

# Production of antipollutant mask with bamboo based carbon activated using $H_3PO_4$ and $K_2CO_3$

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**Abstract.** The increase of developing countries' economic level has led to increase in air pollution problem. This research aims to make activated carbon based gas mask filter that was prepared from bamboo scraps by the combined activation using  $H_3PO_4$  and  $K_2CO_3$ . Bamboo was selected as raw material because of its abundant availability and high cellulose content (42.4-53.6%). Dip coating was conducted to coat activated carbon on the surface layer of mask by adding TEOS compound. Furthermore, adsorption capacity of activated carbon was tested using compartment by flowing air containing CO and  $CO_2$  for one hour. The results of the characterization shows that the iodine number of the activated carbon produced reaches 916.3 mg/g with BET surface area of 465.2 m<sup>2</sup>/g. SEM-EDX analysis shows that the carbon content is 74.83%wt. Adsorption capacity of activated carbon was tested using compartment by flowing air containing pollutant gas and compressed air for one hour. The results indicate that the maximum number of moles  $CO_2$  adsorbed is 4.8 mmol/g with 7 hour saturated time, while adsorption capacity of CO measured in 1 hour test is 0.103 mmol/g. Therefore, activated carbon has met the standards and can be applied for gas mask filter to eliminate CO and  $CO_2$  until below safety limit concentration.

## 1 Introduction

The level of air pollution in big cities has exceeded the safety limits. The substances emitted from motor vehicle such as suspended particulate matter (SPM),  $NO_x$ ,  $SO_x$ , and  $CO_x$  are toxic and very harmful for human health. Among of these hazardous substances, CO and  $CO_2$  has the greatest composition on motor vehicle emissions. Along with the increasing emission of air pollutant gas, it is necessary to prevent the bad aspects on health.

One of the prevention ways to reduce air pollution is via adsorption by using activated carbon based gas mask filter. Additional activated carbon in the mask will give better performance since it can adsorb both of particulate matters and pollutant gases. Activated carbon is a porous material that behaves as a powerful adsorbent because of high surface area, adequate pore size distribution, and relatively high mechanical strength [1]. In this case, bamboo is one of agricultural biomass waste that has potential to be used as a raw material for the production of activated carbon. It is because bamboo has high lignocellulose content (approximately 53.6% cellulose and 26.6% lignin) [2]. Activated carbon was prepared by combined activation using  $H_3PO_4$  and  $K_2CO_3$  and continued by heating in the furnace until 750°C. Furthermore activated carbon was coated on the mask filter by adding TEOS compound. Several characterization and adsorption test were used to obtain the performance of activated carbon produced

## 2 Methodology

Methods applied in this study was started by activated carbon preparation and characterization then continued by adsorption test.

### 2.1 Adsorbent Preparation

Bamboo scraps were collected from Banten, Indonesia. They were crushed to a particle size of 30 mesh, washed with distilled water to remove surface dirt then dried in oven at 100°C until the weight is constant. A certain amount of raw material was soaked with 40% at the impregnation ratio (the mass ratio of  $H_3PO_4$  to bamboo) of 3:1. The mixture was dehydrated in an oven at 80°C for 12 h. The dehydrated sample was placed in a stainless steel tubular reactor and heated to 450°C under a nitrogen flow of 40 cm<sup>3</sup>/min for 0.5 h. The obtained sample was washed with distilled water and NaOH 0.1 N until the pH of filtrate became 6.8.

The dried sample obtained by  $H_3PO_4$  activation was mixed with a saturated  $K_2CO_3$  20% at the mass ratio between  $H_3PO_4$  and bamboo 3:1. The mixture was dehydrated in an oven at 50°C for 12 h. Then, dehydrated sample was heated to 750°C and stayed at a specified temperature for 0.5 h under a nitrogen flow of 40 cm<sup>3</sup>/min. The final products were washed with distilled water and  $CH_3COOH$  0,1 N until the pH of filtrate 7 and dried in the oven to release the moisture content. Furthermore for coating process, 6 gram of activated carbon was dissolved on solution containing 100 mL water and 1 mL TEOS.

