Effectiveness of air filter equipment based on water Hyacinth on combustion smoke

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Abstract. Indonesia as an agrarian country has a variety of plantation plants. The oil palm plantations are widely spread on two islands of Indonesia namely Sumatra and Kalimantan. In these areas, there is a risk of being affected by the haze disaster. Forest and land burning smoke contains carbon dioxide gases (CO₂), carbon monoxide (CO), hydrocarbon (HC) and particles. This study aims to determine the effectiveness of air filter device using water hyacinth cellulose material in combustion fumes. The air filter was filled with a solution of water hyacinth cellulose with variations in concentrations of 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20% and 22.5%, 40% NaOH solution and 10% zeolite solution. Filter device were tested by using a gas analyzer. The gas levels of CO₂ and HC in combustion fumes were 5.82 vol% and 126 ppm vol. The test results showed that the device could reduce the levels of CO₂ and HC gas in combustion fumes. The most effective device was used to reduce CO₂ gas by using 20% cellulose solution where the effectiveness of the device was 100%. The most effective device was used to reduce HC gas by using 22.5% cellulose solution where the effectiveness of the device was 90.48%.

1. Introduction
Indonesia as an agrarian country has a variety of plantation plants. One of the plantation plants is oil palm. According to the Ministry of Agriculture in Kompas (2018), the area of oil palm plantations in Indonesia is 14.03 million hectares, which 5 million hectares are owned by smallholders or the people [1].

The oil palm plantations are widely spread on two islands of Indonesia namely Sumatra and Kalimantan. In these islands, the high production of oil palm is generated by 5 provinces, namely Riau, North Sumatra, South Sumatera, Central Kalimantan and West Kalimantan. Those provinces have covered 64% of the whole oil palm plantations in Indonesia. Oil palm plantations contribute 71% to national CPO production. The highest production of oil palm is Riau. In 2015, Riau contributed to CPO by producing 3.85 million tonnes from just smallholders plantations [2].
Oil palm is one of the plantation plants that has an important role for the national economy, especially as an employment provider, source of income and foreign exchange. In 2007, oil palm plantations provided jobs and a source of income for around 3.30 million farmers, as well as contributing in foreign exchange up to US$6.20 billion [3].

Especially in Riau, almost 50% of its people’s livelihoods depend on oil palm plantations. An area of 1.44 million hectares of oil palm plantations are owned by the smallholders (Perkebunan Rakyat/PR). Riau also has a large private plantation (Perkebunan Besar Swasta/PBS) covering an area of 931,662 hectares [3]. The massive production and opportunities of oil palm plantations in Riau, impact people to keep opening the land and turned into oil palm plantations.

The catastrophic haze that occurs is classified as a disaster due to human behavior. From this disaster eventually arise various problems in society, such as respiratory disorders and views. In addition, community activities can be obstructed, and schools can be dissolved due to the lifting of the haze. Although two years later Riau can overcome the problem of haze by reducing it, but in the year 2018, forest fires and land disaster in Riau is still happening [4][5].

According to regulation of the Minister of Agriculture of the Republic of Indonesia No. 5 of 2018 regarding the opening/clearing and/or processing of plantation land without burn is mentioned that "clearing of plantation land carried out by burning causes negative impacts Environmental function and human life in the health, social and economic sectors. In addition to the loss of physical assets such as forest/land and ecological damage, the negative impact that is prominent and often perceived by the community is the occurrence of haze which is very detrimental especially related to health, such as the increasing patients with upper respiratory tract infections (ISPA) and other respiratory disorders, disrupting the transportation system either air, land, river or sea, which in turn affects the economy of the community, whether local, regional, and international" [6].

Forest and land burning smoke contains carbon dioxide gases (CO$_2$), carbon monoxide (CO), hydrocarbon (HC) and particles. In case of combustion on peatland there will be a large amount of CO2 gas emissions. CO2 is one of the greenhouse gases in the Earth's atmosphere that potentially poses global warming. CO is produced from imperfect combustion. Besides gas emissions, fire events will produce high particle emissions that can harm human health. The number of particles produced in forest fires and land could generate a thick haze [7].

