EFFICIENCY OF CONVENTIONAL AIR PURIFIER AND COCONUT SHELL ACTIVATED CARBON ON IMPROVING INDOOR AIR QUALITY

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ABSTRACT

There several types and technologies of air purifier such as by electrification, biomaterial, ceramic and synthetic material. That technology were very challenging to investigate their effectiveness on improving air quality. Therefore, this research will be investigating the conventional air purifier and coconut shell activated carbon in improving IAQ. The method will be conducted by indirect carbonization process and followed by crushing process to produce the particle size of 18 mesh. The crushed coconut shell charcoal activated by chemical activation using NaOH with ratio of 1:1 for 4 hours. The research will be conducted in office room by comparing the conventional air purifier of particle counter DAZ-400 and Coconut Shell Activated Carbon (CSAC). There are 3 various samples in this research such as by air purifier (type 1), by CSAC (type 2) and by combination of air purifier and CSAC (type 3). The result shows that combination methods has lowest $PM_{2.5}$, PM_{10} and Air Quality Index of 7, 16.56 $\mu g/m^3$ and 1 AQI respectively. The combination technique (type 3) also shows the highest efficiency of 84.46% as compare to air purifier (type 1) and CSAC (type 2) samples. Therefore, the combination filtration process by using air purifier and CSAC was very recommended to applied in office room to improve the IAQ.

1. Introduction

The World Health Organization (WHO) states the biggest environmental problem is air pollution which has a significant impact on human health. In 2020, air pollution has caused 98000 fatalities in the world (DW, 2020). Apart from outdoor air pollution, indoor air pollution also poses serious health risks due to the human spends 90% of his time in the room (USEPA, 2016).

Indoor air pollution is 2 to 5 times more dangerous than outdoor air pollution (USEPA, 2016) because the environment is contaminated by chemical, physical, and biological substances that can change the natural characteristics of the atmosphere (Leman et al., 2017). In general, indoor

air quality can be improved in many ways such as by cleaning, planting, changing air conditioning filters regularly and installing an air purifier (Harvard Women's Health Watch, 2018).

Air purifier is a device that used to improve the air quality from small particles and viruses or bacteria in the room (Cooper *et al.,* 2021). There are 3 types of filters including a pre-filter which used to filter the large particles such as animal hair, hair, and large dust (Budi et al., 2012). The second filter is a deodorising filter which used to remove odors (Lowther et al., 2020). The third filter is dust collection filter (electrostatic HEPA filter) that serves to filter dust, germs, bacteria, viruses, and other small particles. Air purifiers are different from air conditioners (AC), although current AC has an air purification feature in its system (Allen et al., 2011; Barn et al., 2008; Bräuner et al., 2008; Cooper et al., 2021; Karottki et al., 2013).

In order to reduce the pollutants, several researchers conducted studies for controlling VOCs such as adsorption, condensation, photocatalytic oxidation (PCO), negative air ions (NAIs) and non-thermal plasma (NTP) (Das *et al.,* 2004). Among those, adsorption in bulk separation or purification process has an innovative treatment process in environment application. Adsorption method is effective at low concentration level which is part per million (ppm). Large adsorption capacity is achieved by employing large surface area of the filter material and their performance in both equilibrium and kinetics. The conventional air purifier has a limitation in application and absorption capacity due to its media have small porosity that led to efficiency and performance of that filter. However, the potential filtration media come from biofilter media that made from waste material that have high porosity such as coconut shell, palm shell, rubber seed shell etc (Leman et al., 2017).

Air purification through activated carbon adsorption technique is the most common air cleaning method, especially for VOC and other polluted gases (Khan and Ghoshal, 2000). This type of adsorption method can improve indoor air quality and reduce cancer risk and non-cancer risk health problems. Activated carbon is one of the cheapest and popular materials as water purification, cleaned/ desorption which can be used hundred or thousand times (Adedayo *et al.,* 2012).

The other superiority of activated carbon criteria include large surface area, numerous pores network (see Figure 1.) as transportation media of molecules to the interior and more stable performance in dynamic condition (Abechi *et al.,* 2013).

