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Adsorption of Natural Gas on Chemically Modified Empty Fruit Bunch Activated Carbon

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ABSTRACT

Activated carbon (AC) was produced from palm empty fruit bunch through pyrolysis, chemical impregnation and activation. Empty fruit bunch (EFB) was dried and sieved to 3 to 10 mm. The chars formed were modified with phosphoric acid (H₃PO₄) and then activated in CO₂ stream. The AC produced was characterized by Scanning Electron Microscope (SEM), Brunauer Emmett and Teller (BET) surface area, Fourier Transform Infrared Spectroscopy (FTIR). Natural gas (NG) adsorption on the AC was carried out by passing the NG from loading cell to adsorption cell containing the sorbent. Amount of gas adsorbed was obtained from mass balance carried out across the dual cells. The amount of NG adsorbed from the process is 15.926 mmol/g adsorbent. The results indicate that the EFB-AC is a good adsorbent which can be used to adsorb NG efficiently.

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INTRODUCTION

Natural gas which is a colorless and odorless gas with the supply chain that begins with exploration and development activity, which may involve geological survey and drilling of wells [1]. The exploration happens with the search for other hydrocarbon deposits such as oil. In several applications, the extracted gas is processed to separate the natural gas from liquid and other gases that may be present in order to remove and filter any impurities such as water and hydrogen sulphide [2]. Natural gas consists primarily of methane (over 85%) with small quantities of ethane, CO₂ and N₂. Natural gas has the advantage of being cleaner and cheaper than gasoline [3].

Conversion of agricultural wastes such as EFB to a value added product such as activated carbon is a sufficient method to solve environmental problem [4]. The process of activated carbon production involves carbonization and activation with the purpose of creating pores and surface chemistry modifications [5]. AC material has large surface area, well-porosity and rich functional groups. AC is being used widely for gas adsorption process, removal of organic pollutants from water, as well as to act as a catalyst support by using the means of adsorption process [6]. AC also has high adsorption capacities, fast adsorption kinetics and easy to regenerate, it has been considered as a universal adsorbent for removal of pollutants. The aim of this work was to study the adsorption of natural gas on EFB derived activated carbon.

Experimental section:

The empty fruit bunch (EFB) was washed and dried at 105°C for 24 hrs in an oven. The material was ground and later sieved to size 3 – 10 mm. The dried materials were carbonized in a furnace at 700 °C, heating rate 10°C/min, under an inert environment for 2 h. The resultant char was mixed with H₃PO₄ as an impregnating agent in a 1:5 ratio. The solution was stirred vigorously and being heated for 2 hours at a temperature of 85°C and the solution was dried for 24 hours. Moreover, 8g of the impregnated sample was placed in the microwave reactor. For the pre-heating process, the sample was heated in a microwave at 100W for 5 minutes under N₂ gas. While for

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the heating process, the sample continues being heated at 400W for 6 minutes under CO₂ gas. It was then cooled under the N₂ gas. The sample was taking out and stored in a desiccator. The processes for the production of the AC are shown in Figure 1.

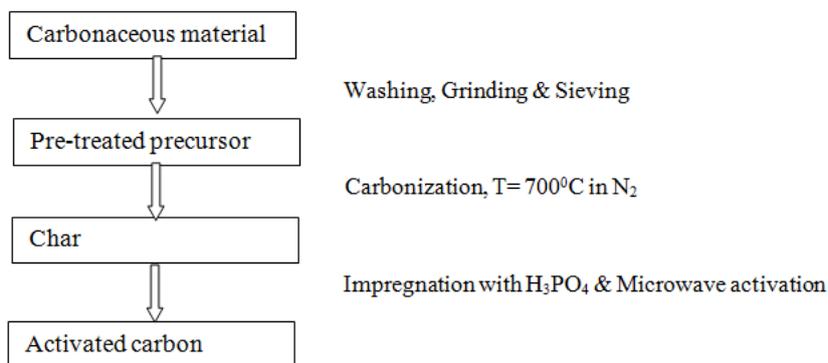


Fig. 1: Processes for production of the microwave porous activated carbons

Sorbent Characterizations:

The characterization was carried out to determine the properties of the activated carbon. The characterization covered includes scanning electron microscope (SEM) and FT-IR analysis. Perkin Elmer Spectrum One series model instrument was used to obtain samples spectra. An FTIR spectrometer simultaneously collects spectral data in a wide spectral range (400 – 4000 cm⁻¹). It provides a quick and simple qualitative technique that uses the standard IR spectra to identify the functional group(s) of the components of the synthesised sorbent. SEM (Karl Zeiss EVO50 XVPSEM, Germany) was used to determine the morphology of the sample by scanning it with a focused beam of electrons.