Coating solution was stirred by hot plate magnetic stirrer at 85°C for 30 minutes. Flannel was dipped several times in coating solution for 10 minutes and then being dried on oven at 120°C for 4 hours before added to mask.

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## 2.2 Characterization

The surface area of activated carbon was determined by Brunauer-Emmett-Teller (BET) and iodine number. Scanning electron microscopy (SEM) and Energy Dispersive X-ray (EDX) was done to identify the surface structure and composition of the activated carbon atoms. EDX is integrated with SEM. The instrument of SEM-EDX used is from JEOL.

## 2.3 Adsorption Test

Adsorption test was conducted in compartment shown in Fig 1, aimed to observe the effect of initial CO and CO<sub>2</sub> concentration to adsorption performance. Two pollutant gases used in this test were CO and CO<sub>2</sub>. Each gases had been mixed with compressed air before entered the compartment. The test is carried on for 1 hour for each inlet concentration variant (250, 500, 750 ppm for CO and 2000, 2500, 3000 ppm for CO<sub>2</sub>). Both of compressed air and pollutant gas were controlled by check valve, and flowmeter. Flowmeters were adjusted until reached the desired initial concentration. Check valves were used for keeping each flow stable and preventing back flow. The gas flows through section B because driven by exhaust fan. Between section A and B activated carbon mask were placed, and final concentration of pollutant gas was measured by analyzer in section B.

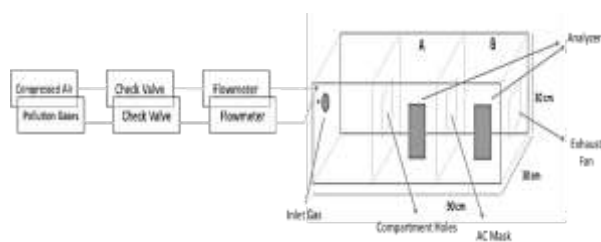


Fig. 1. Schematic diagram of the adsorption test

The amount of adsorbed gas was determined by:

$$\%adsorption = \frac{C_{in} - C_{out}}{C_{in}} \times 100\% \quad (1)$$

Where  $C_{in}$  is initial concentration and  $C_{out}$  is final concentration of gas. Furthermore, the adsorption capacity of activated carbon for each CO and CO<sub>2</sub> gases were determined by Equation 2 [3].

$$F_{in} \cdot C_{in} - F_{out} \cdot C_{out} = \frac{d(q \cdot W)}{dt} \quad (2)$$

Where:

- $F_{in}$  = inlet gas flow rate (mL/min)
- $F_{out}$  = outlet gas flow rate (mL/min)
- $C_{in}$  = inlet gas concentration (ppm)
- $C_{out}$  = outlet gas concentration (ppm)
- $q$  = amount of gas adsorbed (mg/ gram adsorbent)
- $W$  = adsorbent weight (gram)

## 3 Result and Discussion

### 3.1 Characterization

Activated carbon produced has iod number 916 mg/g, equivalent to 1165 m<sup>2</sup>/g. The surface area produced from iod number calculation approach the Langmuir surface area i.e. 957.6 m<sup>2</sup>/g.

In the other hand, BET surface area is 465.2 m<sup>2</sup>/g. Compared with the study of activated carbon from bamboo before, BET surface area is relatively small [3]. This conjecture for this small surface area is because the chemical substance that was used for neutralizing pH would act as impurities and prevent the pore to be opened. The EDX test result shows that activated carbon consist of 74.83%wt carbon. According to Sridhar *et al*, the raw bamboo has about 10% fixed carbon [4]. The increasing number of carbon are caused by the activation process. Activation, especially heating up in the furnace removes the impurities rather than carbon. The more carbon content, the better of activated carbon. Fig. 2 and Fig. 3 show the morphology of the activated carbon in 1500x and 3000x magnification respectively.

