Indoor Air Contaminant Adsorption By Palm Shell Activated Carbon Filter – A Proposed Study

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Abstract. Indoor air contaminant is a public issue. High Volatile Organic Compound (VOC), Carbon monoxide (CO), Carbon dioxide (CO_2), and particulate matter is becoming main issue that needs to solve. Therefore, this study focus on improving indoor air quality by using activated carbon (AC) for Ventilation and Air-Conditioning (VAC). It investigated because AC is widely explored but developing AC as a filter for VAC is not developed yet. The AC prepared by physical and chemical activation process and combination both of process and it was activated by H_3PO_4 and NaOH. Characterization and analysis process are consists of water content, ash content, bulk density, adsorption capacity, iodine number and indoor air filtering analysis. Treated activated carbon potential in achieving higher surface area of the structure to the range of 950 to 1150 m^2/g for gas phase application. The higher surface area will adsorb more air pollution. Maintained properties of activated carbon such as hardness, density, pore, extractable ash, particle size (12 by 40 mesh) and pH are becoming the main concern in achieving high quality of activated carbon.

1 Introduction

Demanding of fresh, healthy and comfortable indoor environment is essential since most people spend their time in indoor as compared to outdoor [1]. The increasing concern towards indoor air quality (IAQ) have gained the suitable technique on mitigating the indoor air contaminant [2] which can effect on health and working performance [3]. Volatile Organic Compound (VOC), Carbon monoxide (CO), Carbon dioxide (CO_2), and particulate matter defined as the major contribution of indoor air contaminant. There are several VOCs in indoor air environment such as BTX (benzene, toluene xylene), trichloroethylene and dichloromethane [4]. During long term exposure may pose adverse health effect related to human respiratory systems (such as asthma, throat irritation, lung cancer), headache, poor memory, eyes, nose and also skin irritation [5, 6]. In order to decrease the pollutant, some researchers have been conducting their methods for controlling

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the VOC such as adsorption, condensation, Photocatalytic oxidation (PCO), negative air ions (NAIs) and non-thermal plasma (NTP) [4]. In recent years, 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). Larger adsorption capacity is achieved by larger surface area of the filter material and their performance in both equilibrium and kinetics.

Generally the concentration of indoor air contaminant is higher than outdoor because it's released by human activities, building materials, furniture, carpets, paints, cleaning product, etc. [7]. Therefore, the maintenance of the indoor air quality is quite needed in order to provide sustainable and healthy environment [8].

There were some approaches methods that has been used for controlling indoor air pollutant such as ventilation and air cleaning method [9]. Mechanical Ventilation and Air-Conditioning (MVAC) system have been improved by reducing indoor particulate level. However, this technique is not promising to diminish of contaminant gases and require more energy consumption [10]. Air purification through activated carbon adsorption technique being most common air cleaning method especially for VOC and other polluted gases [11]. There are several adsorption media which commercially available or existing in the market such as Activated Carbon Fiber (ACF), Silica gel, zeolite, alumina and Granular Activated Carbon (GAC). According to some literature that the constant temperature and relative humidity in a real building for various condition is may vary significantly between months, seasons and years [12, 13]. However, the filter in the market has not been evaluated yet which led to a real VOC contaminant is real building is not recorded [13]. One of the technology which effective and reliable for removing impurities is by using activated carbon filter. Activated carbon is one of the cheapest and popular material as water purification, cleaned/desorption which used hundred or thousand times [14]. There are many advantages of activated carbon such as high carbon content, high density and low ash content, high absorption capacity, for dissolved organic, chlorine and can be used as specific application [14-17]. The other superiority of activated carbon is a reasonable large surface area, have numerous pore network (Figure 1) as a transportation media of the molecule to the interior and it's more stable performance in dynamic condition [18]. Influencing by high pollutant in our environment and many superiority of activated carbon, Therefore, the activated carbon is urgently needed in filtering the pollutant into fresh air. The principle of filtering process of activated carbon is to convert the pollutant to the CO_2, H2O as shown in Figure 2.

