CHARACTERIZATION AND EVALUATION ON THE POTENTIAL OF ACTIVATED CARBON DERIVED FROM DURIAN SHELL FOR ADSORPTION OF TOXIC VAPOURS

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1.0 Introduction

Every day, large quantities of volatile organic compounds (VOCs) are emitted into the atmosphere from anthropogenic and natural sources. VOCs are organic chemical compounds that have high enough vapor pressures under normal conditions to significantly vaporize and enter the atmosphere. Toluene is a mono aromatic organic compound which categorized in the family of VOCs. The common name for toluene is methylbenzene which is widely used as an industrial feedstock and as a solvent. Single short term exposure of toluene can caused eyes and respiratory tract irritations while long-term exposure can lead to damages of neurological and reproductive system.

Activated carbons are widely used as high efficiency adsorbents in gas and liquid-phase separation processes, purification of products and water cleaning operations. One of the most significant usages of activated carbon is to adsorb VOCs. These materials are activated either by chemicals, steam, gas or their combinations. The highly adsorptive efficacy of activated carbon is mainly affected by its porous structure, the pore size and their distribution. In air treatment, activated carbons are recognized a as being effective for removing a large number of hazardous molecules and especially volatile organic compounds (VOC), odorous molecules or dioxins and furans present in industrial emissions. Recently, there is an increasing trend towards the utilization of agriculture byproducts or waste, as they represent a large and inexpensive source of raw material, which can be used as potential precursor materials in the manufacture of activated carbon, usually with comparable adsorptive capacity with that of commercial activated carbon (Kardirvelu *et al*., 2000). Activated carbon can be produced from a number of agricultural by products such as hardwoods, grain hulls, corn cobs, nut shells, olive kernel and others. According to Suzuki *et al.* (2007), activated carbon prepared from rice bran were more economically promising twofold; the agricultural waste would be utilized and production of activated carbons for treatment of pollutants would be achieved at a reasonable cost. The results from Guo and Lua (2000) showed that it is possible to prepare activated carbons with a high density and well developed porosity from oil palm fruit solid wastes. Their studies also showed that the adsorptive capacities of the activated carbons from oil palm fruit solid waste were comparable to those of commercial carbons. In this study, durian shell was chosen as substrate for preparing activated carbon. The objectives are as follow:

1. To determine the physical and chemical characteristics of the activated carbon prepared from durian shell.
2. To compare the performance of activated carbon prepared from durian shell and commercial activated carbon in treating toluene vapour in air.

2.0 Methodology

2.1 Research Material

The durian shells were acquired from the markets in Serdang, Selangor. The shells were washed and cut into 1-2cm particle size before being dried in oven overnight to reduce the moisture content. The activation agent of choice was *ortho*-phosphoric acid of 85% of purity manufactured by MERCK. Aqueous solutions with concentration of 5%, 10%, 20%, 30% and 50% (v/v), respectively, were prepared for the impregnation of the sample. Nitrogen gas with purity of 99.995% in compressed gas cylinder was used to provide inert gas atmosphere during carbonization stage.

2.2 Preparation of activated carbon

Chemical activation method using phosphoric acid was used to activate the raw material. 10g of raw material was weighed. The weighed raw sample was impregnated in 100ml of different concentration of acid phosphoric for 24hour. After impregnation, the wet samples were dried in oven for 12 hr (~85 °C) and subsequently activated in nitrogen atmosphere at 400°C, 500°C, 650°C, and 800°C respectively with heating rate of 5°C/min. The soaking duration at final temperature was set at 20 minutes. The activated samples were cooled in a stream of gaseous nitrogen to room temperature. Then, the samples were washed at ambient temperature with distilled water until the filtrate reached approximately pH6-7, which is the pH of distilled water. The samples were then dried at 85°C in an oven for overnight to make sure they were moisture-free. The yield of the activated carbon was calculated. Finally, the samples were kept in desiccators for further.

2.3 Characterization of activated carbon

2.3.1 Physical Properties

The morphology of the activated carbons was determined by scanning electron microscope (SEM) method. In this study, only the raw durian shell and activated carbon with the highest surface area (S_{BET}) were chosen for the comparison of the morphology structure. The samples were coated with gold (Ag) prior to the scanning in the electron microscope. The samples were then scanned using JOEL-JSM 6400 scanning microscope.