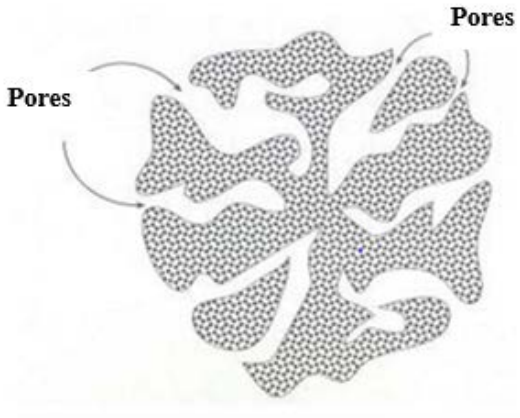

Figure 1. Numerous pores of the activated carbon (Abechi *et al.,* 2013)

The application of coconut shell AC in air filtering system is still limited; thus, it has the potential to be used as adsorbent in filtration process worth to be investigated (Leman *et al.*, 2021 and Supaat Zakaria *et al.,* 2019). Therefore, this research attempted at investigating the methods of producing palm shell AC and their application in air filtration towards IAQ improvement in particular for office buildings and industrial workplaces.

2. Materials and Methods

This study was conducted by various variation of air filtration process such as type 1 is filtration process by using conventional air purifier with the brand of Daikin MC30VVM-H, type 2 use the conventional air purifier with activated carbon filter inside and type 3 is filtration process by using coconut shell activated carbon.

The activated carbon was produced by carbonization process and followed by crushing process to achieve granular size of 18 mesh. The activation process was conducted by chemical activation using NaOH reagent with ratio charcoal and agent is 1:1 and soaked for 4 hours. Heat treatment was conducted after activation process using temperature of 110 ^{0}C for 1 hour. The activated carbon shaped with the dimension of LxWxH (23x30x0.5 cm) as shown in Figure 2.

Figure 2. Coconut shell activated carbon

This research was conducted in office room with dimension of WxLxH is 2.3 x 6 x 3 m. 3 types of air purifiers was examine in office building, type 1 which is Daikin MC30VVM-H was put in the office room for 60 minutes and data recorded for each 10 minutes. Type 2 is air purifier using CSAC by placing the CSAC into the air condition filter and the monitoring was conducted for 60 minutes and data recorded for each 10 minutes. Type 3 is combination between type 1 and type 3 also the monitoring was conducted for 60 minutes and data recorded for each 10 minutes. There are several pollutants that collected in this study such as $PM_{2.5}$, PM10, CO, CO_2, HCHO, and TVOC for every 10 minutes. That pollutant was produced by pollutant initiator to measure the effectiveness of air filter to reduce the pollutants. Air quality and pollutant was collected by using air quality detector with model of JSM-131.

3. Results

3.1 $PM_{2.5}$

$PM_{2.5}$ in various filtration media is shown in Figure 3. This data observed that the highest performance achieved by type 3 that used coconut shell activated carbon and the lowest performance showed by type 1 which use the conventional air purifier. Type 3 have performance of 98.2%, type 2 of 97.7% and type 1 have 95.5% performance on removing PM2.5. it may caused by coconut shell activated carbon has highest porosity as compared to other air purifier which led to highest absorption capacity. According to the PSI parameter index that types 2 and 3 produce air quality in good category with a range of 0- 12µg/m^3 which mean that filter was recommended to applied for improving indoor air quality. High $PM_{2.5}$ pollutant was directly associated with respiratory tract diseases, raised morbidity and mortality of cardiopulmonary diseases and undermined lung function. In addition, that the $PM_{2.5}$ surface was rich in iron, zinc, copper, manganese and other transition elements, as well as lipopolysaccharide and polycyclic aromatic hydrocarbons, etc. These components can increase consume antioxidant ingredients, free radical production in the lung and cause oxidative stress (Martinelli *et al.*, 2012)