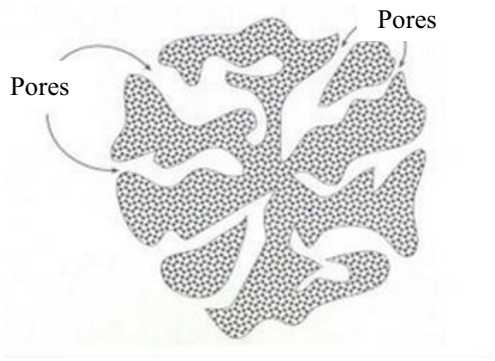

Fig. 1. Numerous pores of the activated carbon [18].

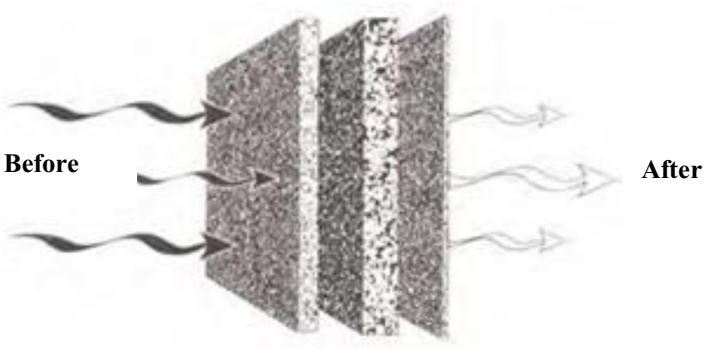

Fig. 2. Air before and after filtered by activated carbon [8, 13].

AC as an indoor air filter in order to improve indoor air quality and to reduce the cancer risk and non-cancer risk health problem. There are many researchers' studies on increasing the pore development of palm shell activated carbon [8, 13, 14, 19-22]. The pore development on activated carbon can be increased by undergoing physical and chemical treatment. In Malaysia, the palm shell is abundant due to there are 4,853,766 hectares oil palm forest in 2010 [23]. Therefore, palm shell AC (Figure 3) is very potential to explore in Malaysia.

Fig. 3. Palm shell activated carbon [23].

According to Abdullah and Wahid [23], their AC has several base properties such as bulk density (0.4-0.47), moisture content (3 %), ball-pan hardness (90-95 %), ash content (5-7 %), iodine number (950-1100 mg/g) and pH value (10).

2 Surface Modification of Palm Shell Activated Carbon

Surface modification is conducted using physical and chemical treatment. That treatment is conducted to achieve good pore structure and good adsorption properties.

2.1 Physical Activation Process

Physical activation of AC is consists of 2 steps which are hydrogen and oxygen content elimination by using pyrolysis carbonaceous material at inert atmosphere and at high temperature. Second steps are chars activation at high temperature and in the presence of

CO_2 as oxidizing gases [24]. According to Abechi et al. [18], that highest physicochemical properties are signed by the sample which treated at a temperature of 1000^0C, holding time of 45 min, Yiel of 19.25 % and bulk density of 0.62 gcm^{-3} and its micostructure analysis as shown in Figure 4.

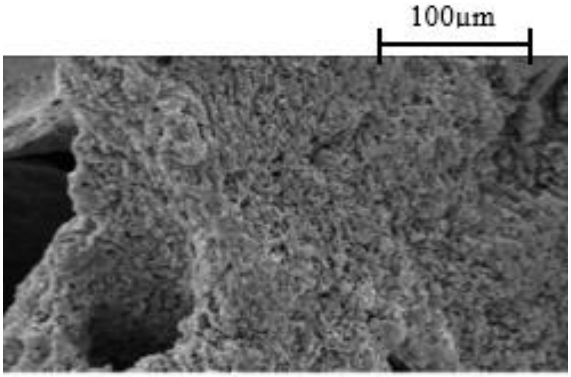

Fig. 4. Microstructure of treated AC in temperature and holding time of 1000^0C and 45 min [18].

