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# Adsorbation of Carbon Monoxide Gas with Activated Carbon from Rubber Fruit Shells

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**ABSTRACT**

Carbon Monoxide (CO) emitted by motorized vehicles can have a negative impact on human health. One way to absorb CO gas is with adsorption technology using activated carbon. Activated carbon has the potential to be used as an adsorbent. This research aims to study the efficiency of CO gas absorption in motorbike emissions using activated carbon from rubber fruit shells. Activated carbon was prepared by carbonization process at 500oC for 1 hour using 10% H3PO4 activator and sieving with a sieve size of 200 mesh. The operating conditions of the adsorption process that were varied were the length of the adsorbent, namely 3; 4; and 5 cm. The activated carbon product is then tested using proximate analysis. The results of proximate analysis show that activated carbon meets SNI 06-3730-1995 with a water content value of 7.6%; ash content 8.7%; volatile matter 8.2%; and fixed carbon 75.5%. The research results showed that the highest removal of CO gas emissions on motorbikes occurred at a contact time of 1 minute of 80.809% with a media thickness of 5 cm. The best adsorption capacity value occurred at a contact time of 1 minute, with an activated carbon media length of 3 cm, namely 158.635 mg/g.

**Keywords**: activated carbon; adsorption; carbon Monoxide; gas emission; rubber fruit shell

## Introduction

The very rapid growth of Pekanbaru City was also followed by an almost 3-fold increase in the number of motorized vehicles from 465,082 units in 2013, to 1,325,458 units in 2018 (BPS Kota Pekanbaru 2019). The rapid economic improvement and the need for rapid mobilization and cheap down payments for purchasing motorized vehicles have also contributed to the increase in the number of vehicles. This will also increase air pollution, especially CO emissions by using motorized vehicles as a mode of transportation. The increasing use of motorized vehicles increases the number of emissions into the atmosphere (Catleya, Yustiani, and Hasbiah 2021). Air pollution caused by motorized vehicles reaches 70% of the total air pollution that occurs (Purwadi, Suhandi, and Enggarsasi 2020).

CO pollution emitted by motorized vehicles has a negative impact on human health. CO is a very toxic gaseous pollutant, while particulates are solids in the air in the form of smoke, dust and steam (Ruhban and Rahmadana, 2019). This CO compound binds hemoglobin (Hb), which functions to deliver fresh oxygen throughout the body, which can cause the function of Hb to carry oxygen throughout the body to be disrupted. Exposure to CO gas at low concentrations can cause

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neurological changes, decreased activity, increased hematocrit and changes in the fetus or foetus for pregnant women, while exposure to high concentrations or the acute impact of exposure to CO gas can cause death (Aprilia, *et al*. 2017).

One way to absorb CO gas is adsorption technology using adsorbents (Redha, *et al*. 2018). Activated carbon from lignocellulosic materials, especially activated carbon produced from agricultural waste, is renewable, abundant, available and inexpensive. Activated carbon has attracted more attention in recent times because its large surface area and pore diameter are useful in environmental applications (Olorundare *et al*. 2015). Currently, forest and agricultural waste are considered as promising adsorbents for their application in adsorption. In addition, agricultural waste is a cheaper material and is available in large quantities (Saka, 2012).

One of them is the rubber fruit shell. Materials that have been known as less useful materials. Rubber fruit shells can be used as raw material for making active carbon (Jaya, *et al*. 2019). According to (Meilianti, 2018) the lignin content of 33.54% and cellulose of 48.64% in rubber fruit shells allows these materials to be used as active carbon. This is in line with research conducted by (Suhdi and Wang, 2021) and (Miarti and Iskandar, 2022) who used rubber fruit shells as a material for activated carbon.

The aim of this research is to compare the characteristics of activated carbon made from rubber fruit shells with quality standards (SNI 06-3730-1995), compare the effect of variations in adsorbent length on the ability to absorb CO gas, and calculate the adsorption capacity of activated carbon from rubber fruit shells. in absorbing CO gas emissions.

