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ScienceDirect

Procedia Engineering 148 (2016) 106 – 113

Procedia Engineering

www.elsevier.com/locate/procedia

4th International Conference on Process Engineering and Advanced Materials

Preparation and characterization of impregnated activated carbon from palm kernel shell and coconut shell for CO_2 capture

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Abstract

Activated carbon was produced from palm kernel shell (PKS) and coconut shell (CS) through physical steam activation and chemical activation. The optimum activation temperature for physical activation is 800°C and for chemical activation is 550°C. The activated carbons produced also loaded with different metal oxides (BaO, MgO, CuO, TiO_2 and CeO_2). Both loaded and unloaded activated carbons are characterized using ultimate analysis, BET surface area measurement method, fourier transform infrared (FT-IR) analysis and x-ray diffraction (XRD) analysis. The BET surface area and pore volumes showed that the activated carbons prepared from PKS by chemical activation (PCAC) and from CS by physical activation (CPAC) were found to be much higher than others activated carbons. Hence, the metal oxides were loaded on these two activated carbons. The loaded and unloaded activated carbons produced will be tested for application of CO_2 adsorption from the simulated flue gas.

Peer-review under responsibility of the organizing committee of ICPEAM 2016

Keywords: Palm kernel shell; Coconut shell; Activated carbon; Physical activation; Chemical activation; Impregnation, Physical-chemical properties

1. Introduction

Activated carbon has been known as the most effective and useful adsorbents for the removal of pollutants from polluted gas and liquid streams. This is due to the properties of activated carbons which have a large active surface area which can provide high adsorption capacity, well developed porous structures and good mechanical properties [1, 2]. In addition, activated carbon is most widely used since most of its chemical (e.g. surface groups) and physical properties (e.g. surface area and pore size distribution) can be designed and adjusted according to the required application [3]. Besides, the adsorption on activated carbon appears to be most common techniques because of its simplicity of operation since the sorbents material can be made highly efficient, easy to handle and in some cases they can be regenerated [4].

The most common precursors used for the preparation of activated carbons are organic materials that is rich in carbon. Therefore, the development of methods to reuse waste materials as activated carbons is greatly desired and offers a promising future. Agricultural wastes, such as jatropha, corn cob, coconut shell, oil palm fiber, wood sawdust and date stone are of interest to be converted into activated carbons because of their hardness and high strength in which these desired properties are due to its high lignin, high carbon content and low ash content of the materials [2, 5]. Therefore, in this study, palm kernel shell and coconut shell were chosen as a precursor for the production of activated carbon since both of them are abundantly available in Malaysia and has very low market value.

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Peer-review under responsibility of the organizing committee of ICPEAM 2016
doi:10.1016/j.proeng.2016.06.463

The most frequent method used for the preparation of activated carbon is the carbonization of the precursors at high temperature in an inert atmosphere followed by the activation process. The activation process is subdivided into physical and chemical. Physical activation process comprises treatment of char obtained from carbonization with oxidizing gases, generally steam or carbon dioxide at high temperature (400-1000^{o}C) [6]. In the chemical activation process, the starting material is mixed with an activation reagent and the mixture is heated in an inert atmosphere [7, 8]. This process is usually done at lower temperature and activation time, higher producing surface area and better porosity as compared to physical activation.

The goal of this study is to prepare activated carbon from palm kernel shell and coconut shell by physical steam activation and chemical activation with zinc chloride ($ZnCl_2$) to adsorb CO_2 from its source such as flue gas. To further improve the adsorption efficiency of the activated carbon, this paper also aims to impregnate the best activated carbon with different metal oxides. The selection of metal oxides will be based on the gas to be adsorbed. In this study, the metal oxides that were selected are barium oxide (BaO), magnesium oxide (MgO), copper oxide (CuO), titanium oxide (TiO_2) and cerium oxide (CeO_2). The properties of the pure and impregnated activated carbon were analyzed using ultimate analysis, Fourier Transform Infrared (FT-IR), nitrogen adsorption-desorption analysis, X-ray diffraction (XRD) analysis and thermogravimetric analysis.

2. Material and methods

2.1. Raw material

The palm kernel shell (PKS) and coconut shell (CS) were selected for activated carbon preparation. PKS was collected from a palm oil mill that is located in Dengkil, Selangor and CS was collected from the local community in Shah Alam. The materials were cleaned with distilled water several times to remove dust and impurities. The PKS and CS samples were later dried in the oven at 110^{o}C for 24h to remove any surface moisture and were then ground to a desired size. The proximate and ultimate analysis were carried out to evaluate the volatiles and fixed carbon contents as well as to quantify the elemental composition, respectively.

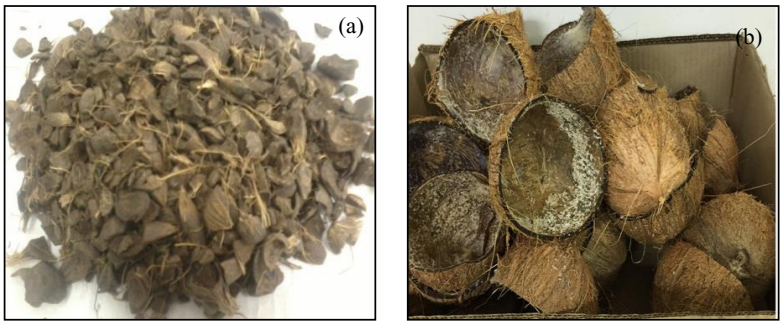

Fig. 1. (a) Palm kernel shell; (b) Coconut shell

2.2. Activated carbon preparation

2.2.1 Physical activation

The palm kernel shell (PKS) and coconut shell (CS) were loaded into a stainless steel reactor (Fig.2), which was heated up by an electrical tube furnace. In the initial stage, the reactor was heated up to 300^{o}C and was kept at this temperature for 30 minutes. The temperature was later ramped up to about 800^{o}C. At this rate, PKS and CS were completely pyrolyzed. Water was then injected at the flow rate of 120 mL/hr to the reactor to activate the samples. The reaction between steam and carbon was taken place and pore was generated [9]. After completing the activation process, the reactor was cool down, the samples was taken out and washed using distilled water.

2.2.2 Chemical activation

PKS and CS were mixed with $ZnCl_2$ solution with the ratio 1:1 (mass basis) and kept for about 24h at room temperature. The samples were then transferred into a stainless steel reactor as shown in Fig.2. Nitrogen gas flow of 200 mL/min was used for making inert environment inside the reactor and transporting out the volatile compounds. The reactor was heated to 550^{o}C and was kept at this temperature for about 1h. After the activation process was completed, the reactor was cool down and the samples were taken out and washed repeatedly for about 5 times with distilled water to remove access chemical from adsorbents. The list of adsorbent samples prepared in this study is shown in Table 1.