Natural Gas Adsorption Procedure:

A fixed bed adsorption system containing dual sorption vessels was fabricated and used to obtain the natural gas storage capacity. The pressure and temperature were monitored using digital pressure transducer (Autonics PSA/PSB series) and K type thermocouple respectively. Prior to each experiment, the sorbents were dried and out gassed overnight in an oven. About 1.5 g of the adsorbent was charged into the adsorption column which was then placed in an adsorption cell. The sorbent was then dried in-situ at 170°C under nitrogen flow for 1 hour. The valve between the loading cell and the adsorption cell was open to allow the gas contact the adsorbent in the cell. The adsorption was initiated when the pressure and temperatures in the loading and adsorption cells reached the required initial level. The adsorption cell pressure reduced until the equilibrium conditions were reached. i.e. conditions at the temperature and pressure remain constant. The amount of natural gas adsorbed was calculated using the mass balance across the loading and adsorption cell.

RESULTS AND DISCUSSION

Characterization:

SEM micrographs:

SEM images of char and activated are shown in Fig. 2. The results show that there are morphological changes which caused the formation of pores due to the carbonization and activation of samples. There are small pores on the char but more pores were created after activation (Figure 2).

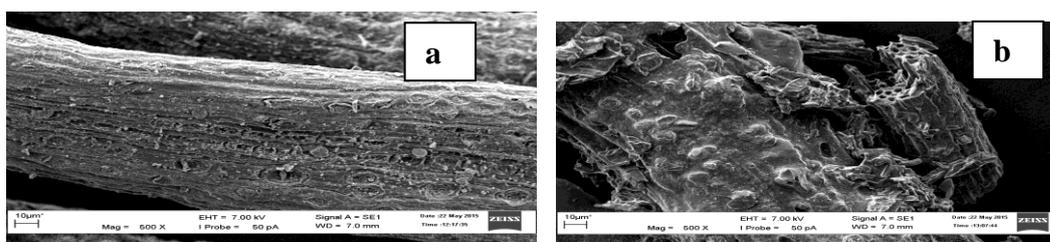


Fig. 2: SEM Images obtained (x500) of (a) bio-char and (b) AC.

Fourier Transform Infrared Spectroscopy:

From Figure 3(a), it can be seen that there were several group present on the bio-char. The weak band around $3640\text{-}3610\text{ cm}^{-1}$ indicated that there was presence of hydroxyl group. Common group of carbon can be seen from the small band around $3100\text{-}3000\text{ cm}^{-1}$ band which indicates the presence of C-H stretching of aromatics bonding. At the peak of 2345.44 cm^{-1} , the broad bonding was being shown by the alkynes group of $\text{C}\equiv\text{C}$ stretching. The broad and strong peak at 1400 cm^{-1} was attributed to the nitro and aromatics compound of N-O asymmetrical stretch and C-H bending. The peaks of 871.82 and 854.47 was assigned to either amine or aromatics group that has N-H and C-H stretching respectively.

After the bio-char was being treated and turned into AC in Figure 3(b), the weak but many bond of alcohol and phenol group was being observed at the peak around $3640\text{-}3610\text{ cm}^{-1}$, which indicates that the presence of acidic sites in the AC compared to the bio-char. There were many functional groups of acidic sites present in the AC. The obvious band was being shown at peak 1988.61 cm^{-1} that indicates the present of carboxylic acid groups from $\text{C}=\text{C}$ stretching. The intensity of the band located from $1750\text{-}1400\text{ cm}^{-1}$ ascribed for ester, nitro compound, alpha and beta saturated ester or 1° amines group. The presence of this group was due to the treating process of the AC with phosphoric acid. These types of functional groups that present at the EFB-AC evaluated had the high potential for the adsorption of natural gas.

