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Research Article

The Synthesis of Zeolite from Biomass Ash for Hydrogen Sulfide and Volatile Organic Compounds Remova

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ABSTRACT

This research aims to study the optimum condition for zeolite synthesis from rice straw for removing hydrogen sulfide or volatile organic compounds (VOCs). The synthesis process is calcining the rice straw at 700°C for 3 hours; after that, digesting with an acid solution, drying and calcining at 700°C for 3 hours. The rice straw ash was fused with sodium hydroxide at 550°C for 1 hour and then stirred in 3 M of sodium hydroxide solution and aluminum hydroxide solution for 30 minutes. The zeolite was crystallized by hydrothermal process at various temperatures (80, 105 and 120°C) and reaction times (3, 4 and 5 hours). The zeolite synthesis product was investigated by X-ray diffraction (XRD), scanning electron microscope (SEM), and X-Ray fluorescence spectrometer (XRF) techniques. The results found that the chemical compositions of rice straw ash are silica and alumina. Moreover, the crystalline characteristics of synthetic zeolite from rice straw ash are cubic particle size of 1.4 micrometer. In conclusion, the rice straw ash can be synthesized to 4A zeolite, which has an adsorption efficiency of hydrogen sulfide and volatile organic compounds in asphalt of 75.00% and 94.09%, respectively.

Keywords: Rice straw ash, Zeolite, Adsorption, Asphalt, Volatile organic compounds.

INTRODUCTION

Rice straw is a waste product generated after the harvesting of rice crops and is commonly disposed of by burning it off in open fields. The open burning of rice straw has harmful environmental impacts causes emissions of detrimental gases and particulate matter which significantly increase air pollution and greenhouse gas and carbon footprints. Moreover, other gaseous pollutants such as carbon dioxide, sulphur dioxide, volatile organic compounds, and carcinogenic polycyclic aromatic hydrocarbons (PAH), are also produced. In addition, burning rice straw is also an essential source for aerosol particles (coarse dust particles and fine particles), which affect the air quality and reduce visibility11. Rice straw burning also poses a threat to the ecosystem since it depletes soil silicon and potassium stocks by losing significant amounts of important nutrients, including nitrogen (5.5 kg), phosphorous (25 kg), and sulphur (1.2 kg) [1]. Rice straw especially presents an opportunity for valorization, in the absence of feasible management methods for these agricultural residues. If feasible collection, storage, and processing methods for rice straw and stubble can be established, farmers can tap into this as a potential source of revenue in order to bring about a sustainable behavioral change away from burning. The chemical composition of rice straw ash mainly consists of silica (SiO_2) and alumina (Al_2O_3) and other mineral compounds which can convert to silicon-base material by hydrothermal treatment for alternative adsorbent such as zeolite. The synthesize zeolite from rice straw ash by the hydrothermal treatment in aqueous solution at elevated pressure and temperature. Several articles have proposed various methods for the hydrothermal activation of biomass ash in zeolite synthesis, using for this variation of several parameters involved in this synthesis [2]. Zeolites are aluminosilicates crystalline consisting of a framework of SiO4 and AlO_4 which exhibit features as high selectivity, high ion exchange capacity and high stability which the properties of sorption and catalysis, provided their technological application in various sectors. Zeolites have been proved to be adsorbents for hydrogen sulfide (H_2S) removal [3]. Organic chemicals known as volatile organic compounds (VOCs)

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are organic chemical compounds found in various products that easily vaporize and reach in the environment under normal conditions. VOCs have increased volatility, mobility and they are resistant to degradation, being able to be transported to long distances in the environment [4]. VOCs have a variety of direct and indirect impacts on people and the environment, and the main problems refer to: harmful effects on people health and on environment through toxicity; carcinogenicity and other adverse effects; the damage to materials; the tropospheric photochemical oxidant formation; stratospheric ozone depletion; global climate change; odor released. The aim of this study is to utilize agricultural waste for zeolite adsorption synthesis by using rice straw ash as raw material for hydrogen sulfide and volatile organic compound removal.

MATERIALS AND METHODS

Preparation for Zeolite

The rice straw was collected from Saraburi Province, the chemical composition of rice straw ash was analyzed by X-Ray fluorescence (XRF). For synthesis of zeolite A, the rice straw ash was pretreatment by mechanical, acid wet digestion, thermal and fusion prior hydrothermal treatment, activated by 3 M NaOH and Al_2O_3 under hydrothermal treatment at 105 °C for 5 hours. The synthesized zeolite products were characterized by using advanced instruments technique such as X-Ray diffraction (XRD) and scanning Electron Microscope (SEM).