2.3.2 Chemical Properties

The pH of an activated carbon suspension provides information about the average acidity and basicity of the surface. The surface pH of the activated carbon was measured by pH meter (Orion Five star). About 0.2g of carbon was added into 50ml of distilled water at room temperature in a 250ml flask. The mixture was shaken for 24 h to reach equilibrium and the pH was measured after the filtration with a membrane filter (0.45 µm in diameter).

Boehm titration is one of the most widely used methods to quantify acidic groups on the activated carbons (Boehm, 1994). It was used initially for the differentiation of oxygen-containing groups. The acid value on the surface of the carbon was determined by Boehm Titration method. About 0.2 g of activated carbon was added in 50ml of 0.1 N NaOH solutions and then shaken for 24 h. The mixture was given time to settle down before 10ml of the mixture was withdrawn and titrated with 0.1 N HCl standard solutions, using a few drops of 1% phenolphthalein solution as indicator. The numbers of acidic sites were calculated from the amount of NaOH that reacted with the carbon. The acidic sites were expressed in meq/g of activated carbon.

2.4 Toluene adsorption test

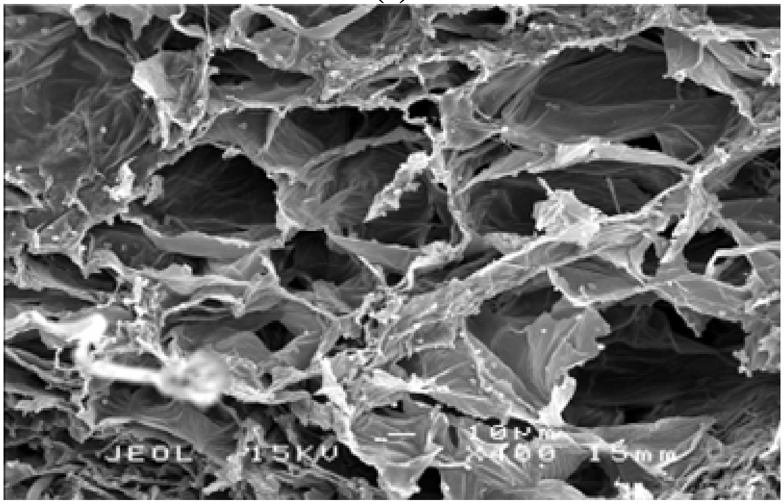
The activated carbons produced using treatments with different acid concentrations were chosen for the adsorption studies. Commercial activated carbon (HACH) was used for comparison purposes. The samples were dried in oven at 120°C for 24 hours prior to the study. After drying, 0.5g of each activated carbon was enclosed in a degassed 5L gas-sampling bag (Tedlar-SKC). Five litter of nitrogen gas was filled into the sampling bag. Subsequently, 10µL of pure toluene solvent (Fisher Chemical) were injected into the sampling bags respectively to simulate a service conditions in air purification processes for industrial occupations. The contact time started on injection of the toluene solvent. Portable handheld VOC detector (ppbRAE 3000) was used for direct measurement of the toluene concentration. The concentration of toluene was evaluated at 24-26°C and ambient pressure.

3.0 Results and Discussion

3.1 Physical Properties

The microstructure and morphology of the raw durian shell and activated carbon with 30% of acid concentration treatment are shown in Fig 1. For raw material, the surface exhibited many thin sheet or layers with large pores within the structure. Scanning electron micrograph of the activated carbons obtained from the durian shell treated with 30% of acid treatment followed by heat treatment showed a well-developed porous structure. There are mixtures of meso- and micro-pores in the structure. The activation process has resulted in the creation of pore and substantial removal of inorganic compounds in the raw material.