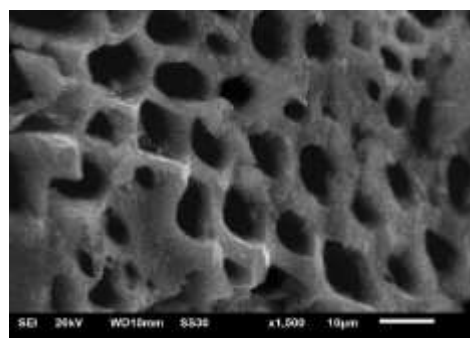


Fig. 2. SEM micrograph (1500X)

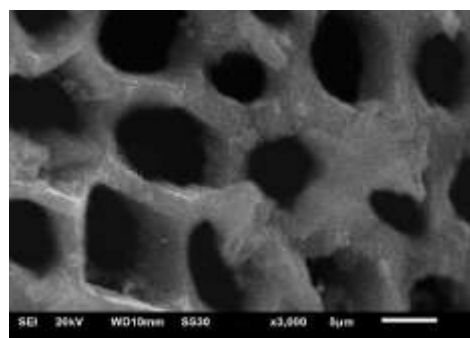


Fig. 3. SEM micrograph (3000X)

Scanning electron microscopy (SEM) is widely used to study the surface morphology, including pore structure and pore arrangement on a material surface. As seen in Fig 2 and 3, the whole process of activation were effective in creating high surface area with well-developed pores on the surface of activated carbon, although there are still several dirty molecules covering up the pores. More amount of demineralized water would be needed to clear off the dirt.

### 3.2 Adsorption Test

Results for CO and CO<sub>2</sub> adsorption test is graphically shown by Fig. 4 and 5.

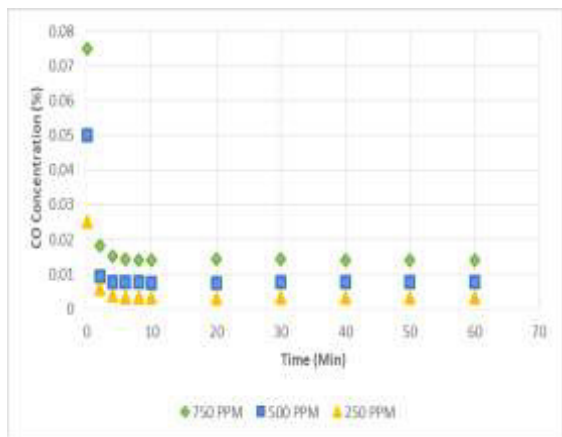


Fig. 4. Effect of increased inlet for CO adsorption

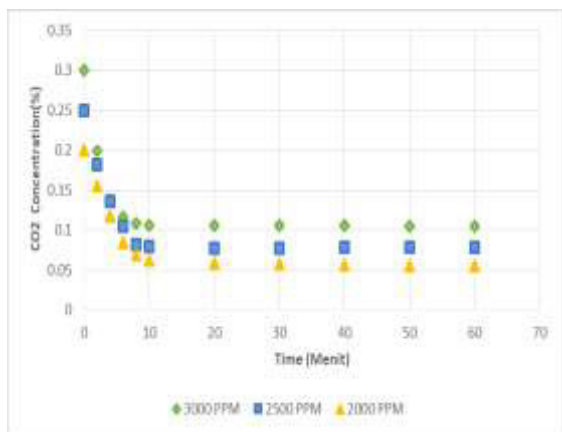


Fig. 5. Effect of increased inlet for CO<sub>2</sub> adsorption

Fig. 4 and 5 indicates that the activated carbon mask remains capable to adsorb both CO and CO<sub>2</sub> despite an increase in initial concentration. It appears that the final concentration increases with the increasing initial concentration. This can be explained by Langmuir adsorption model that in equilibrium condition, the amount of total gas adsorbed per unit weight of solid will remain constant, indicating that the entire area of activated carbon has been fully occupied by gas. Thus the increasing initial concentration will reach a condition where activated carbon become saturated and causing the concentration of gas leaving the mask become higher. It is proven in this research for the initial CO<sub>2</sub> concentration 2000 ppm, the mask is capable to reduce 72.15% CO<sub>2</sub> with final concentration 557 ppm while at concentration 3000 ppm, the mask is only capable to reduce 64.83% CO<sub>2</sub>. These results are slightly better than those obtained by Nazif *et al*, where his activated carbon capability reducing CO<sub>2</sub> are 70% and 62.53% for concentration 2000 and 3000 ppm respectively [5]. This is reasonable, because BET surface area in this research is higher than that obtained in Nazif work (432.26 m<sup>2</sup>/g).