Figure 4 shows a highest adsorption capacity with surface area of 217 gm^{-2}, micropore volume (Vµ) is 11 $x10^{-2}$ $cm^{-3}g^{-1}$ and mesopore volume of 1 $x10^{-2}$ $cm^{-3}g^{-1}$. During physical activation process, There are 2 major reactions as in Eq. 1 and Eq. 2 [18].

$$C + CO_2 \rightarrow 2CO \quad (1)$$

$$C + H_2O \rightarrow CO + H_2 \quad (2)$$

Physical treatment or thermal activation is conducted by carbonization of palm shell at the temperature range of 500 to 900 ^{0}C in order to remove volatile metter. Many researchers used different temperature in thermal activation such as 500^0C [25, 26], 600^0C [26, 27], 700^0C [26, 28], 800^0C [18, 26, 29], 900^0C [18, 24], 1000^0C [18] and 1200^0C [24]. The influence of the temperature in enlargement of pores and to enhance the adsorption solvent by increasing activation temperature [30]. The normal physical activation time for palm shell activated carbon is 1-8 hours [31]. Moreover, physical activation process also varied by relative pressure (P/Po) in the range of 0 to 1 with the highest adsorption capacity is signed by A1 sample of 80 cm3/g STP in 1 relative pressure like shown in Figure 5 [18].

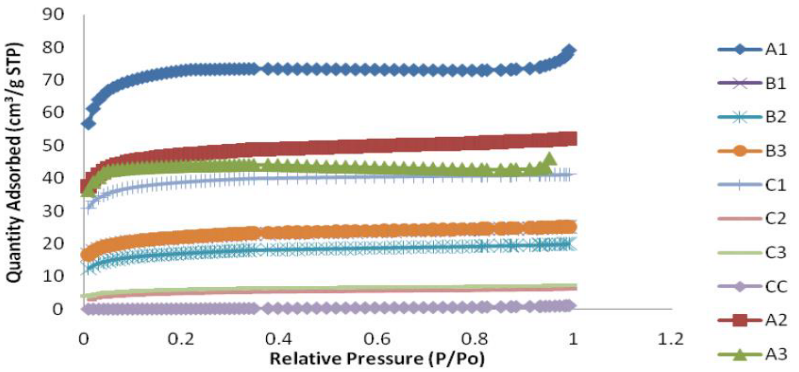

Fig. 5. Adsorption capacity of AC in different relative pressure [18].

2.2 Chemical Activation Process

The chemical activation process of AC covers the precursor treatment with chemical agent and followed by heat treatment which influence to the carbonization process and porosity generation [26, 32]. There are some dehysrating agent such as phosporic acid (H_3PO_4), zing chloride (ZnCl2) and natrium hydroxide (NaOH) [26]. The chemical analysis of palm shell is shown in Table 1.

Table 1. Chemical analysis of oil palm shell as activated carbon material [29]

Approximate analysis (wt%)		Element analysis (wt%)		Content (wt%)	
Fixed carbon	18.7	C	50.01	Cellulose	29.7
Ash	7.96	H	6.85	Halo cellulose	47.7
Moisture	1.1	N	1.9	Lignin	53.4
Volatile	72.46	O	41.15		

There are many researchers which conduct the chemical activation process in producing activated carbon using various chemical agents as listed in Table 2.

