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Comparison of Wastewater Treatment using Activated Carbon from Bamboo and Oil Palm: An Overview

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Abstract

Developing country causes growth of industries sectors. Despite that industrial sectors releases massive amount of waste water into the environment. At the same time, the increasing number of vehicles in Malaysia promotes the development of automobile workshop that produces huge amount of wastewater as well. Wastewater contains high level of suspended total solids and leave untreated. For instance oil, grease, dyestuff, chromium, phosphate in washing products and colouring, as well as heavy metals such as lead, cadmium, barium and others potential metals. All these hazardous wastes directly pollute the environment especially the groundwater and harm the ecosystem. In order to minimize and reduce the impact to the environment, the wastewater needed to be treated using technology such as permeable reactive barrier (PRB). Activated carbon is one of the PRB utilised. It is a compromised material for treatment of wastewater where there are varieties of sources to produce activated carbon. Malaysia as an active agricultural country, massive amount of agriculture wastes can be turned into activated carbon. They are two methods used to produce activated carbon, namely furnace heat processing and microwave processing. The usage of furnace and microwave instruments can produce different quality of activated carbon due to different mechanism involves. Furnace heat processing transferred the heat from external to the internal but microwave processing is vice versa. In this article, a brief overview of activated carbon usage for wastewater treatment is highlighted.

1. Introduction

There are many types of wastewaters that pollute the environment especially the aquatic ecosystem. Textile wastewater, industry used water, landfill leachate and oily wastewater are the examples cause pollution to the Mother Nature. In Malaysia and most of the Asian countries, textile industry is producing or contributing large amount of wastewater to the environment [1]. Textile wastewater contains a lot of dyes, chemical substances and heavy metal that can pollute the environment [2]. Dye molecules are very hard to break down because most of the dye molecules are consists of double bonds, carbon-nitrogen or nitrogen-nitrogen double bond, heterocyclic ring and aromatic ring [3]. According to a research, there are more than 100,000 types of dyes and over 700,000 of dyestuff produced annually. Textile wastewater also contains high BOD and COD value, suspended solids and toxic compounds. Coloured wastewaters or textile wastewaters also introduce the

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potential danger to human being through the process of bioaccumulation. Bioaccumulation is a process of transferring the contamination through the food chain and affects the health of human being. Not only this, small amount of dyes can cause environmental pollution where it will disturb the photosynthesis activity in aquatic life by reducing the light penetration and affect the health of the aquatic living [4]. The presence of aromatic materials, metals and chlorides will give a big impact to the quality of the receiving water bodies, aquatic eco-system and the biodiversity itself due to the direct flow into the nearby drainage system, rivers, stagnant, pond or lagoons [5]. At most of the time, industrial used water will be discharge daily from the industrial area into the aquatic systems [6]. Especially wastewater discharge from chemical – intensive industries contain high amount of heavy metals such as Cr, Cu, Cd, Ni, As, Pb, Hg, and Zn which are hazardous to the environment [6]. The exposure of Hg(II) will affect the central nervous system, chromosomes and pulmonary kidney functions; Pb(II) can affect the health of human through bioaccumulation process; Cu(II) can cause lung cancer as well [7].

Another type of waste will be the oily wastewater that generated or produce by the industry or mainly from automobile workshop [8]. Due to the low biodegradability of oil, it will create a serious pollution problem to the environment [9]. Activities in automobile workshop suck as colouring, washing and many other manufacturing process is generating polluted wastewater like oil, grease, phosphate, chromium and dyestuff [8]. These kind of waste is containing high amount of toxics contents and heavy metals such as zinc, chromium and nickel which will create a serious problems towards the environment [8]. Throughout the research, range for total suspended solid contain in oily wastewater is 610 – 4950 mg/L; BOD is 75 – 570mg/L; COD is 270 – 1640 mg/L and grease concentration is 14 – 420 mg/L [10]. The type of oily wastewater can be divided into dissolved oil, dispersed oil, floating oil, spent engine and transmission oil [11]. All of these cannot be discharger or treat easily because of the oil content and residual organic pollution is very high [12]. Some of the oily wastewater are carcinogenic such as Polynuclear Aromatic Hydrocarbon, PAHs is increased the happen of skin, bladder, liver, stomach and lung cancer as well affect the immune system [13]. Landfill is one of the ways to dispose municipal solid waste but it will produce leachate that will pollute the environment. Leachate usually contains high chemical oxygen demand (COD) concentration and large fraction of high molecular weight organics [14].