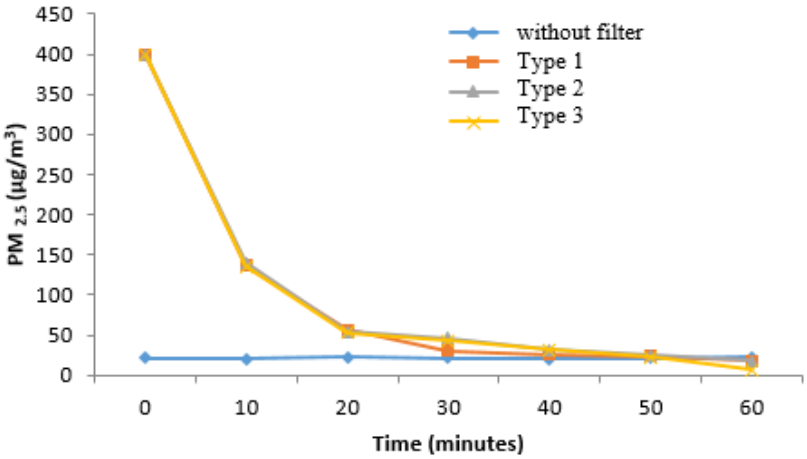

Figure 3. $PM_{2.5}$ in various filtration methods

3.2 PM_{10}

Figure 4 shows the PM10 value in various filtration media with time-based investigation. PM10 may cause by distributed by furniture stuff in the room which consist of sofa, table, cupboard and hangings which contribute to serious health risk problem (Dafit Feriyanto *et al.*, 2020). The data shows that type 3 was very effective to remove PM10 for 96.9% as compared to type 2 and type 1 of 96.2% 92.1%, respectively. After filtration process, the air quality meet the Regulation of the Minister of Health of the Republic of Indonesia Number 1077 of 2011 that the maximum level of PM10 is 70 g/m^3. Without filter means that while the investigation was not conducted pollutant initiator, therefore the pollutant is low for the 60 minutes. However, the pollutant in without filter was higher than type 2 and 3 after 60 minutes which means that the type 2 and 3 is very effective to reduce the pollutant with the initial PM_{10} of 550 ppm. It means that when the initial pollutant is lower, type 2 and 3 will reduce a significant PM_{10} and it will achieve the lowest PM_{10} after 60 minutes

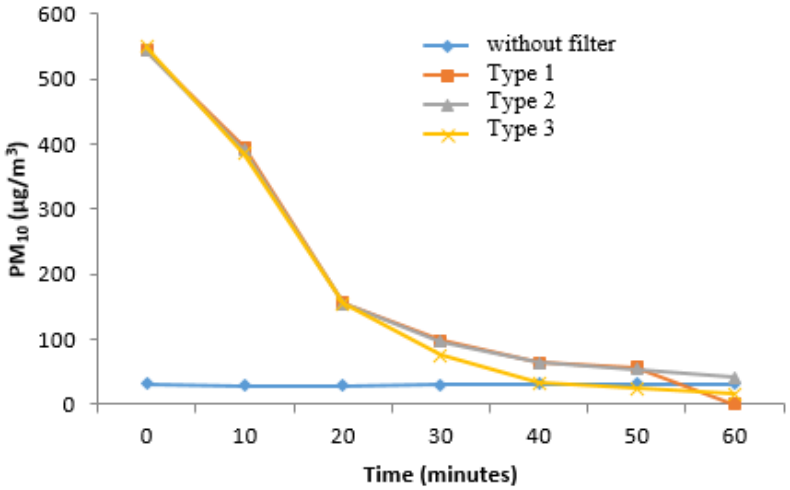

Figure 4. PM_{10} in various filtration methods

3.3 CO

CO value of various filtration media and initial condition is shown in Figure 5 that all the variation achieve the CO value below than acceptable limit of 9 ppm and after the filtration process has a lower CO pollutant as compared to without filtration process. The lowest performance showed by type 1 for 80% with the lowest CO is 4.78ppm. type 2 was higher that type 1 for 86.9% with the lowest CO is 3.33ppm and the highest performance showed by type 3 for 91% with the smallest CO is 2.33ppm in 60 minutes. It means that all filter media within 60 minutes very effective to reduce the CO pollutant and meet the acceptable limit of 9ppm based on Regulation of the Minister of Health of the Republic of Indonesia Number 1077 of 2011. Without filter is the initial condition in office room and it compared to various filter technology with pollutant initiator. The first CO pollutant value approximately of 25-27 ppm and it can be seen that after 50 minutes filtration process, the CO concentration was lower than maximum CO and after 60 minutes produce the lowest CO of 2.33 ppm. Meanwhile, CO concentration of without filter is gradually increase with time increase which means that the CO concentration is increased with the constant occupant. It not applicable when filter media performed, the CO decreased with time increased which can explained that the air purifier is very important to stabilize CO concentration below than maximum concentration.