## Methods

### Research Tools and Materials

The tools used in this research were adsorption tube, furnace, oven, gas analyzer, hydraulic press, desiccator, Whatmann 42 filter paper, grinder, beaker glass, 500 mL beaker, 250 mL measuring flask, 100 mL beaker, glass 500 mL chemical, porcelain mortar, porcelain cup, 200 mesh filter, digital scale, stirring rod, glass funnel, dropper pipette, spray bottle, brush, spatula, aluminum foil, and motorbike. The materials used in this research were rubber fruit shells obtained from the Riau University Arboretum rubber plantation with 10% phosphoric acid ($H_3PO_4$) activator and distilled water.

### Research variable

The fixed variables in this study are activated carbon that passes through a 200-mesh filter, 10% $H_3PO_4$ activator, carbonization temperature of 500$^o$C, and the initial and final pollutant content of the sample. The independent variables in this study were variations in adsorbent length of 3 cm, 4 cm and 5 cm. The dependent variable in this study is the air pollutant CO.

### Carbonization and Fruit Shell Activation Process

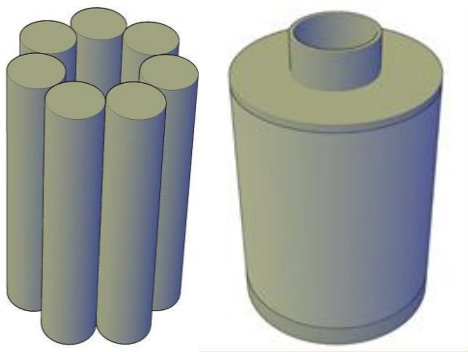
The process of making activated carbon starts with preparing the rubber fruit shells which are washed until clean and then dried using an oven at a temperature of 110˚C for 2 hours, then the rubber fruit shells are crushed to optimize the combustion process. The carbonization process was carried out at a temperature of 500˚C for 1 hour. The basis for choosing this carbonization temperature is the superiority of chemical activation, the temperature used is relatively lower compared to physical activation (Arofah, *et al*. 2019).

In the chemical activation stage, carbon is added with a 10% (w/v) H3PO4 solution with a purity of 85% and rubber fruit shell material is added with an impregnation ratio of 3/1 for 24 hours in a chemical glass container. The impregnation results were then filtered using Whatman No. filter paper. 42. The residue is washed with distilled water to pH 7 (Al-Manhel, *et al*. 2018). After that, the carbon is washed, filtered, and dried at a temperature of 110˚C until constant weight to reduce the amount of solvent remaining in the activated carbon (Arofah, *et al*. 2019).

Next, the activated carbon is filtered using a 200 mesh filter. The basis for selecting this filter size is the important characteristics of an adsorbent, namely the adsorbent pore size and surface area. The activated carbon obtained is ready for analysis. Then, to fulfill the activated carbon requirements of the Indonesian National Standard (SNI 06-3730-1995), an analysis was carried out based on ASTM D1762-84.

**Table 1**. Adsorbent Specifications

| Adsorbent Components | Adsorbent 1 | Adsorbent 2 | Adsorbent 3 |
|---|---|---|---|
| Adsorbent length (cm) | 3 cm | 4 cm | 5 cm |
| Tube Diameter (cm) | 5 cm | 5 cm | 5 cm |
| Working Volume (cm3) | 0,11775 $cm^3$ | 0,11775 $cm^3$ | 0,11775 $cm^3$ |
| Adsorbent Mass (gr) | 21,60 gr | 29,04 gr | 36,84 gr |
| Density (gr/cm3) | 0,764 $gr/cm^3$ | 0,771 $gr/cm^3$ | 0,782 $gr/cm^3$ |



**(a)** **(b)**

**Figure 1.** (a) Adsorbent shape, (b) Adsorption tube design

The adsorbent was printed using a hydraulic press with activated carbon adsorbent according to the specifications in Table 1 (Wibowo *et al*. 2017). This research uses a hydraulic press equipped with a mold heating device with a pressure force of 10 tons with a mold size of 25 pieces, each measuring 5 x 5 cm. The activated carbon printing process requires the addition of starch adhesive 10% of the weight of the activated carbon (Redha, *et al*. 2018). Then the adsorbent is put into an adsorption tube which has been designed according to the length of the adsorbent in the research for further testing.