In order to minimize the pollution towards the environment, many technologies have been developed to treat the wastewater such as membrane separation process, flocculation, coagulation and adsorption [15]. Coagulation is a process that begin to agglomerate when colloidal particles and very fine solid suspensions are destabilized [16]. Process of coagulation is to produce the removal of particles which is large in the size compare to colloidal particles and trap the particles in the flocks to separate it [16]. Meanwhile, flocculation is a process where the destabilized particles will conglomerate into larger aggregates so that it can be separate it from the wastewater [16]. An example of flocculation is using inorganic polymeric flocculants in the water or wastewater treatment and it can effectively remove the oil content and pollutants.

Due to the development of advanced technologies, adsorption technology is one of the simplest and efficient method for water treatment [17]. Activated carbon contain high surface area, micro and macro porous and large pore volume which apply in the field of drinking water treatment plant, adsorption of contaminants in atmosphere, separation of various organic and inorganic chemicals and deodorization [18]. However, the high production cost of activated carbon is the biggest challenge for the commercial manufacturers [17]. The reasons for the production of commercial activated carbon to be high in cost are due to the usage of non-renewable resources such as natural coal and application of expensive procedure such as conventional heating production [19]. Therefore, it is necessary to develop a new technology or new method to produce a low cost and economic activated carbon [19]. In realisation of the problem arise, researchers begin to study on production of low-cost activated carbon by using agricultural waste from bamboo, oil palm, coconut shell, corn cob, orange peel, rice husk and coir pitch [1]. Agricultural waste is one of the low

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cost material and has high surface area because it contains high volatile matter, renewable resources and lignocelluloses contents [19]. In the agriculture field, harvesting and processing of the agriculture product will produce plenty of by-product like the coconut shell [20].

Bamboo is very common natural resources that can be found in Asia especially China, Thailand and Vietnam [21]. Bamboo can be used as building materials, decoration and slope maintenance work because it is strong, light, flexible and handy to build [21]. Unfortunately, there are more than 50,000 tonnes of bamboo scaffolding ended up at landfill annually [21]. Bamboo is used as the base of production for activated carbon because it is considered as the renewable source due to the rapid growth in short period of time [22]. Not only this, price of production is lower when using bamboo to produce activated carbon because the price of bamboo is about 1/3 to 1/5 compare to commercial activated carbon [22]. There was a study on the bamboo used as the absorbent for the application of gas pollutants such as benzene, ammonia and some other volatile organic particles that can be found in the air [23]. Chemical compositions of bamboo are alcohol-toluene extraction, holocellulose, alpha-cellulose and lignin; different part have different percentage of chemical composition [24]. For example, for the base of bamboo contain 3.74 % of alcohol – toluene, 63.04 % of holocellulose, 46.14 % of alpha – cellulose and 16.12 % of lignin [24]. Malaysia is one of the main producers of oil palm plantation and the production can reach approximately 2 million per year [25]. The huge amount oil palm plantation will produce a large amount of waste such as oil palm shell and oil palm empty fruit bunch [26]. Excess amount of waste will used as fuel combustion for generating electricity or else will used to undergoes combustion process in a long period of time in order to obtain the ash for other purposes [26]. Therefore, oil palm shell and empty fruit bunch can be used to produce activated carbon because of the high carbon content, high density and low ash content [25].

