 60 min. The diffraction peak of $Na_6CaAl_6Si_6(CO_3)O_{24}{\cdot}2H_2O$ in red mud was decreased during the active roasting process, whereas the mineral phases of $NaOH{\cdot}H_2O$ and $Na_2Ca(CO_3)_2$ were appeared. The content of alkali obviously decreased and the grade of other elements increased during the process of active roasting and water leaching, which was in favor of next application process of red mud. The water leaching was controlled by internal diffusion of SCM and the apparent activation energy was 22.63 kJ/mol.

1. Introduction

Red mud is a kind of alkaline solid waste generated from alumina production of bauxite [1–3]. The production of 1 tonne of alumina generates between 1 and 1.5 tonnes of red mud. With the increasing demand for alumina worldwide, the generation of red mud is estimated to be 4 billion tons by 2015 based on its current rate of production [4–6]. The damming disposal of red mud easily causes environmental problems [7–10]. Red mud can be applied in building materials, fillers and valuable metals recovery [11–17]. However, the strong alkalinity of red mud leads to the difficulty as the raw material of construction materials, where the high alkalinity can move to the surface of building materials leading to scumming and weak intensity. Furthermore, it also results in high acid consumption and cost during valuable metals recovery. So the procedure of dealkalization of red mud is the necessary premise of next comprehensive utilization.

Recently, the methods of dealkalization from red mud mainly include water leaching, acid leaching, replacement of calcium oxide and pressure leaching of carbon dioxide [18–22]. The process of direct water leaching could effectively remove free alkali, but not chemically bonded alkali of red mud. The dealkalization rate was less than 50% under the condition of liquid to solid ratio of 5 mL/g, leaching time of 5 day and five stage water leaching. The process of acid leaching could remove more than 75% of alkali, but it may also dissolve calcium and aluminum. The process changed the physicochemical property of red mud, so it led to more difficulty of application in building materials. The process of replacement of calcium oxide had the problems of high reagent consumption and low dealkalization rate. The dealkalization rate was less than 75% under the condition of liquid to solid ratio of 4 mL/g, CaO additive amount of 10%, leaching temperature of 70 °C and four leaching stage. The process of pressure leaching of carbon dioxide was difficult to operate due to high pressure. The dealkalization rate was more than 50%

* Corresponding author at: School of Materials Science and Engineering, Henan Polytechnic University, Jiaozuo, Henan 454000, China. Tel.: +86 391 3986937.
E-mail address: zhuxiaobo0119@126.com (X. Zhu).

http://dx.doi.org/10.1016/j.jhazmat.2014.12.048
0304-3894/

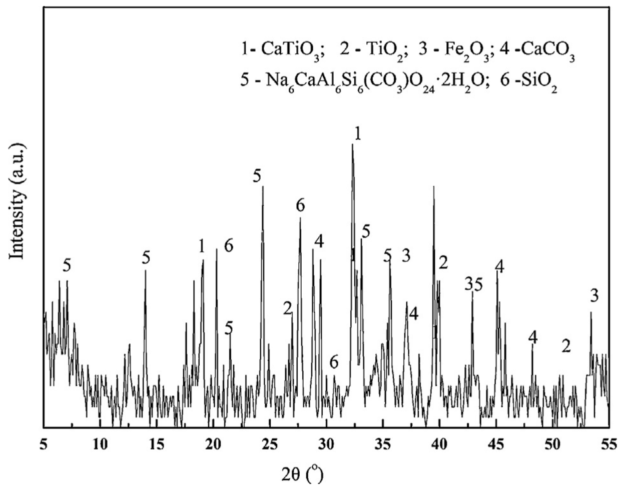

Fig. 1. The XRD pattern of the red mud sample.

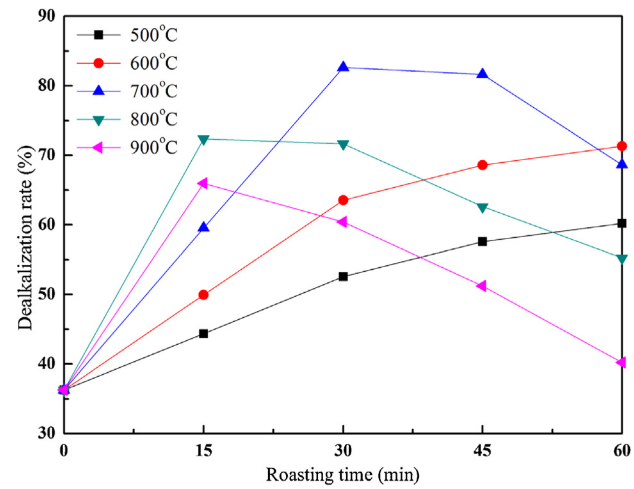

Fig. 2. Effect of roasting temperature and time on dealkalization rate.

under the condition of CO_2 airflow of 0.3 L/min, leaching temperature of 50 °C, liquid to solid ratio of 7 mL/g and reaction time of 2 h.