Furthermore, saturated time measurement for CO<sub>2</sub> adsorption was conducted under initial concentration of CO<sub>2</sub> 2000 ppm as shown in Fig 6.

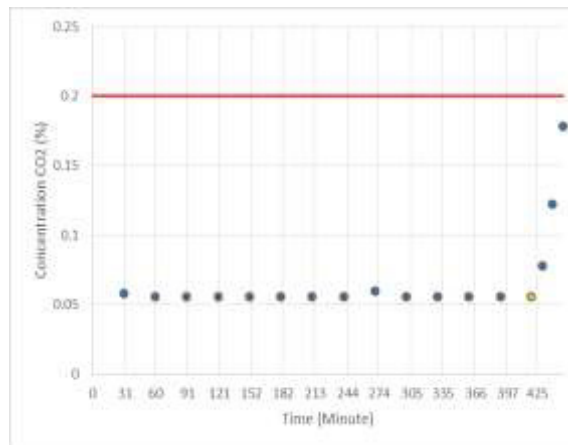


Fig. 6. CO<sub>2</sub> saturated time measurement

It shows that the activated carbon mask becomes saturated over a span of time between 420-430 minutes (approximately 7 hour). A large concentration will speed up the saturated process of activated carbon as more pores of activated carbon adsorb CO<sub>2</sub>. In addition, the amount of activated carbon and TEOS attached to this activated carbon mask is 0.88 grams, relatively small amount thus accelerating the saturated process of activated carbon. Based on saturated time, the adsorption capacity for CO<sub>2</sub> is calculated using Equation 2 and tabulated in Table 1.

Table 1. CO<sub>2</sub> Adsorption Capacity

Time (min)	CO <sub>2</sub> Outlet (ppm)	CO <sub>2</sub> Adsorption (mmol/g)
30	578	0.339
60	557	0.344
90	555	0.345
120	558	0.344
150	556	0.345
180	555	0.345
210	558	0.344
240	557	0.344
270	600	0.334
300	559	0.344
330	557	0.344
360	556	0.345
390	556	0.345
420	555	0.345
CO <sub>2</sub> Adsorption Capacity		4.806

The result shows that for CO<sub>2</sub>, the mask has adsorption capacity 4.806 mmol CO<sub>2</sub>/ gram AC. This is the maximum adsorption capacity that the mask can

adsorbed because it was calculated until it reach equilibrium condition. This CO<sub>2</sub> adsorption capacity value is closed to the value obtained by Sudibandriyo, *et al.* [6]. Moreover, adsorption capacity for CO is measured for 1 hour test long, having value of 0.103 mmol/gram AC as tabulated in Table 2.

**Table 2.** CO Adsorption Capacity for 1 h

Time (min)	CO Outlet (ppm)	CO Adsorption (mmol/g)
10	33	0.0172
20	31	0.0174
30	32	0.0173
40	33	0.0172
50	33	0.0172
60	32	0.0173
CO Adsorption Capacity		0.1036

The prescribed safety limit for CO and CO<sub>2</sub> should not exceed 9 and 5000 ppm. Based on Devita, *et al.* CO and CO<sub>2</sub> concentration on the road has an average of 10.6 and 973.2 ppm, respectively [7]. From percentage of elimination showed in Fig. 4 and 5, it is known that this activated carbon mask can be applied to eliminate CO and CO<sub>2</sub> gases below the safety limit. Furthermore, the production of antipollution mask from bamboo is very potential to be scaled up by increasing production capacity and creating comfortable design for consumer.

## 4 Conclusion

The BET surface area of the activated carbon from bamboo is 465.18 m<sup>2</sup>/g. SEM characterization shows that the whole process of activation were effective in creating high surface area with well-developed pores on the surface of activated carbon. Activated carbon has been successfully coated on the mask using TEOS adhesive. This mask can eliminate pollutant gases with adsorption capacity 0.103 mmol CO/gram AC and 4.806 mmol CO<sub>2</sub>/gram AC. Based on the results, it can be conclude that the produced activated carbon can be used in a gas mask filter production to overcome air pollution problem.

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