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Characterization of Activated Carbon from Oil Palm Shell Prepared by H_3PO_4 for Procion Red Dye Removal

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Abstract. Characterization of activated carbon from oil palm shell prepared by H_3PO_4 and application for the removal of procion red dye was investigated. Oil palm shell was carbonized at 500^0C and prepared by H_3PO_4 5 % with ratio of 1:3. Characterized activated carbon by Fourier Transform Infra Red Spectroscopy (FTIR), Brunauer Emmet Teller (BET) surface area, Scanning Electron Microscope-Energy Dispersive X Ray Spectrometry (SEM-EDS). The result indicated that functional groups on the activated carbon surface were influenced by acidic treatment. The activated carbon have surface area 385.991 m^2g^{-1} and volume of micro porous 0.201 cm^3g^{-1}. The SEM-EDS image showed that activated carbon have many porous structure and the strong peak of C was 92.7 %. Adsorption capacity of activated carbon prepared by H_3PO_4 5 % was 278.197 mg g^{-1} which is higher than not chemical activation was 216.456 mg g^{-1} at equilibrium time 5 h.

Introduction

Activated carbon has many applications in a variety of area as adsorbents because activated carbon has high surface area, pores structure and special reactivity [1]. Activated carbon can efficiently adsorb gases and compounds dispersed or dissolved in liquids [2-4]. Moreover, there are used as catalyst and catalyst supports. Activated carbon can beprepared from organic materials rich carbon content likes coal, coconut shell, lignite, wood etc. using the two basic activation methods: physical and chemical [5-8]. The physical activation involves carbonization of precursor followed by activation of the resulting char in presence of activating agents such CO_2 or steam. On the other hand, chemical activation involves the carbonization of precursor with presence of chemical agents. However, in chemical activation need a through washing during due to the use of chemical agents [9,10]. Combination of chemical and physical activation is another technique to prepare highly micro porous activated carbon.

Palm shell as by product of the palm oil industries is abundantly mainly in South Asia like Malaysia, Indonesia and Thailand [11]. In Indonesia, approximately 19 million tons of oil palm shell product annually from 7.8 million ha of oil palm plantations.The palm oil industries produce wastewater and solid waste. Solid waste as such palm shell. Currently, most of solid waste the palm oil industries used as boiler fuel and compost [12]. Palm shell contains high carbon like cellulose (29.7%), hallo cellulose (47.7%) and lignin (53.4%), so oil palm shell is potential to be raw material of activated carbon production [13]. Many studies have been done of the utilization palm shell as raw material of activated carbon using chemical activation likes $ZnCl_2$, HCl, KOH [11, 13, 14].

Every activated carbon have different characteristic like surface area, pore structure and pore size distribution depending raw materials and activation methods. Chemical activation has more advantages over physical activation with respect to higher yield, more surface area, better development of porous structure and oxygenated surface complex in carbon [10]. Chemical activation used by acidic reagent to introduced acidic functional group onto the surface of carbon was by far, availability of oxidizing agents and established nature of this technique which has been used for past several decades [15].

In the present research, H_3PO_4 treatment was applied on an activated carbon prepared oil palm shell. H_3PO_4 is often used as chemical activation, for example activated carbon prepared from Euphorbia anti quorum L and lignin [10,16]. The product was characterized by Fourier Transform Infra Red (FTIR), Brunauer Emmet Teller (BET) surface area, Scanning Electron Microscope - Energy Dispersive X Ray Spectrometry (SEM-EDS). In this work, also application of activated carbon for procion red dye removal.

Many dyes are toxic to some organism and may cause direct destruction of aquatic communities. Removal of dyes from such wastewater is a major environmental problem and it is necessary because dyes are visible even at low concentrations [17]. The procion dye including azo dyes which have -N=N- bond. Additionally, procion dyes have two of aromatic groups and one atom of sodium. These dyes are used in the textile industrial for dyeing process. The adsorption performance of modified activated carbon on procion red dye was then compared with untreated activated carbon.

