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Effect of acid concentration on the aluminum leaching process

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Abstract. This paper explains a study on microwave-assisted leaching of aluminum from peat clay. Microwave-assisted leaching was undertaken using the Iwaki Pyrex glass reactor in a modified microwave oven. A research was made of the effect of acid concentration, microwave power, temperature, and reaction time on the aluminum leaching recovery. The dominant presence of aluminous minerals determined leaching of aluminum values in hydrochloric acid medium at different concentration and microwave power. The optimum leaching ratio for 4 M hydrochloric acid concentration, 40 °C temperature, and 15 min reaction time was obtained 67% dan 46,6% for 100 W dan 80 W respectively. The microwave assisted leaching is more efficient about overall aluminum dissolution.

1. Introduction

Peat clay is land scattered in many parts of the world. The main chemical compositions of peat clay are iron, silica and aluminum. It is potentially applied as a material for coagulation, adsorption, and other catalytic applications. Aluminum is the third largest element found in the mineral, rock, therefore it is a clay group abundant metal. A peat clay also contains aluminum salts. The major elements of it are silica oxide (SiO_2), iron oxide (Fe_2O_3), and aluminum oxide (Al_2O_3) are. Based on Mirwan et al. [1], the peat clay obtained from Gambut District, South Kalimantan contains SiO_2 , Fe_2O_3 and Al_2O_3 38.8%, 27%, and 11% respectively.

Aluminum is recovered from any land based resource by hydrometallurgical process, consisting of leaching, solid-liquid separation, purification and precipitation [1-3]. Leaching is a critical unit operation in the process and it has reaction temperature as important controlling parameter [4]. The main methods pursued in this strive include chemical conditions manipulation [5] or/and microwaves application which is having the selective leaching of minerals [6].

Microwave energy is a non-ionizing electromagnetic radiation, with frequencies in the range of 300 MHz to 300 GHz, lower energy and higher wavelength than ultraviolet, visible and infrared radiation [7]. Last two decades, microwave technology has been applied to several of mineral processing and considered its potential such as principles and application of microwaves in different ore processing unit operations like size reduction, roasting, flotation, leaching etc. [6, 8]. The leaching operation of microwave has advantage over conventional heating method. Microwave heating is rapid and selective in nature, high efficiency, flexible and distributes uniformly in the cavity of particle [4]. This technology has been applied to microwave leaching of copper [9] and nickel ores [10, 11], and the desulfurization of coal [12].

In this study, the aim was to investigate the effects of microwave-assisted leaching parameters such as acid concentration and microwave power as a function of reaction time by which high aluminum leaching ratio is obtained.

2. Materials and Method

2.1. Materials

The peat clay sample in this research was obtained from Peat Village, Subdistrict of Peat, District of Banjar, South Kalimantan, Indonesia and in the depths about 3.0 meters from the surface of the earth. After drying under direct sunlight 48 h and milling, peat clay particles were separated by sieving size of +200-325 mesh standard sieve based on the American Society for Testing and Materials (ASTM) and calcined at 700 °C for 2 h for thermal treatment. Hydrochloric acid was obtained from Sigma-Aldrich (37%) and required acid concentrations were diluted with deionized water.

2.2. Microwave-assisted leaching method

The series of equipment used for the microwave-assisted leaching process are shown in Figure 1. A domestic microwave oven was modified and produced power of 900 W at a frequency of 2.45 GHz. A three-neck 500-mL Iwaki Pyrex glass reactor was placed into the microwave oven.

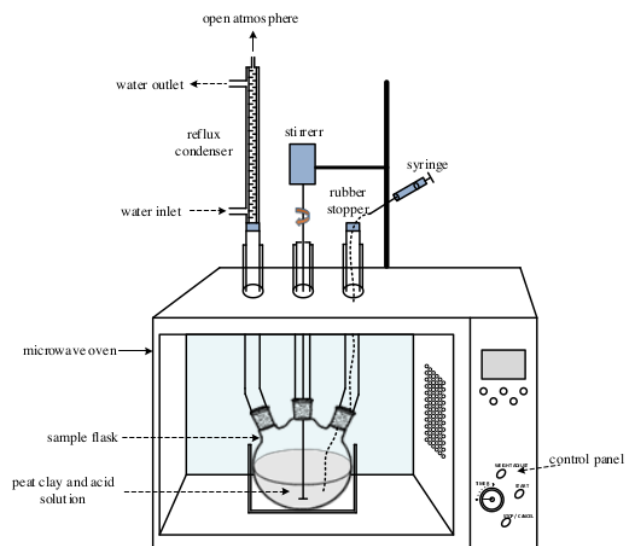


Figure 1. The microwave-assisted leaching experiment equipment

As much as 5 g of calcined peat clay was added to 250 ml agitated hydrochloric acid solution (solid/liquid ratio is 0.02). The effect of acid concentration (1, 2, 4, and 6 M) and microwave power (80 and 100 W) on aluminum leaching was studied and performed at 60 min. At selected time interval, all samples were collected using a syringe and filtered for analysis determine aluminum content in solution using inductively coupled plasmacluster optical emission spectrometer (ICP-OES) (9060-D Teledyne Leeman Labs. USA). The aluminum leaching ratio (x) can be calculated as:

$$x = \frac{X}{X_0} \quad (1)$$

where X_0 indicates total aluminum obtained through acid leaching process and X is the amount of aluminum obtained through microwave-assisted leaching at different conditions (mg/g).