Preparation of activated carbon can be completed with two main steps in activation stages: carbonization and activation [27]. Carbonization stage is a process which create an initial porosity through enrichment of carbon content and activation process is to improve or develop the pore structure [24]. During the carbonization stage, agriculture waste is heat up until certain temperature to release volatile gases and produce a material which contains only the carbon [27]. Whereas, the activation stage involved the secondary reaction or process which activate the materials using activated agent such as phosphoric acid to increase the surface area and perform the functional group on the surface [27]. For the carbonization stage, there are two methods to heat up the raw material: furnace heating processing and microwave processing. Furnace heating processing is a process where the heat source is come from outside and transfer into the particles through convection, conduction or radiation [20]. Therefore, the sample is heated start from the surface then only transfer into the inner part [17]. For this method, it may take some times for the particles to be heated up completely and it will carry the risk that overheating of the samples will cause the samples become ash [27]. But microwave processing can help to solve the overheating problem and reduce the cost of activated carbon production [27]. Microwave is converting the electric energy into heat energy through the interacting process of dielectric materials [28]. Microwave processing is heating up the inner part of the particles and transfer the heat to the outer surface area of the particles [17]. Due to the present of freely – move delocalized π-electrons, carbon materials are able to be heated up and form the foundation of "unconventional" microwave processing [28]. Huge amount of thermal gradient is transfer from the interior of the sample to the cool surface area and performed a quick and effective microwave-induced reaction [20]. Over the past few years, there had been several results showing that microwave processing can produce low cost activated carbon, high surface area and significant adsorption capacity. This is because the microwaves will heat up the inner part of the particles through microwave irradiation and performed a quick volumetric heating which can cause higher sintering temperatures, higher energy saving and shorten the processing time [29]. Because of the thermal gradient, microwave radiation will help to released more pores in the sample. In addition, due to the higher temperature in the interior than the surface of the sample,

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temperature of the microwave radiation will decrease rapidly [17]. Microwave radiation method is creating a hot spots in the sample and generate heat from inside, thus interior temperature is higher compare to the surface of the sample. Therefore, temperature of the sample only can only measure from the surface but not accurate [17]. There are several advantages using microwave radiation such as high efficiency, time saving, using electrical energy instead of heat energy, lower temperature involved, low cost equipment and it is more safe compare to furnace heating processing [30].

For the activation stages, there are chemical and physical activation processes in producing activated carbon. Physical activation is using high temperature under inert atmosphere such as nitrogen gas in order to remove the hydrogen and oxygen content and produce the activated carbon with the desired porosity [17]. For chemical activation, the use of acidic or basic solution to soak with the samples to influence the pryolytic decomposition of the starting materials, suppress tar formation and lower the pyrolysis temperature [27].

2. Preparation of Activated Carbon

2.1. Furnace Heating Processing

At first, the collected agricultural wastes were wash with hot distilled water to remove the dust-like impurities that stick on the surface [1]. Then, the agricultural wastes were dried up using hot air oven under 105°C for 24 hour to remove the moisture content [31]. Agricultural wastes were crushed, grind and sieve to 200 – 300 μm [2]. After that, the agricultural wastes undergo carbonization process where vertical furnace was used to heat up the materials under 700°C with the continuous flow of nitrogen gas [32]. After that raw materials were leaved in the furnace for cooling down purpose before proceed activation stage using activating agent. Materials were soak into activated agents like H_3PO_4, HNO_3, K_2CO_3, NAOH or KOH [32]. Later on, distilled water was used to wash the materials until the pH reached 5 – 7 and dried under the hot air oven for 4 hours to remove the moisture content [32]. Activated carbon was formed and ready to be used.

2.2. Microwave Processing

Agriculture wastes were washed with distilled water to clean or remove the impurities and dried using oven under 105 ˚C for 24 hour [33]. Then, it were crushed, grind and sieved to the size of 200 – 300 μm [19]. The raw materials were placed in the microwave to undergo microwave irradiation process with the flow of nitrogen gas. After that, materials were soaks with activating agent for chemical activation and leaved for overnight. The materials were then rinsed with distilled water until the pH reach 5 – 7. Last but not least, materials were dried using oven under 105°C over night and activated carbons is ready to be use [19]. Figure 1 is showing the modified microwave for the process of microwave processing to product activated carbon. Quartz reactor is act as the microwave radiation absorbent to absorb and transfer the radiation into heat energy for heating up the raw materials. Meanwhile, the present of nitrogen gas is to ensure the raw materials will not undergo combustion due to the present of oxygen gas. Gas outlet container is used to ensure the out flow of the gas through looking at the bubble present in gas outlet container.