In the research of air purification, the results show that NaOH solution, Solution Ca(OH)$_2$ [8] and KOH can absorb carbon dioxide (CO$_2$) in the biogas [9]. In the research of air purification, the results show that NaOH solution, Solution Ca(OH)$_2$ [8] and KOH can absorb carbon dioxide (CO$_2$) in the biogas [9].

Other materials that can be used to reduce the carbon dioxide gas content in the air is zeolite [10][11]. Zeolite is a porous material which has the ability of Adsorption. Thus, it has a high potency to capture CO$_2$ [12][13].

Water hyacinth is one of the aquatic plants that grow quickly. Within 2 weeks, water hyacinth can double the population. These plants can reach a height of 1 m which rich in fiber content [14]. Water hyacinth contains 60% cellulose, 8% hemicellulose and 17% lignin [15]. It can absorb heavy metals and sulfide compounds Water hyacinth can be used to remove pollutants, because it has function as a biological filtration system, eliminating mineral nutrients, and removing heavy metals such as cuprum, Aurum, cobalt, strontium, lead, cadmium, and nickel [16][17].

Cellulose could be isolated from water hyacinth [18]. Water hyacinth is rich in its cellulose compounds [19]. According to Lowel in [20] One of the plants that have high cellulose levels is water hyacinth which reaches 72.63% and can be utilized as an absorbent material. Cellulose itself is a simple polymer, forming a chemical bond that has a uniform cellulose chain surface and forms a porous layer. This porous solid material absorbs other materials surrounding it. Thus, it can be used as material to absorb hazardous materials for the Environment [21].

Individual acts in anticipating the haze is important. Air filters derived from water hyacinth cellulose is developed during the research as an effort to clear the air from the haze. This study aims to identify the effectiveness of air filters derived from water hyacinth cellulose on combustion smoke. The gases measured in this study are gases contained in combustion smoke i.e. carbon dioxide gas (CO$_2$) and hydrocarbons (HC).
2. Research Methods

2.1. Time and place
The study was conducted on September-December 2018 at the Basic Chemistry Laboratory and Automotive Laboratory of Yogyakarta State University.

2.2. Tools and Materials
The equipments used in this study were air filter equipment in the form of cans, plastic bottles, plastic jars, plastic pipes and aquarium pumps. Other tools are, reflux tools, buckets, large-sized jars, scissors, beaker cups, spatulas, digital balance sheets, blender, glue firing, mancis and gas analyzer. The materials used were water hyacinth, purified water, zeolite, NaOH solution, Ca(OH)\textsubscript{2} solution and paper.

2.3. Procedures
The work procedures implemented are as follows:

2.3.1. Preparation of materials
Water hyacinth material was taken from a pond in the village of Lambang Sari III, sub-district Lirik, District Indragiri Hulu, Riau. Then, it’s stem was cleared and cut along 2-3 cm, as shown by Figure 1.

![Figure 1. Water Hyacinth Stem](image1)

The cutting stem then were put into the purified water for 24 hours and dried for 3 days until becomes dry and brownish.

2.3.2. Production of cellulose and solution
The dried water hyacinth stem was taken to the chemical laboratory for reflux. Before the reflux process, 20 grams of water hyacinth stem soaked into 150 ml of Ca(OH)\textsubscript{2} 2.5% solution (m/v) for 3 days. After the soaking process, it was washed with purified water and put into the round base flask that was filled with 300 ml of NaOH 17.5% (m/v), then reflux for 4 hours. The temperature of the reflux device was set at 60 °C. The reflux process can be seen in the Figure 2.

![Figure 2. The Reflux Process and Results of Water Hyacinth](image2)
The result of reflux was cellulose then it was washed with water until it was cleared from alkaline and smoothed by using blender to produce smooth cellulose. Then 60 grams of other water hyacinth stem was made into cellulose in the same way as the initial step.

The next step is the production of cellulose solution, NaOH and zeolite. Cellulose weighed with a mass of 15 grams, 30 grams, 45 grams and 60 grams was mixed with 300 ml purified water and stirred evenly. This mixture produced cellulose solution with concentrations of 5%, 10%, 15% and 20%. After that the production of 1 M NaOH, it was weighed with a mass of 200 grams and mixed with 500 ml purified water. The mixture was stirred until the whole NaOH soluble in purified water to generate 40% or 1 M NaOH solution. The last solution is zeolite solution. Zeolite was weighed with a mass of 50 grams and mixed with 500 ml purified water by stirring. From this, mixing obtained zeolite solution with a concentration of 10%.