Experimental Procedure

Preparation of activated carbon. The oil palm shell was washed and dried. The drying oil palm shell was carbonized at 500^0C and flowed with nitrogen for 60 minutes. The carbonized product was milled to 200 mesh and heated with H_3PO_4 5 % (oil palm shell:H_3PO_4= 3:1) at 300^0C for 2 hours. Finally, the activated carbon product was ground, washed with water and dried at 110^0C to get activated carbon [18]. Quality of activated carbon was characterization by FTIR Shimadzu 5400, BET surface area NOVA 4000 quanta chrome and SEM –EDS JEOL-JSM-6510 LV.

Adsorption of Procion Dye. The dye adsorption data from water were performed by batch method with agitation provide by an orbital shaker at 120 rpm. Series of procion red dye solution with concentration 100 mgL^{-1} volume 100 mL prepared in 250 mL flask. The variety of activated carbon dosage is 0 to 0.5 mg L^{-1}.Concentration of procion red dye is observed 0 to 6 hours. Concentration of procion red dye was determinate using spectrophotometer UV-Vis Shimadzu 2550.

Result and Discussion

Characterization of activated carbon. The surface chemistry of the activated carbon after chemical activation underwent some changes. Many of peaks at 461-860.6 cm^{-1} and 3035.7-3190.0 cm^{-1} at activated carbon without activation are loss. Activation process causes some organic compounds at the material to form water vapor, methanol and acetic acid and hydrocarbons. The compound will evaporate upon heating. FTIR spectra activated carbon shown in Fig 1. The result were comparison with the work done [19] which reported that more acidic groups such as carboxylic and ether were produced by acid (HCl) treatment.

Activated carbon prepared oil palm shell by H_3PO_4 activation could be proposed have functional groups of phenols, carboxylic acids, and carbonyl groups. All of which are typical acidic functional groups. Mechanism of chemical activation with H_3PO_4 in particular for the evolution porosity and the formation of surface functional groups can be suggested [5].

$$C_nH_xO_y + H_3PO_4 \rightarrow [C_nH_xO_y—HPO_3] + H_2O\uparrow \qquad (1)$$

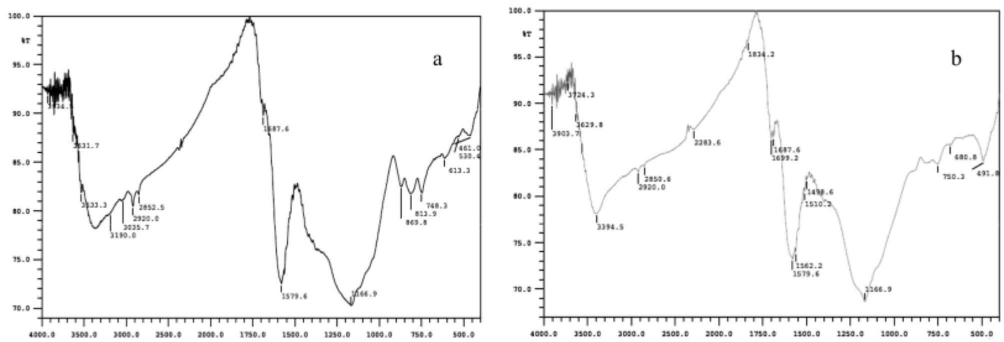

Fig 1. FTIR spectra activated carbon (a) without chemical activation and (b) by chemical activation with H_3PO_4 5 %