(a)



(b)

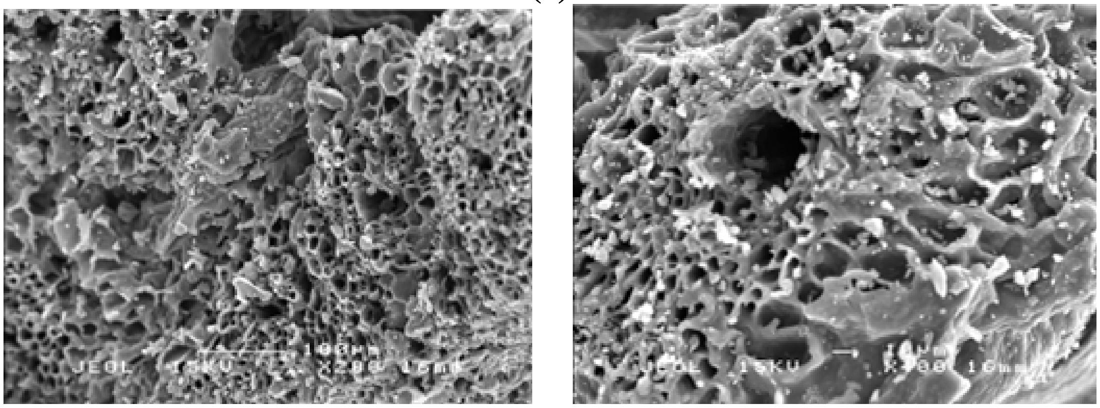


Fig. 1. (a) SEM images for raw material and (b) activated carbon prepared from 30% acid concentration at different magnification.

3.2 Chemical Properties

Table 1 shows the surface pH of the activated carbons prepared from different acid concentration. All the carbons produced are in acidic form although the pH is increasing as the acid concentration increased. This is may be due to the complicated composition of the raw durian shell which also in acidic form (surface pH of raw durian is 4.88).

The total acidic groups reached maximum at the acid concentration of 30% as shown in Fig. 2 It is clear that the number of acidic surface groups increases upon treatment with higher acid concentration. This is because H_3PO_4 is a strong acid which would oxidize the carbon atoms, causing the carbon surface to lose its electrons and become positively charges, subsequently, the oxygen anions exist in the acid solution would be adsorbed to form surface oxides (Wibowo et al., 2007).

Table 1. The mean surface pH values for the activated carbons prepared from different acid concentration, 500°C and 20 min heating duration. Distilled water without carbon is measured as control.

Acid concentration (%)	**5**	**10**	**20**	**30**	**50**	**Control**
Surface pH	2.87	2.98	3.29	3.60	5.11	6.92

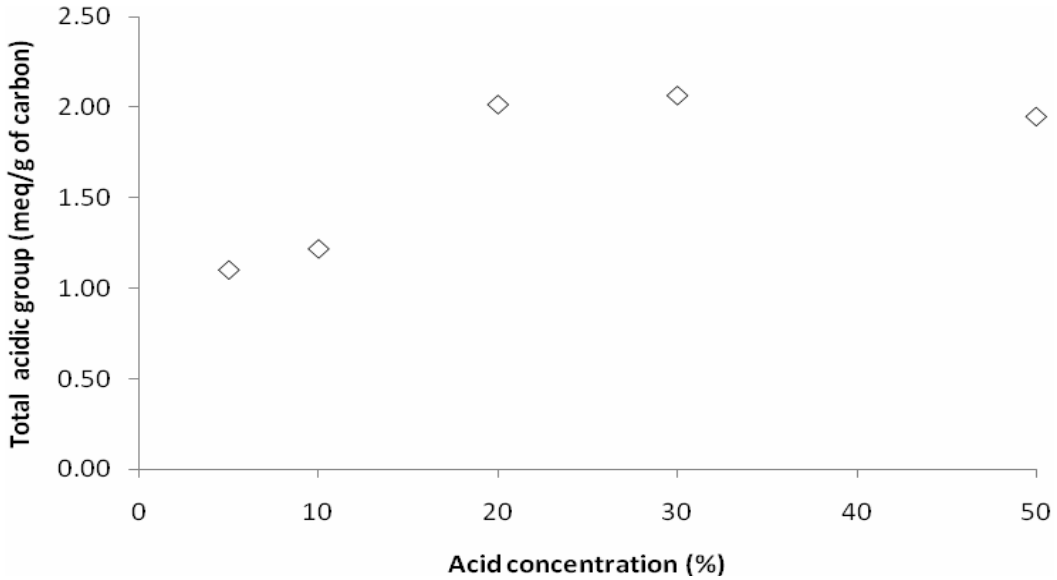


Fig. 2. Total surface acidic group on carbons prepared from durian shell at different acid concentration (phosphoric acid) at 500°C.