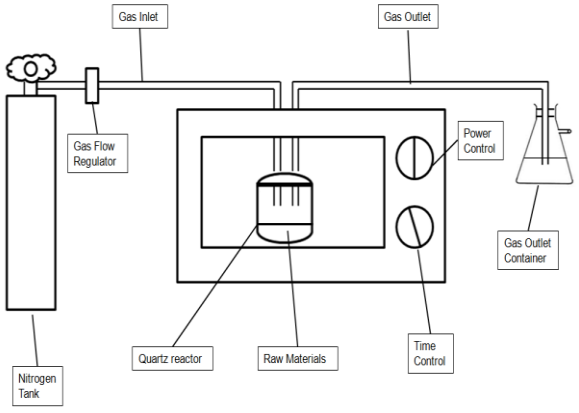

Figure 2: Modified microwave for preparation of activated carbon.

2.3. Effect of furnace heating processing and microwave processing on the physical structure of activated carbon.

According to the review, pore structure of activated carbon produced by microwave is well developed compare to activated carbon produce by furnace heating processing. Bet surface area of bamboo

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and oil palm empty fruit bunch based activated carbon produce by microwave processing is higher compare to furnace heating processing. At the same time, total pore volume of bamboo and oil palm empty fruit bunch based activated carbon produce by microwave processing is higher compare to furnace heating processing method. Microwave processing also shorten the activation time and produce higher temperature which can help to enhance the development of the pore structure [35]. Microwave radiation is heating the interior part of the sample and create a temperature gradient reducing from the centre to the surface [35]. Furnace heating processing need a longer activation time which can lead to higher weight loss of the carbon precursor or become ash [35]. The reason of adsorption capacity in microwave radiation is higher is because of the micropore structure, existence of carboxylic groups and higher charge density on the surface of the absorbent [17]. Not only this, microwave radiation also performed a higher carbon yield compare to the furnace heating processing [35].

Specific surface area and pore structure are the main properties to determine the physical properties of porous carbon. There are three types of porous materials: micropores (<2 nm), mesopores (2-50 nm) and macropores (>50 nm) [17]. Micropores is good in adsorption but mesopores also well performed in adsorb larger molecules and faster adsorption rate is required [17]. Factors that can affect the pore structure are the type of raw materials, activation time, temperature and types of activation agents [17]. On the other hand, BET surface area of activated carbon is one of the most concern and vital physical properties which can directly affect the reactivity and combustion behaviour of the carbon [17]. With the help of microwave processing method, higher BET surface area of activated carbon is obtained compare to furnace heating processing [17]. One of the characterizations to study the morphology and the structure of activated carbon is scanning electron microscope (SEM). The use of SEM can displays the activated carbon image up to 1000x times [36].

Table 2. Activation effects of furnace heating processing and microwave processing

Samples	Carbonization	S_{BET} (m^2/g)	V_{micro} (cm^3/g)
Bamboo	Microwave Processing	1432 [17]	0.503[17]
	Furnace Heating Processing	1215 [17]	0.448 [17]
Oil Palm Empty Fruit Bunch	Microwave Processing	807.54 [34]	0.45 [34]
	Furnace Heating Processing	255.77 [34]	0.14 [34]

2.4. Adsorption kinetics

Pseudo second order model better fitted compare to pseudo first order model because pseudo second order model indicates that chemisorptions dominated in the adsorption process [37]. Based on the research of Peng Liao, the adsorption rate constants (k2) of methylene blue were higher compare to acid orange 7 and the boundary layer of methylene blue is thicker than acid orange 7 by bamboo based activated carbon produce by microwave processing. Due to the reason that bamboo based activated carbon produce by microwave processing had larger pore diameter than bamboo based activated carbon produce by furnace heating processing, the adsorption rate constants, k2 value for bamboo based activated carbon produce by microwave processing is higher [37]. The absorption of dye molecules are depend on the size of pore diameter, therefore the factor that affect the pore structure such as activation time and type of raw materials should be concern [37]. Not only this, K.Y. Foo's research also showing that agriculture waste as the base of activated carbon produced by microwave processing has the higher adsorption capacity compare to furnace heating processing method [34].

3. Conclusion

Based on the several researches, activated carbon can be produce economically with low cost of production, environmental friendly and more

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efficient by using microwave processing. Microwave processing method can produce better quality of activated carbon compared to furnace heating processing. With a large amount of micropores and mesopores structure of activated carbon, it can help to absorb the organic pollutants and minimize the pollution towards the environment.

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