**Testing the Initial and Final Values of the Sample**

Initial sampling was carried out with the aim of determining the stability of vehicle emissions during testing. The CO and particulate concentration values in this initial control will be used as a standard/reference for reducing CO and particulate emissions. Initial sampling was carried out without using an adsorption tube.

After all samples of CO gas and particulates have been tested, the final sample is taken without using an adsorption tube/directly from the motorbike exhaust. The final sampling aims to determine the final emissions of CO gas and particulates which will be compared with the initial concentration of the two gases so that the stability/consistency of the engine in producing gas emissions emitted by the motorbike during sampling can be determined.

**CO Gas Emission Test (SNI 19-7118.3-2005)**

The CO gas sampling process is carried out using digital equipment, namely a gas analyzer. This testing process is carried out on the vehicle in a flat position, the exhaust pipe (exhaust) is not leaking, the engine temperature is normal (60˚C to 70˚C according to manufacturer recommendations), workplace conditions are at a temperature of 20˚C to 35˚C and the system accessories such as lights are off. Next, make sure the tool is calibrated and continue by turning on the tool according to the operating procedure. After that, do an experiment by increasing (accelerating) the engine speed to 1,900 rpm to 2,100 rpm and

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holding for 60 seconds then returning it to idle condition. Next, carry out measurements in idle conditions with an engine speed of 800 rpm to 1400 rpm or according to the manufacturer's recommendations. Insert the test tool probe into the flue gas pipe to a depth of 30 cm, if it is less than 30 cm then install an additional pipe. Wait for 20 seconds then collect CO gas concentration data in percent (%) measured on the test equipment. The same thing was also done to measure the adsorption capacity, efficiency and number of particulates using an adsorption tube that had a filter and adsorbent installed. The installation of the adsorption tube on a motorbike exhaust can be seen in Figure 2.

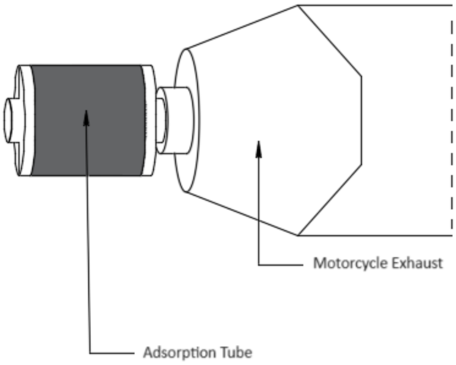


**Figure 2.** Installation of Activated Carbon Media in Motorcycle Exhaust

### Data Analysis and Processing

CO gas emissions are captured using a gas analyser, analysed directly by looking at the concentration reduction results on the gas analyser monitor screen. Calculation of the number of particulates is carried out by weighing changes in the mass of the filter plate which has been installed simultaneously in the adsorption tube according to the gravimetric method.

## Results and Discussions

### Characteristics of Activated Carbon from Rubber Fruit Shells

Determination of the characteristics of active carbon from rubber fruit shells was carried out through proximate analysis using the gravimetric method. A comparison of the test results for the characteristics of activated carbon from rubber fruit shells with SNI 06-3730-1995 can be seen in Table 2 below.

**Table 2.** Activated Carbon Characterization Test Results from Rubber Fruit Shells

| Parameters | Meilianti (2017) | This research | SNI 06-3730-1995 |
|---|---|---|---|
| Water Content (%) | 3,25 | 7,6 | Max 15% |
| Ash Content (%) | 3,36 | 8,7 | Max 10% |
| Volatile Matter (%) | 3,15 | 8,2 | Max 25% |
| Fixed Carbon (%) | 90,24 | 75,5 | Min 65% |

Table 2 shows the test results for the characteristics of water content, ash content, volatile matter, and fixed carbon for activated carbon from rubber fruit shells. In (Meilianti, 2018) produced activated carbon from rubber fruit shells with phosphoric acid activator at a temperature of 750$^o$C with characteristics of a water content of 3.25%, ash content of 3.36%, volatile matter of 3.15%, and fixed carbon of 90. 24%. In this study, activated carbon was produced with the characteristics of a water content of 7.6%, ash content of 8.7%, volatile matter content of 8.2%, which is higher and a fixed carbon content of 75.5% which is lower than [10] and has met the provisions of the SNI 06-3730-1995 quality standards.