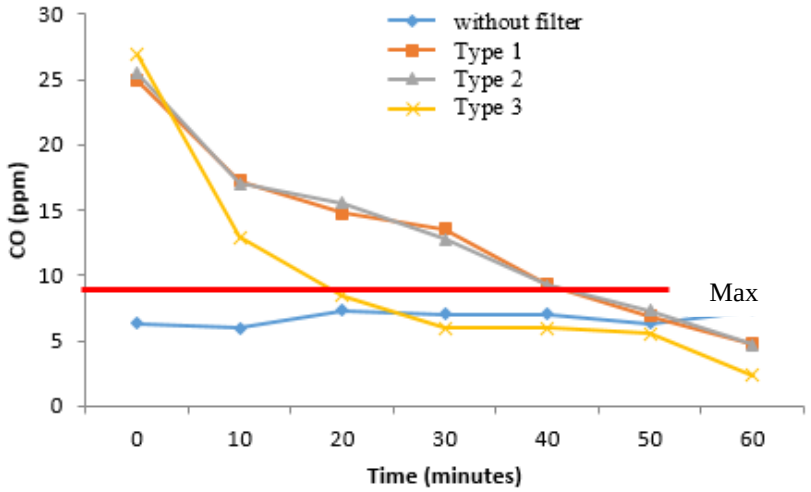

Figure 5. CO in various filtration methods

3.4 CO_2

CO_2 value of various filtration media and initial condition is shown in Figure 6. CO_2 levels indicate that they were maintained below the ceiling limit value of 1000 ppm throughout the time of measurement. Generally, number of occupants and room size affect the ability to dilute CO_2 level. The type 1 can purify the CO2 to 600ppm (40%) and type 2 produce the lowest CO_2 ppm up to 597.78ppm (41%) and the highest filtration showed by type 3 with the lowest CO_2 pollutant is 372.78ppm (59%). The source of CO_2 concentration was identified to be mainly from human respiration system. When narrowed down, two sources in the low and high CO_2 concentration from human respiratory were ascertained to the number of humans in the room and high intensity of human activity.

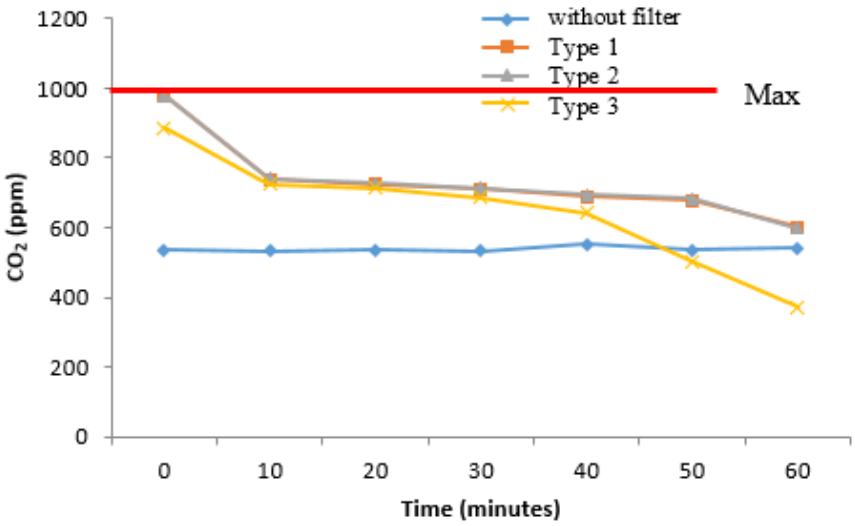

Figure 6. CO_2 in various filtration methods

3.5 TVOC

TVOC value of various filtration media and initial condition is shown in Figure 7. It can be seen that the type 1 was successfully reduce the TVOC to 0.3 ppm (88.9%), type 2 successfully reduce the TVOC from 2.71 to 0.096 ppm (96.5%) and type 3 from 2.88 to 0.07 ppm (97.6%). According to the Regulation of the Minister of Health of the Republic of Indonesia Number 1077 of 2011 that the limit of TVOC is 3 ppm. It means that the coconut shell activated carbon filter was very effective to remove the TVOC pollutant as compared to other filtration media. The suspended particles in indoor air become serious when it exceeds the acceptable limit (Silvia *et al.*, 2013). Air circulation through air-conditioning system did not seem to have significant effects in reducing indoor air contaminants especially TVOC. Therefore, it may be practical to install an effective TVOC and respirable particulate matter controlled system to diminish the harmful pollutants (i.e. activated carbon filter).