3.3 Adsorption studies

Fig 3 shows the removal percentage of toluene by different type of activated carbons prepared from varied acid concentrations and was compared to the removal percentage of the commercial activated carbon for sample weights of 0.5 g. The results showed that the acid concentration or impregnation ratio had a large influence on the removal of toluene vapour. As the acid concentration was increased, higher removal rate was achieved faster in the early stage of the adsorption. It can be observed that the best removal performance is by commercial activated carbon and activated carbon prepared from 30% of acid concentration is the most similar with the removal performance of the commercial activated carbon. It is mainly due to the high surface area and large pore volume.

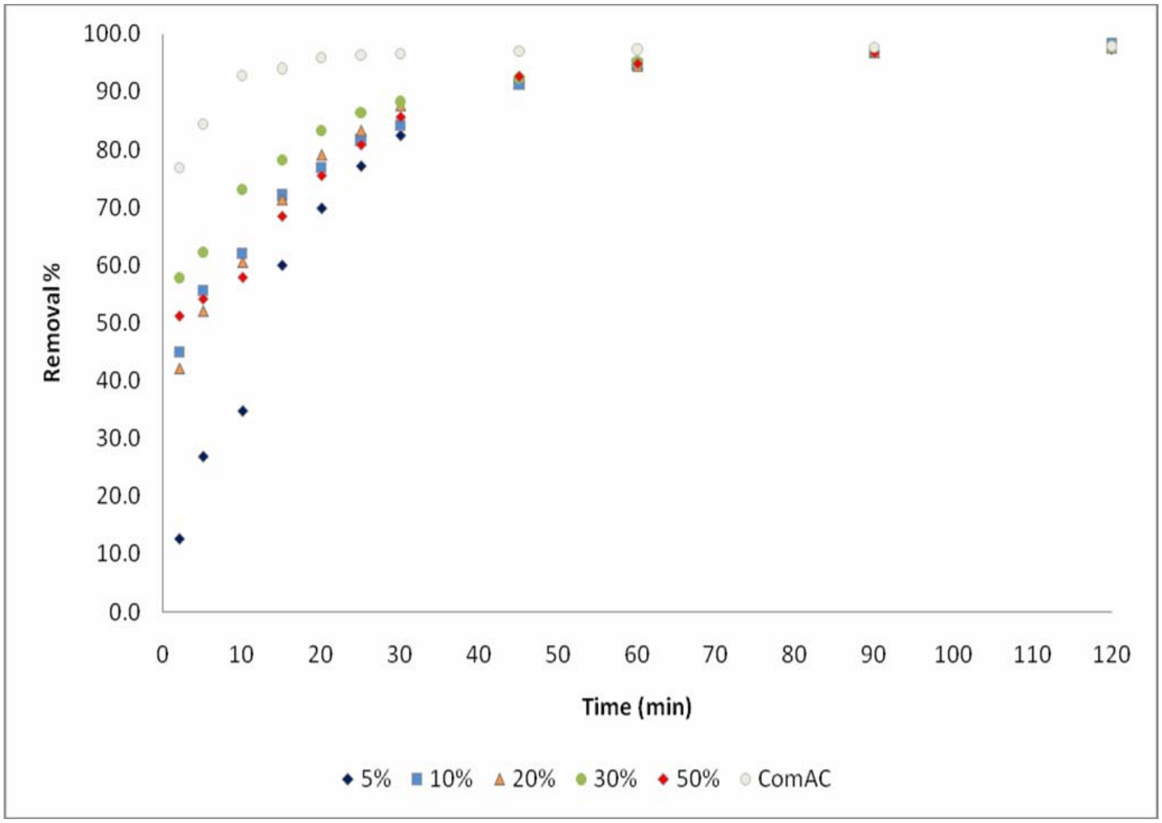


Fig. 3. The toluene removal percentage for activated carbons prepared from different conditions and comparison to the commercial activated carbon.

4.0 Significance of Finding

Concentration of acid has significant influence on the physical and chemical characteristics of the activated carbon prepared from durian shell. The activated carbons produced from different acid concentration also showed that it can be applied in toluene vapour adsorption. Adsorption rate of 30% of acid treatment activated carbon was the most similar to the rate of commercial activated carbon. The optimum preparation method found in this study was obtained by 30% concentration of H_3PO_4, activation temperature of 500°C and 20 minutes of heating duration. Therefore, activated carbon prepared from durian shell has the potential to become a low cost effective adsorbent.

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