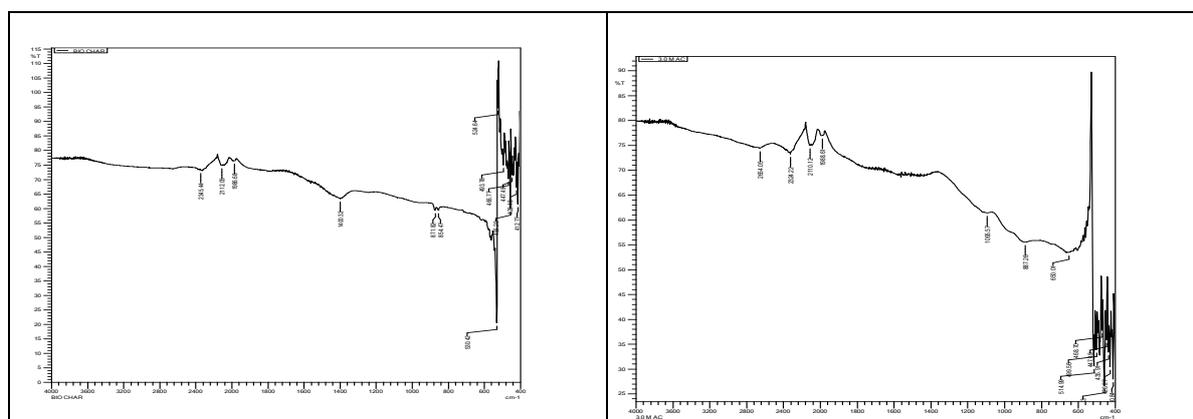


Fig. 3: FT-IR spectra obtained for (a) bio-char and (b) activated carbon.

NG Adsorption:

The natural gas adsorption data on the impregnated activated carbon was being shown in Figure 4. It can be observed that the amount of natural gas adsorbed on the NG was very high initially and then later reduces with time. The maximum amount adsorbed was 15.926 mmol/g adsorbent. Compare to the previous research paper of NG adsorption [7], this value was quite higher which shows that it has capability to adsorb huge amount of NG. This result proved the result obtained from the SEM analysis which shows well developed pores suitable for NG adsorption.

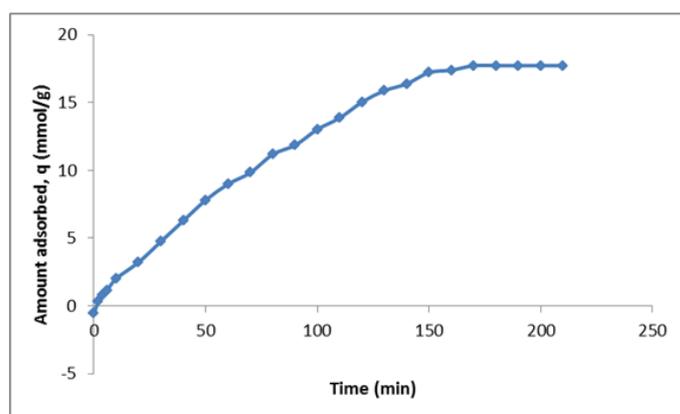


Fig. 4: Amount of natural gas adsorbed at constant pressure of 4 bar

Conclusions:

In conclusion, it can be seen that the waste generated from the palm oil which was the empty fruit bunch (EFB) had been successfully converted into AC. Pores are well developed and were visible in the SEM micrograph of the AC and therefore contributed to adsorption of NG. The adsorption process was carried out by carrying out mass balance across loading and adsorption cell. The AC prepared using 3.0M of H₃PO₄ demonstrated NG adsorption capacity of 15.926 mmol/g adsorbent. Based on the results, it can be said that the 3.0M H₃PO₄ AC developed has high natural gas (NG) adsorption capacity and can therefore be used as a type of AC in the adsorption filtration systems.

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