### CO Emission Removal Efficiency

The results of exhaust gas emission tests using activated carbon showed a relationship between the effect of adsorbent length and CO emission removal. The results of CO removal and efficiency tests by activated carbon from rubber fruit shells can be seen in Figure 3.

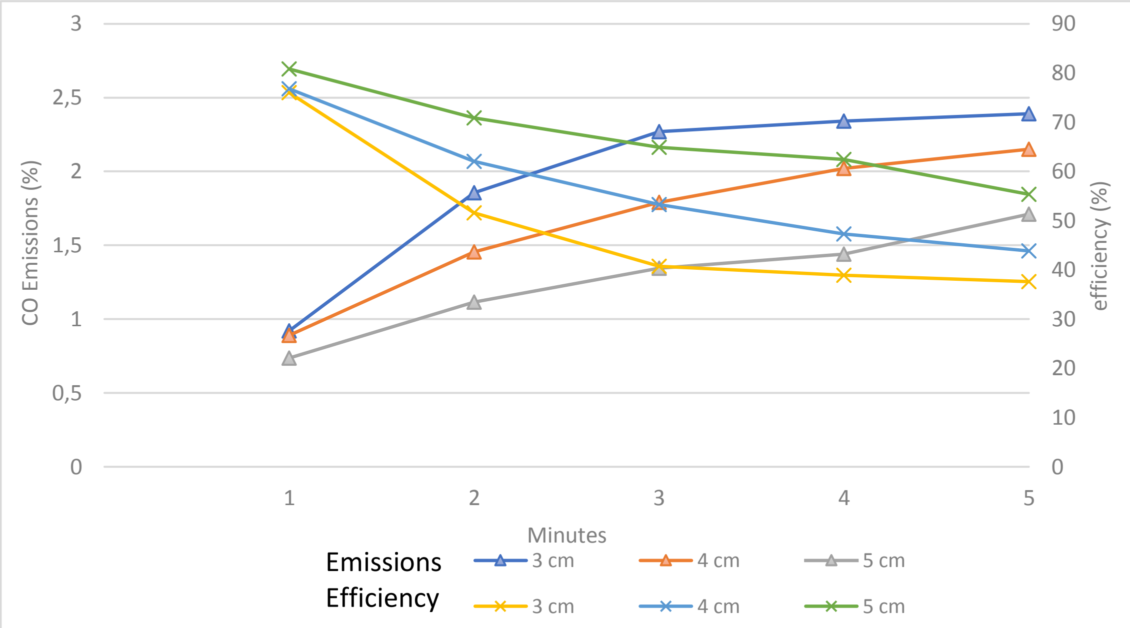


**Figure 3.** Results of CO Removal Test by Activated Carbon from Rubber Fruit Shells

Figure 3 shows the increase in emissions and decrease in CO emission removal efficiency. CO emissions in the first test decreased and gradually increased as the absorption time increased. Initial testing of CO emissions without using adsorbents obtained a value of 3.83%. In the 1st minute there was a decrease in CO emissions so that a value was obtained for varying adsorbent length of 3 cm; 4cm; and 5 cm respectively, namely 0.92%; 0.89%; and 0.735% and experienced an increase every minute until the 4th minute, namely 2.39%; 2.15% and 1.71%.

The research results showed that the lowest CO emission value occurred in the 1st minute with an adsorbent length of 5 cm, namely 0.735% and the highest emission value occurred in the 5th minute with an adsorbent length of 3 cm, namely 2.390%. So we get the percentage of CO removal in the 1st minute with varying adsorbent length 3; 4; and 5 cm, namely 75.979%; 76.762%; and 80.809% and in the 5th minute it became 37.598%; 43.864%; and 55.352%.