The present research work is to investigate the active method of dealkalization with roasting and water leaching in order to obtain efficient dealkalization of red mud. Based on the above dealkalization method, the main influence factors and action mechanism are in-depth studied.

2. Experimental

2.1. Materials

The sample of red mud was collected from Henan province, China. The sample was analyzed by using ICP–AES (inductively coupled plasma – atomic emission spectrometry), and the result is given in Table 1.

It is shown from Table 1 that the main alkaliferous composition was sodium, but not potassium. Furthermore, it also contained many other metals such as aluminum, ferrum, calcium, titanium and vanadium, etc. The XRD pattern of the red mud sample is depicted in Fig. 1.

It is indicated that the main minerals in the red mud were of perovskite, brookite, hematite, calcite, cancrinite and quartz. Above all, it is found that alkali existed in cancrinite, where the alkali was difficultly removable with water leaching.

The analytical purity chemical reagent including hydrochloric acid from Dengke Chemical Reagent Technology Co., Ltd. was used. The water used in this study was distilled water.

2.2. Methods

The red mud sample was roasted with using SXZ-10-B muffle furnace (China) at different temperature for a time, which was taken out of the muffle furnace and then cooled further to room temperature outside the muffle furnace. Then 20 g dried sample was added some distilled water and the ore slurry was stirred at the speed of 250 rpm under different condition of leaching stage, leaching temperature, liquid to solid ratio and reaction time by using a KX79-1 magnetic heating mixer (China). The water leaching solution was collected through filtration with a SHB-IIIA vacuum suction filter (China). And then the content of alkali in leaching solution and leaching residue was determined by ICP–AES. Firstly, the solid sample was grinded to −0.047 mm, and then 0.1–0.5 g grinded sample was placed to polytetrafluoroethylene beaker. Secondly, some hydrofluoric acid, hydrochloric acid and nitric acid were added into the beaker to decompose the sample. Finally, the elements in the solution were analyzed by ICP–AES.

Table 1
The main chemical composition of red mud.

Content (%)	4.24	0.19	14.61	1.23	7.44	11.82	8.83	3.98
Element	Na	K	Ca	Mg	Fe	Al	Si	Ti

3. Results and discussions

3.1. Effect of roasting temperature and time

The effect of roasting temperature and time on dealkalization rate is illustrated in Fig. 2 under the condition of four stage leaching, liquid to solid ratio of 7 mL/g, leaching temperature of 90 °C and reaction time of 60 min.

It is indicated from Fig. 2 that the dealkalization rate of red mud without roasting was 36%. The dealkalization rate increased with increasing roasting time in 500 °C and 600 °C. The increase of dealkalization rate was obvious at low roasting time, whereas the decrease of dealkalization rate was appeared at high roasting time in 700 °C, 800 °C and 900 °C. The dealkalization rate of red mud could reach 82% in 700 °C at 30 min. Those were 71% and 65% in 800 °C and 900 °C, respectively at 15 min. Therefore, the suitable roasting conditions were roasting temperature of 700 °C and roasting time of 30 min.

3.2. Effect of water leaching stage

The effect of water leaching stage on dealkalization rate is shown in Fig. 3 under the condition of roasting temperature of 700 °C, roasting time of 30 min, liquid to solid ratio of 7 mL/g, leaching temperature of 90 °C and reaction time of 60 min.

It is seen from Fig. 3 that the effect of water leaching stage on dealkalization rate was obvious. The dealkalization rate could reach 36% at the first stage, and then it was 24%, 15% and 7% respectively at the second, third and fourth stage. The total dealkalization rate was 82% with four stage leaching.

3.3. Effect of leaching temperature

The effect of leaching temperature and reaction time on dealkalization rate is indicated in Fig. 4 under the condition of roasting temperature of 700 °C, roasting time of 30 min and liquid to solid ratio of 7 mL/g.