2.3.3. Tools Fabrications

The design of the tool was adopted from a simple air purifier by Fika, Pratama, Huda & Widya [22]. The air filter was assembled from one large size canned fruit, one large size jar fruit, two medium size plastic bottles and one small size jar fruit. It was connected by a small plastic pipe and glazed with glue to prevent air entering the bottle or jar. To pull the air, an aquarium pump was used and placed on large sized jars. The tools can be seen in Figure 3.

![Figure 3. Air Filter](Image)

The tool was filled with cellulose solution, NaOH and a pre-made zeolite solution. Large size jars were filled with NaOH, two plastic bottles were filled with zeolite and cellulose with the last cellulose sequence.

2.3.4. Testing Tools

The tool was taken to the Automotive laboratory. Testing tools was done using a gas analyzer that can measure CO2 and HC. First, gas analyzer measures the air on cans that have contained combustion smoke. The burning materials were paper. The results of this first measurement were gas content in combustion smoke. Secondly, the gas analyzer measures the air output of the tool that has been variated in its cellulosis solution of 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, 20% and 22.5%. The results of this second measurement were CO2 and HC gas data from combustion smoke that has passed through the air filter equipment.

2.4. Data Analysis

The effectiveness of the air filter equipment was identified from its ability in absorbing CO2 and HC. The equipment effectiveness is calculated as follows:

$$\text{Effectiveness (\%) =} \frac{A-B}{A} \times 100\%.$$  \hspace{1cm} (1)

Where: \(A\) is Initial measurement of gas content, and \(B\) is Final measurement of gas content.
3. Result And Discussion

3.1. Result

The first measurement results were obtained as gas levels of CO$_2$ and HC resulted from burning paper. The output of gas analyzer from this measurement reached 5.82% vol and 126 ppm vol. In the second measurement, the combustion smoke was streamed to the air filter to obtain filtered gas as seen in the Table 1.

| Concentration of Cellulose Solution (%) | CO$_2$ (% vol) | HC (ppm vol) |
|----------------------------------------|----------------|--------------|
| 5                                      | 0.05           | 0            |
| 7.5                                    | 0.04           | 27           |
| 10                                     | 0.03           | 14           |
| 12.5                                   | 0.05           | 20           |
| 15                                     | 0.03           | 16           |
| 17.5                                   | 0.01           | 19           |
| 20                                     | 0              | 13           |
| 22.5                                   | 0.03           | 12           |

Then the second measurement result data was presented into the chart which separated into, the CO$_2$ level graph shown in Figure 4 and the HC level graph shown in Figure 5.

In Figure 5 (a) carried out the cutting of hydrocarbon data on a 5% cellulose solution. This cutting was done due to unique data at the concentration of the solution. The cuts were made to generate more representative data. From the data cuts obtained a different trendline as presented in Figure 5 (b). Figure 5 (b) that presents a gas analyzer output data after the data cut will be discussed in a subsequent discussion.

![Figure 4. The CO2 Level in Filtered Air](image-url)
From Table 1 can be deduced the highest levels of CO\textsubscript{2} in the filtered air results, when the tool was filled with a concentration 5\% and 12.5\% of cellulose, was 0.05\% vol. While the lowest level of CO\textsubscript{2} in the filtered air, when the tool was filled by 20\% cellulose solution, was 0\% Vol. The highest HC level was obtained when the tool was filled by 7.5\% cellulose solution, was 27 ppm vol. While the lowest level of HC in the filtered air, when the tool was filled by 22.5\% cellulose solution, was 12 ppm vol. After data cutting on the 5\% cellulose solution.

Compared to the first measurement and measurement of both combustion smoke before and after using air filter, the level of carbon dioxide (CO\textsubscript{2}) and hydrocarbons (HC) decreased in air. After the combustion smoke passed on the air filter tool. Thus, it could be seen as an effective tool for air filtration. Analysis of measurement data resulted in the effectiveness of air filter tool. The effectiveness of the air filter was reviewed from the level of CO\textsubscript{2} and HC. As for the effectiveness of air filter tool based on the CO\textsubscript{2} level can be seen in the following Table 2.