In this study, the highest CO removal efficiency test results occurred in the 1st minute with an adsorbent length of 5 cm, namely 80.809% and the lowest removal was in the 5th minute test with an adsorbent length of 3 cm, namely 37.598%. From the allowance data above, it can be seen that the CO emission allowance decreases with each increase in contact time. This is in accordance with research conducted by (Redha, *et al*. 2018) stating that in the initial process where the active carbon still does not absorb emissions, when measured, CO emissions decrease. However, within a certain time interval the measured CO emissions will increase again, due to the decreasing CO emission absorption process. Several studies show that increasing the mass of the adsorbent also increases the absorption of exhaust emissions (Yuliusman *et al*. 2020)

In research conducted by (Ghofur *et al*. 2022) obtained activated carbon from peat soil with a CO gas absorption rate of 41.7%, while in (Wardani *et al*. 2018) research it reached 25% from banana peels. In (Nurullita and Mifbakhuddin, 2016) research, the reduction in CO gas with coconut shell adsorbent was 62.6%, while durian skin was 70.6%. The removal of CO gas in this study was higher than in previous studies, this was due to differences in the materials used in the carbon manufacturing process.

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### Activated Carbon Adsorption Capacity on Media Thickness and Absorption Contact Time

Determination of adsorption capacity aims to determine the amount of CO emissions that can be absorbed by each gram of activated carbon adsorbent. A comparison of the adsorption capacity of activated carbon from rubber fruit shells can be seen in Figure 4.

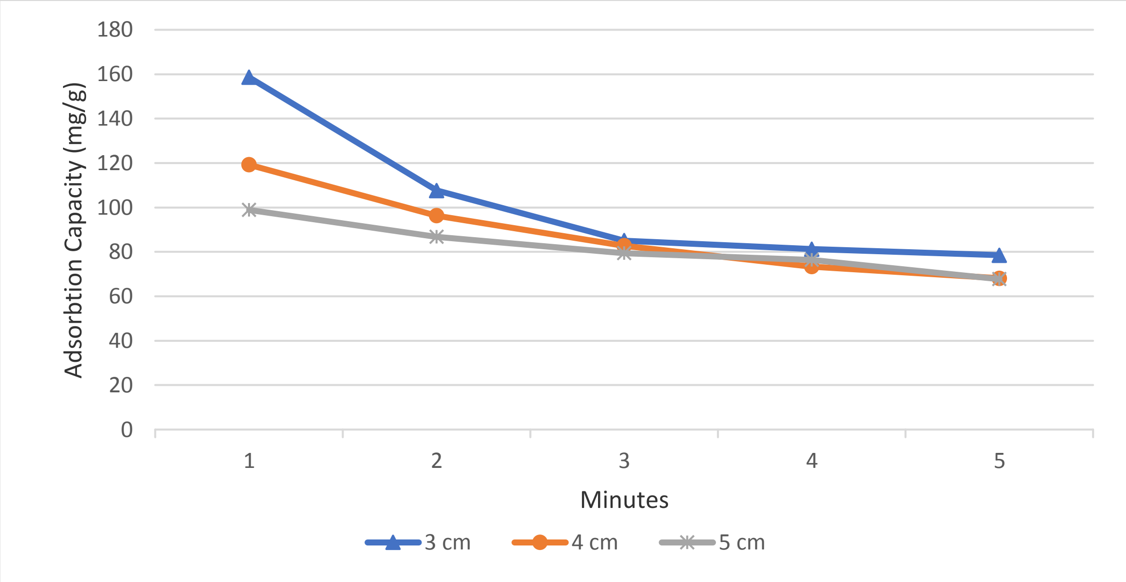


**Figure 4.** Comparison of Adsorption Capacity of Rubber Fruit Shell Activated Carbon on Media Length and Absorption Contact Time