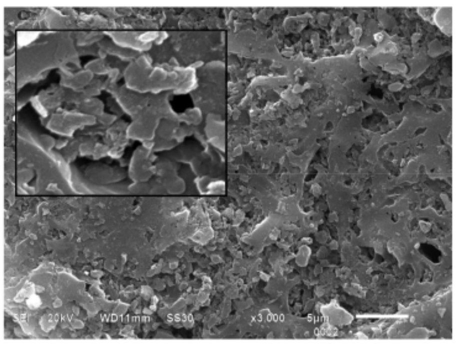

Fig 2. SEM image activated carbon

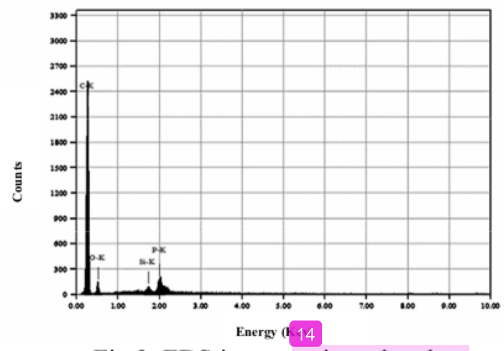

Fig 3. EDS image activated carbon

The morphology of activated carbon was investigated by SEM as Fig 2. It can be seen that activated carbon have many porous structure. Indicated that activated carbon could be used as a promising and effective adsorbent. The EDS spectra activated carbon as Fig. 3 showed the strong peak of C (92.76%), the peaks of Si (1.039 %) and P (1.01%). The main components are carbon showed that activated carbon had formed. The BET surface area analysis showed that activated carbon have surface area 385.991 m^2g^{-1} and volume of micro porous 0.201 cm^3g^{-1}. The commercial of activated carbon normally has a very porous structure with a large surface area ranging 300-3500 m^2/g [20]. Activated carbon produced according to standards of quality commercial activated carbon.

Capacity Adsorption. The removal percentage of procion red dye onto activated carbon as a function of time various amounts of the activated carbon are displayed in Fig 4. The effect of activated carbon dosage was studied on procion red dye removal from aqueous solutions by varying dosage from 0-0.5 mg L^{-1} at initial concentration of procion red dye 100 mg L^{-1}. It showed that an increase in adsorbent dosage could increase the color removal percentage from solution. With increasing activated carbon dosage more surface area was available for adsorption due to the increase in active sites on the surface of activated carbon and thus making easier penetration of adsorbate to adsorption sites [21]. The equilibrium time of activated carbon for all dosage at 5 h.

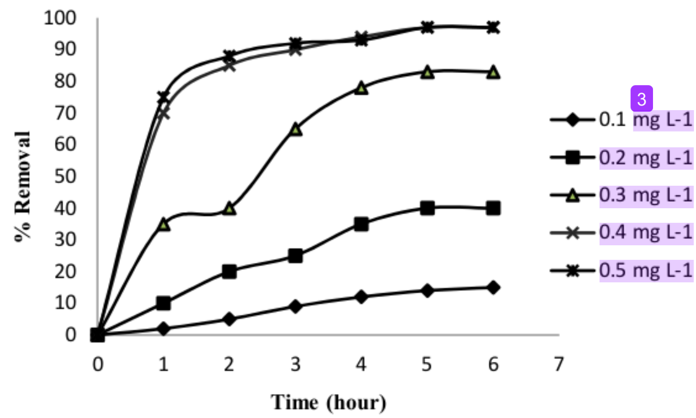

Fig 4. Removal percentage of procion red dye function of time using different amounts of activated carbon

The Adsorption capacity is calculated using relation:

$$q = (Ci - Cf)V/m \tag{1}$$

Where *Ci* and *Cf* is initial and final concentrations of procion red dye, respectively in mg L^{-1}, *m* is mass of the activated carbon in mg and V is volume of solution procion red dye. The value of q of activated carbon prepared chemical activation by H_3PO_4 5 % with dosage 0.4 mg $L^{-1}$was calculated as 278.197 mgg^{-1} but not chemical activation was 216.456 mg g^{-1}. So, chemical activation be able to increase adsorption capacity which was 28.52 % higher.

Conclusions

In summary, activated carbon from oil palm shell prepared by H_3PO_4can be product in a large surface 385.991 m^2g^{-1} and volume of micro porous 0.201 cm^3g^{-1}.The chemistry surface of the activated carbon consists of more acidic groups such as phenol, carboxylic and ether. The activated carbon can used to remove procion red dye with adsorption capacity 278.197 mg/g at the equilibrium time 5 h. The surface modification activated carbon from oil palm shell using H_3PO_4 5 % was shown to be able to increase adsorption capacity on procion red dye.

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