**Figure 5.** The HC Level in Filtered Air
Table 2. The Effectiveness of Air Filter Tool Based on CO₂ Level

| Concentration of Cellulose Solution (%) | Effectiveness (%) |
|----------------------------------------|-------------------|
| 5                                      | 99,14             |
| 7,5                                    | 99,31             |
| 10                                     | 99,48             |
| 12,5                                   | 99,14             |
| 15                                     | 99,48             |
| 17,5                                   | 99,83             |
| 20                                     | 100               |
| 22,5                                   | 99,48             |

From Table 2, it can be concluded that the usage of 20% cellulose solution resulted as the most effective air filter in absorbing CO₂. As for the effectiveness of air filter tool based on the HC level can be seen in the following Table 3.

Table 3. The Effectiveness of Air Filter Tool Based on HC Level

| Concentration of Cellulose Solution (%) | Effectiveness (%) |
|----------------------------------------|-------------------|
| 7,5                                    | 78,57             |
| 10                                     | 88,89             |
| 12,5                                   | 84,13             |
| 15                                     | 87,30             |
| 17,5                                   | 84,92             |
| 20                                     | 89,68             |
| 22,5                                   | 90,48             |

From Table 3, it can be concluded that the usage of 22.5% cellulose solution resulted as the most effective air filter in absorbing HC.

3.2. Discussion

One of the studies relating to air filters using cellulose is a study conducted by Aurista Miftahatul I, Dyah Hikmawati and Siswanto. His research was in the form of synthesis of water hyacinth-based cellulose-based air filter membranes used as lead metal (Pb) metal filters in the air. The results show that this membrane can filter out lead with the best ratio of cellulose acetate 16%, formamide 8%, acetone 76% so that the percentage of PbCO₃ emissions is absorbed by 0.714% [23]. Strong anionic and cationic binding by the water hyacinth root system enables them to easily extract heavy metals and other pollutants from water [24]. Analysis of heavy metals in water hyacinth shows the presence of heavy metals in water hyacinth but with a concentration that does not pose a threat because it is within safe limits [25].

To predict the level of CO₂ and HC in filtered air if the concentration of cellulose solution is increased or reduced, could be conducted by using trendline of measurement graph. From the graph 4, the trendline of CO₂ level is:

\[ y = -0.002x + 0.0575 \]  (2)

where:
\( y \) = CO₂ Level (% vol)
\( x \) = The concentration of cellulose solution (%).

From the graph 4, the trendline of HC level is:

\[ y = 0.7x + 27.75 \]  (3)

where:
\( y \) = HC Level (ppm vol)
\( x \) = The concentration of cellulose solution (%).
Furthermore, research conducted by Su, Z., Zhang, M., Lu, Z., Song, S., Zhao, Y., and Hao, Y obtained the results of efficient cellulose-based ‘green’ air filtering for PM0.3 to achieve 99.9% [26]. Other studies are research conducted by Hajar, Wardoyo, and Masruroh who conducted research on the use of water hyacinth and banana leaf based filters which have the character to reduce PM0.1 concentrations with efficiencies up to 59% and 64%, respectively. The efficiency of this filter is influenced by cellulose content which can absorb organics [27].

From the results of this study the use of cellulose solution from water hyacinth material can reduce the CO2 and HC gas content. The cellulose solution acts as a filter when the gas is passed into it. This air filter also uses NaOH liquid and Zeolite liquid. The gas passed in these two liquids will also be filtered. NaOH liquid can be a chemical cleaner in water filtration [28]. While zeolite has the ability as an ion exchanger which has long been known and used as a chemical pollutant remover [29]. So that the tools arranged with these three materials can become an air filter. Air filters can reduce harmful gases, especially CO2 and HC gases from combustion fumes.

4. CONCLUSION
The air filter tool is effective to reduce CO2 and HC gas levels in combustion smoke. The most effective tool was used to reduce CO2 gas by using a 20% cellulose solution, a 40% NaOH solution and a 10% zeolite solution and the most effective tool was used to reduce HC gas by using a 22.5% cellulose solution, a solution of NaOH 40% and 10% zeolite solution. Suggestions for further research are to make tools with compact and portable models so that they can be used directly by smog disaster victims.

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