Figure 4 shows the decrease in CO adsorption capacity values for each variation in adsorbent length. CO gas adsorption capacity in the 1st consecutive minute with variations in media thickness of 3 cm; 4cm; and 5 cm, namely 158.635 mg/g; 119,210 mg/g; and 98.924 mg/g. then decreases every second until the 5th minute, the adsorption capacity becomes 78,500 mg/g; 68.120 mg/g; and 67.761 mg/g. From the results of the adsorption capacity calculation, the best value was obtained in the 1st minute of testing with an adsorbent length of 3 cm, namely 158.635 mg/g and the lowest adsorption capacity value in the 5th minute with an adsorbent length of 5 cm, namely 67.761 mg/g.
In this research, there is an influence of length (adsorbent surface area) on the adsorbent mass which will later influence the adsorption capacity value, so an adsorbent with a length of 3 cm has a larger ratio. Meanwhile, the decrease in adsorption capacity with respect to contact time is according to (Wahyuhadi, *et al*. 2023), namely due to the shift of the adsorption zone to the bottom by the adsorbate *et al*. 2022), in this case CO emissions are characterized by an increase in effluent concentration or a decrease in CO emission allowance.

### Previous Research on Activated Carbon

Research related to making activated carbon from various types of materials with physical activation and chemical activation can be seen in Table 3 below.

**Table 3.** Previous Research on Making Activated Carbon

| Researcher | Adsorbent | Methode | Results |
|---|---|---|---|
| [18] | Activated carbon from kepok banana peels – Adsorption of CO and SO2 gas | Carbonization temperature 450°C 1.5 hours, $H_2SO_4$ activator | CO gas removal: 25% |

| Researcher | Adsorbent | Methode | Results |
|---|---|---|---|
| [6] | Activated carbon from coffee bean shells – Adsorption of CO and NOx | Carbonization temperature 450$^o$C for 30 minutes, HCL and $ZnCl_2$ activator | CO gas removal: 6,62-39,02% |
| [16] | Activated carbon from using magnesium oxide loaded on durian peel | Carbonization temperature 450$^o$C for 30 minutes, MgO 1 M activator. | CO gas removal as much as 99.14%. |
| [22] | Activated Carbon from Biomass Sustainable Sources | Carbonization temperature 600$^o$C, 700 $^o$C, 800 $^o$C. KOH activator. | CO gas removal: 90% - 96% |
| This Reasearch (2023) | Activated carbon from rubber fruit shell waste – Adsorption of CO gas emissions and particulates | Carbonization temperature 500$^o$C, $H_3PO_4$ activator, 200 mesh filter | CO gas removal: 80,809% Adsorption capacity: 158,635 mg/g |

Based on Table 3, it shows previous research on the process of making activated carbon. If the results of this study are compared with (Redha, *et al*. 2018) and (Wardani, *et al*. 2008), it produces a higher removal percentage, this is due to differences in the type of material, selection of filter size and activator used. Meanwhile, when compared with research by (Yuliusman *et al*. 2020) and (Gan, 2021), it produces a lower removal percentage, this is due to differences in the raw materials used as adsorbents, carbonization temperature, adsorbent diameter, type of vehicle as emission source, amount of adsorbent and length of time in testing.

**Conclusions**

Based on the results of the research carried out, it can be concluded that activated carbon from rubber fruit shells meets the active carbon requirements based on SNI 06-3730-1995, with water content, ash content, volatile matter and fixed carbon respectively 7.6%; 8.7%; 8.2%; and 75.5%. The best percentage of CO emission removal occurred in the 1st minute of testing with a media thickness of 5 cm, namely 80.809% and the lowest percentage with a media thickness of 3 cm in the 5th minute was 37.598%. Adsorption capacity is influenced by the length of the adsorbent and will decrease along with increased contact time. The highest CO adsorption capacity value occurred in the 1st minute with an adsorbent length of 3 cm of 158.635 mg/g and the lowest with an adsorbent length of 5 cm in the 5th minute with a value of 67.761 mg/g.

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**Author Contributions**

“Conceptualization, A.S and E; methodology, A.A. and R.F.S.; formal analysis, R.F.S. writing—original draft preparation, X.X. and R.F.S.; writing—review and editing, A.A. and R.F.S.; visualization, R.F.S.”

**Conflicts of Interest**

“The authors declare no conflict of interest.”

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