Zeolite Characterization

The synthesized zeolite products were characterized by XRF, XRD and SEM-EDX analysis. The X-Ray Diffraction patterns (XRD) of zeolite synthesis from bottom ash and zeolite standard were recorded in 2θ ranging between 5° and 60° with scanning rate of 2°/min and CuKα radiation (Lab X (XRD 6000), SHIMADZU).

The morphology and elemental compositions of the zeolite products were investigated by a scanning Electron Microscope (SEM) JSM-5410 LV. (JEOL, Japan). The samples were sputtered with a thin film of gold to minimize the charging effects. Energy dispersive X-ray spectroscopy (EDXS) was performed in Oxford ISIS 300 model. An X-ray Fluorescence, XRF (Bruker AXS S8 Tiger model) was used to measure the chemical composition of the raw material. The cation exchange capacity was analyzed for the adsorption capacity. The cation exchange capacity (CEC) of zeolite products was calculated according to equation (1)

$$CEC = \frac{(V_1 - V_2) * N * 100.09 * V * 100}{m * (100 - L)}$$

When

V1 is volume of EDTA, blank (ml)

V2 is volume of EDTA, sample (ml)

N is concentration of EDTA (Normal)

V is volume of sample solution (ml)

m is mass of sample (g)

L is loss on ignition (LOI) of sample (%)

Adsorption Experiments

The adsorption tests were carried out by using a self-assembled fixed-bed reactor (stainless tube with the inner diameter of 13.05 mm and height of 216 mm.). 0.6 and 0.1 grams of the adsorbent were mixed with asphalt in reactor. Heat up of mixed asphalts at melting point, the gas emission especially H_2S and VOCs from melting asphalt process was measured by MRU OPTIMA 7 Biogas Analyzer, Germany.

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RESULTS AND DISCUSSION

Synthesis of Zeolite from Rice Straw Ash

The rice straw ash contains the highest amounts of SiO_2 and Al_2O_3 (74.90% and 1.41%, respectively). The SiO_2/Al_2O_3 molar ratios of rice straw ash is 89.28. It indicated that rice straw ash can used as raw material to synthesis zeolite. Moreover, the rice straw ash is also rich in K_2O and CaO. Figure 1 shows XRD patterns of the zeolite A products from rice straw ash compared with the commercial zeolite A as the standard. It indicated the most crystalline phases of synthesized zeolite A from rice straw ash is Sodium Aluminum Silicate Hydrate, (ICDD No. 00-038-0241).

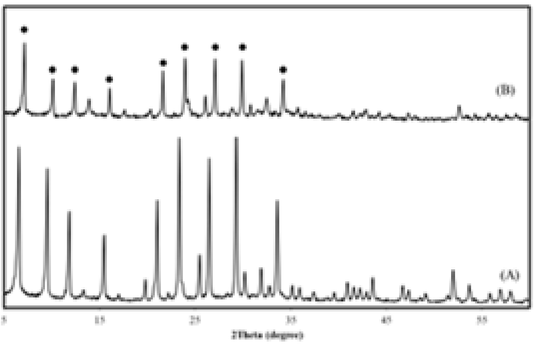

Figure 1 X-Ray Diffraction (XRD) patterns of Zeolite Standard (A), Synthesized zeolite from rice straw ash at 5 hours (B) (• Peak position of Zeolite)

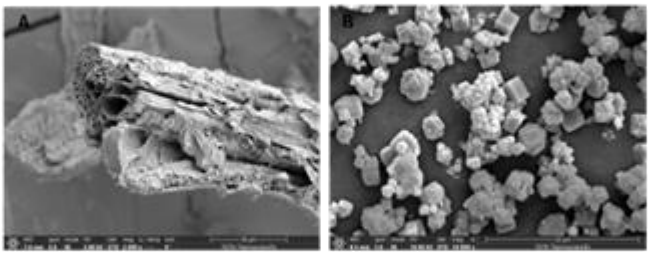

Figure 2 Scanning electron microscope (SEM) of raw rice straw ash (A) and Synthesized zeolite from rice straw ash (B)

The Morphology images of synthesized zeolite product from rice straw ash by fusion with NaOH in the weight ratio of 1:3 at 550 °C for 1 hours and activated with 3M NaOH for 5 hours is shown in Figure 2. It was found that the particles of zeolite products have a clear cubic morphology.