3. Results and Discussion

3.1. Effect of acid concentration

Effect of hydrochloric acid concentration on the leachability of aluminum was studied in the concentration range of 1.0–4.0 M at 40 °C using input MW power of 100 W. The other process conditions kept constant are: particle size: -200/+325 mesh, stirring of the reactor contents 300 rpm, solid to liquid ratio 0.02 g/mL, and reaction time 60 min. Figure 2 provides experimental results. The maximum leaching ratio, around 0.67 was seen using a concentration of hydrochloric acid around 4 M in the microwave assisted process compared to 0.35 and 0.47 achieved under conditions of 1 and 2 M hydrochloric acid respectively. Further increase in acidity indicated an increase in the value of dissolved aluminum. The significant increase with various acid concentrations in the heating microwave-treated solution was also caused by the differential breakage of peat clay particles under the microwave effect.

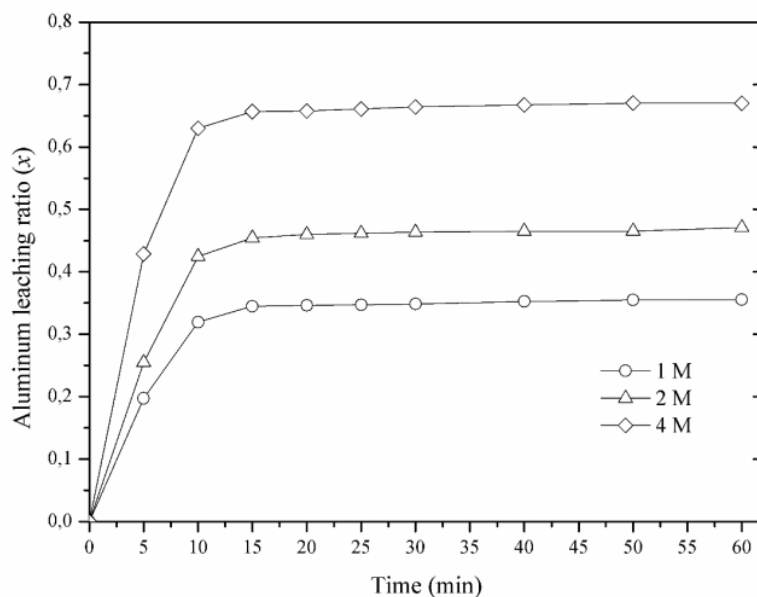
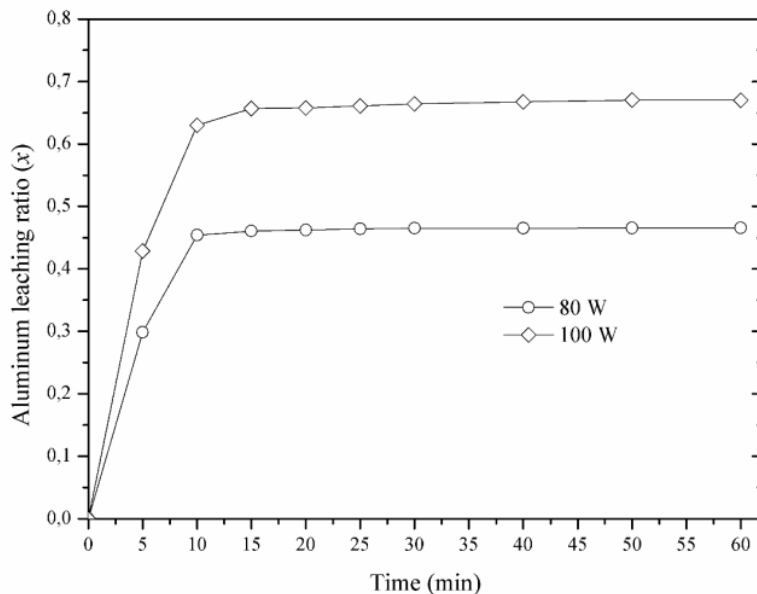


Figure 2. Effect of microwave heating on aluminum leaching as a function of reaction time

3.2. Effect of microwave power

The effect of microwave power is shown in Figure 3. The aluminum leaching ratio increased with increase in microwave power in the range of 80–100 W. The kinetic energy of peat clay molecules is converted to heat energy as a consequence of molecular interactions and as a result the temperature increases. Because aluminum ions dissolve at high temperatures, leaching ratio increases with increasing microwave power. Microwave power is a factor highly affecting the rate of microwave heating [4]. According to Xia and Pickles [13], higher microwave power has an incredible effect on increasing metal dissolution.



3 Figure 3. Effect of microwave power on aluminum leaching as a function of reaction time

1 Conclusions

A study on microwave-assisted leaching of aluminum from peat clay has been conducted. The results suggest that dominant presence of aluminous minerals determined leaching of aluminum values in hydrochloric acid medium at different concentration and microwave power. The optimum leaching ratio for 4 M hydrochloric acid concentration, 40 °C temperature, and 15 min reaction time was obtained 67% and 46.6% for 100 W and 80 W, respectively. The microwave assisted leaching is more efficient about overall aluminum dissolution.

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PAGE 2

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PAGE 4

PAGE 5

PAGE 6