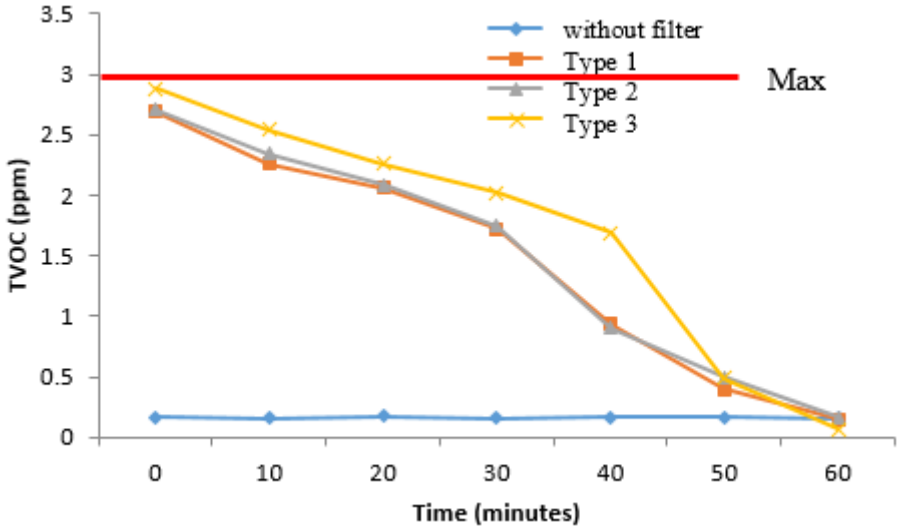

Figure 7. TVOC in various filtration methods

3.6 HCHO

HCHO value of various filtration media and initial condition is shown in Figure 8. It can be seen that the type 1 was successfully reduce the HCHO to 0.04 ppm (77.8%), type 2 successfully reduce the HCHO from 0.18 to 0.02 ppm (88.9%) and type 3 from 0.177 to 0.01 ppm (94.4%). According to the Regulation of the Minister of Health of the Republic of Indonesia Number 1077 of 2011 that the limit of HCHO is 0.1 ppm. It means that the coconut shell activated carbon filter was very effective to remove HCHO pollutant as compared to other filtration media. HCHO could cause eyes to water, causes burning feeling to the eyes and throat and can cause difficulty in breathing in humans who are exposed to its higher concentrations. The HCHO pollutant mainly source from furniture, press wood products, insulating material, textile product, painting product, wallpaper, carpet cleaner, etc. All the filtration technologies were produce the pollutant below the limit which means that the conventional air filtration or CSAC filter were effective to reduce the HCHO which may effect to occupant or employee performance to conduct their task.

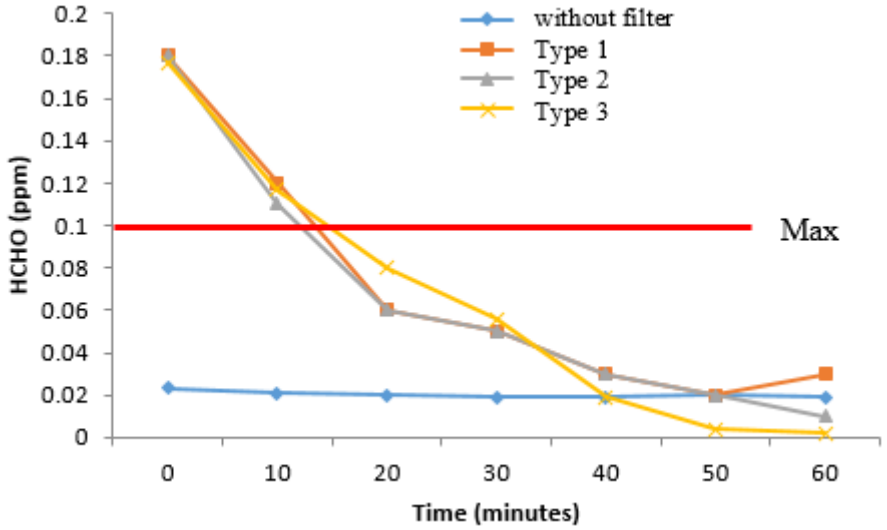

Figure 8. HCHO in various filtration methods

4. Conclusion

The comparison of the conventional air filtration, conventional combined with activated carbon and full activated carbon have been successfully achieved. The result shows that the type 3 that use the full activated carbon has highest effectiveness of pollutant reduction as compared to other filtration media which may caused by high absorption capacity and high porosity of activated carbon. Type 3 have highest performance for $PM_{2.5}$, PM_{10}, CO, CO_2, TVOC and HCHO for 98.2%, 96.9%, 372.78ppm, 97.5% and 94.4%, respectively. Higher performance of air purifier will led the human health improvement by better air quality and it cause the higher performance of employee on doing their task. The CSAC may applied for air and water purification technology in form of mask, odor absorption and as granular form as air filter.

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