Hydrogen Sulfide and Volatile organic compound Adsorption Capacity

The hydrogen sulfide and volatile organic compound adsorption capacity at equilibrium time of rice straw ash zeolite and standard zeolite 4A is shown in Table1. In this study, the synthetic zeolite from rice straw ash were use as an adsorbent for hydrogen sulfide and volatile organic compound removal in asphalt melting process at different dosage of adsorbent of 0.1 and 0.6 gram.

Table1. Hydrogen Sulfide and Volatile organic compound Adsorption Capacity

Absorbent	Dosage (gram)	% removal	
		H_2S	VOCs
Rice straw ash zeolite	0.1	92.0	92.47
	0.6	98.20	94.09
Zeolite 4A	0.1	89.0	87.60
	0.6	95.0	92.94

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In figure 3-4 show the result the efficiency of 0.1gram rice straw ash zeolite which can remove H_2S and VOCs of 92.0% and 92.47%. In addition, 0.6 gram of rice straw ash zeolite can remove H_2S and VOCs of 98.20% and 94.09% while 0.1 and 0.6 gram of zeolite 4A show the percentage of H_2S and VOCs removal of 89.0%, 87.60%, 95.0% and 92.94%, respectively.

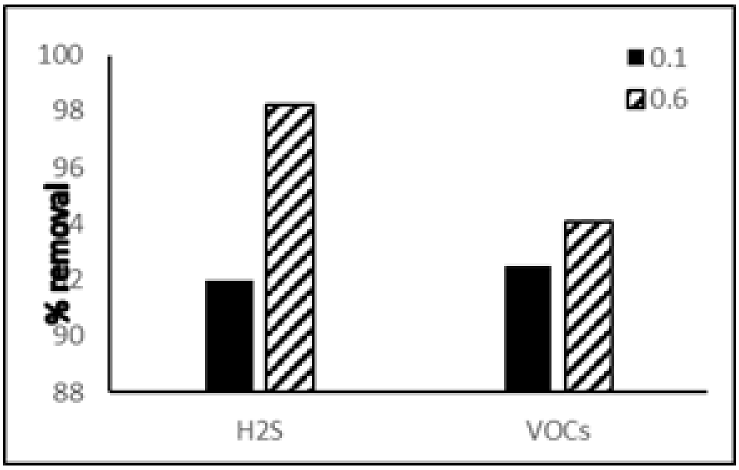

Figure 3. The adsorption capacity at equilibrium time of rice straw ash zeolite with difference dosage at 0.1 gram and 0.6 gram

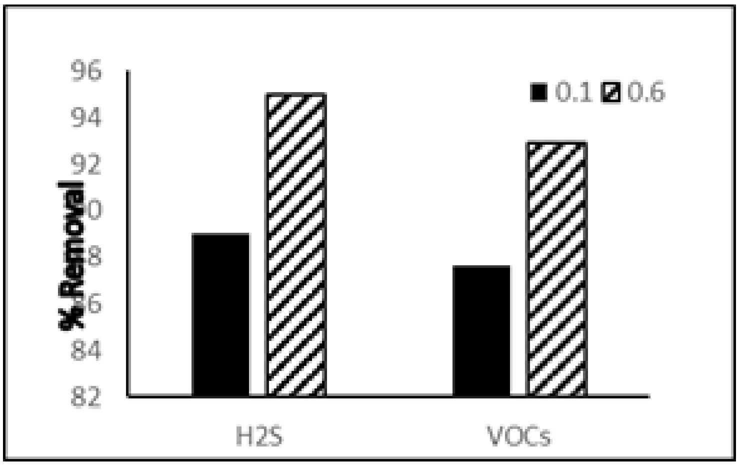

Figure 4. The adsorption capacity at equilibrium time of zeolite 4A with difference dosage at 0.1 gram and 0.6 gram

CONCLUSION

The synthetic zeolite products from rice straw ash were synthesized by a fusion and hydrothermal process with 3 M NaOH at 105°C for 5 hours. Which can be applied to absorbent for the purpose of removing hydrogen sulfide (H_2S) and volatile organic compounds in the asphalt melting process. The results of H_2S removal efficiency indicated that the synthetic zeolite products from rice straw ash exhibited the higher adsorption capacity than zeolite 4A. The optimum condition for odor removal from asphalt melting process is 6%w/w of an adsorbent and asphalt. Moreover, the synthetic zeolite products from rice straw ash can remove other gas emission such as NOx SOx and CO including reducing PM2.5 and PM10.

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