Table 2. Chemical agent for activating charcoal

Chemical agent	Composition
H_3PO_4	85 % [24]
$ZnCl_2$	65 % [26]; 98% [24]
NaOH	1000 mg/L [33]; 10 to 300 mg/L [34]
KOH	50 % [18]
HNO_3	1000 mg/L [33]
K_2CO_3	1000 mg/L [33]
H_2SO4	10 to 300 mg/L [34]
$NaHCO_3$	10 to 300 mg/L [34]
NaCl	10 to 300 mg/L [34]

3 Research Approch

AC is produced by some methods and it have explored by many researchers. The activation process is divided into 2 types which are physical (various temperature between 500 to 900^0C [25] and time of 1-8 hours [31] and chemical activation as listed in Table 2. It has conducted using various temperature, and chemical agent. According to Niya et al., (2011) [24] H_3PO_4 is used as chemical agent which heat treatment under temperature of 900 and 1200^0C. Abechi et al. [18] also activate the palm shell using a chemical agent of KOH and treated under temperature of 800, 900 and 1000^0C. Palm shell was burned in various temperature using commercially burner that unidentified reference of burner design [23, 33, 34]. The burner may not frequently release the heat flow and air flow which cause overheated of the burner and it led to a high volume of its content and decreasing adsorption properties of activated carbon. After burned, palm shell is cruised and sieved in various sizes such as 1–2 mm [24], 1.18 mm [18], 1.0–2.0 mm [35], 250–300 μm diameter [19] and 425 μm [36]. There is some limitation of those researches in combining the activation process, and in burning process. That process is strictly controlled in order to achieve high quality activated carbon based on the adsorption capacity/ surface area, hardness, density, pore, extractable ash, particle size and pH.

Research Approach is more to innovative technology and treatment process. It involves the burning process which is a fabrication process based on air and heat flow calculation in order to achieve the prevalent air and heat distribution. It conducted to reduce the possibility buner in producing high value of ash content. In this study the activated carbon size is divided into 2 types which are powdered AC and granular AC. Powdered AC especially used in lab scale and it most recommended for batch treatment of liquid (water treatment plant). It caused by slower diffusion through particles and high pressure loss across the bed. Granular activated carbon is used in pilot plant and industrial sector and in this case, it applied to air filter because better mechanical by sacrificing some efficiency. Testing process include iodine number which typically in the range of 500–1200 mg/g, water content is performed under temperature of 100^0C, ash content is performed using atmospheric furnace with various temperature of 650^0C, 700^0C and 850^0C and bulk density analyzed through drying under temperature of 100^0C for 1 hour and weighed. Adsorption analysis is conducted using dipping methods where the activated carbon is dehydrated in a convection oven at 150^0C. Indoor air quality improvement is conducted by AC filter (Figure 6) which performed by a pilot-scale acrylic chamber with a volume of 1 m3 and temperature as well as the humidity in the chamber were maintained at 20–26^0C and 40–70 %, respectively.

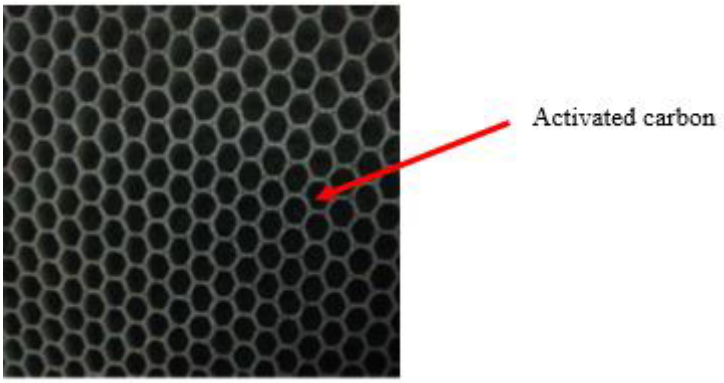

Fig. 6. Concept of AC filter [37].

4 Conclusion

AC filter has been developed by previous researcher but it still very challenging to explored. This research, proposed AC air filter completed by effective technique for improving indoor air quality. This paper proposes an innovative method inactivate an activated carbon by physical, chemical and combination of physical and chemical with new treatment parameter. Approach technology for burning process is one of the innovative technique in achieving high quality of activated carbon.

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