

PERFORMANCE OF SUGARCANE BAGASSE
ACTIVATED CARBON IN REMOVING OIL
AND GREASE FROM WASTEWATER

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CARBON IN REMOVING OIL AND GREASE FROM WASTEWATER

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ABSTRAK

Minyak dan gris adalah salah satu contoh pencemar yang boleh menyebabkan masalah alam sekitar yang teruk. Kepekatan minyak dan gris tertinggi di dalam sistem pembetulan boleh mengakibatkan penyumbatan di dalam pembetung yang menjurus kepada berlakunya limpahan. Terdapat pelbagai kaedah penyingkiran minyak dan gris; salah satu daripada contohnya adalah dengan menggunakan kaedah penyerapan. Kaedah ini biasanya menggunakan karbon aktif yang merupakan salah satu penyerap yang berkesan. Walaubagaimanapun, kos kepada karbon aktif adalah mahal justeru kajian dilakukan dengan menggunakan hasil buangan pertanian sebagai penyerap alternatif. Objektif kajian ini adalah untuk menentukan kapasiti optimum karbon aktif (SBAC) tebu sebagai bio-penyerap dalam merawat air kumbahan domestik. Selain itu, ia juga bertujuan untuk membandingkan kesan saiz, dos penyerap, nilai awalan pH sampel air buangan dan jangka masa tindak balas dalam penyingkiran minyak dan gris. Kajian ini juga menganalisis kajian penyerapan berdasarkan dos, tahap pH dan jangka masa tindak balas dengan menggunakan persamaan penyerapan Langmuir. Model penyerapan Langmuir yang digunakan disahkan oleh plot kesamaan C_e / q_e terhadap C_e . Keputusan menunjukkan bahawa kapasiti penyerapan optimum untuk kedua-dua 600 μ m dan 1.18mm SBAC adalah 3.0g dengan tahap pH 4 untuk 600 μ m SBAC dan tahap pH 8 untuk 1.18mm SBAC. Sementara itu, dari segi kesan tindak balas masa menunjukkan bahawa kedua-dua saiz SBAC menyerap dengan kadar penyerapan meningkat secara beransur-ansur dan mencapai penyerapan optimum selepas 90 minit bertindak balas. Kajian ini mendedahkan bahawa saiz terbaik SBAC yang boleh digunakan sebagai penyerap minyak dan gris adalah 600 μ m kerana ia dapat menyerap lebih banyak zarah minyak dan gris berbanding 1.18mm SBAC.

ABSTRACT

Oil and grease are one of the examples of a pollutant that can cause a severe environmental problem. The highest concentration of oil and grease inside the sewer system can cause the sewer to clog that can lead to overflow. There are various methods of oil and grease removal; one of the examples is by using adsorption method. This method commonly uses activated carbon that is one of the effective adsorbents. However, the cost for activated carbon is expensive and therefore a study was conducted by using agricultural residues as alternative adsorbents. The main objective of this study was to determine the optimum capacity of sugarcane bagasse activated carbon (SBAC) as bio-adsorbent in treating domestic wastewater. Besides, it also aims to compare the effect of size, adsorbent dosage, initial pH value of wastewater sample and contact time in the removal of oil and grease. This study also analyse the adsorption study based on dosage, pH level and contact time by using Langmuir adsorption equation. Langmuir adsorption model was used which is confirmed by a linear plot of C_e/q_e against C_e . The results showed that optimum adsorption capacity for both 600 μ m and 1.18mm of SBAC are 3.0g with the pH level 4 for 600 μ m of SBAC and pH level 8 for 1.18mm of SBAC. Meanwhile, in term of contact time effect shows that both of SBAC sizes adsorbent adsorption rate increase gradually and reach optimum adsorption after 90 minutes of contact time. This study revealed that the best size of SBAC that can be used as an adsorbent of oil and grease is 600 μ m as it can absorb more oil and grease particles compare to 1.18mm of SBAC.

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LIST OF SYMBOLS

μm	Micrometre
mm	Millimetre
$^{\circ}\text{C}$	Degree Celcius
%	Percentage
b	Constant that related to the affinity of binding sites
C_e	Equilibrium concentration
q_e	Equilibrium adsorption capacity
Q_o	Maximum amount of pollutant per unit weight of adsorbent
R^2	Equilibrium parameter

LIST OF ABBREVIATIONS

DOE	Department of Environment
EAC	Extruded Activated Carbon
EQA	Environment Quality Act
FKASA	Fakulti Kejuruteraan Awam dan Sumber Alam
GAC	Granular Activated Carbon
PAC	Powder Activated Carbon
SBAC	Sugarcane Bagasse Activated Carbon

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Water is a common chemical substance that is important to all forms of life especially to human being. Availability of water to our human population in the world for cleaning purpose is directly can control and reduce the possibility for disease to spread. While the world's population tripled in the 20th century, the use of renewable water resources has grown six-fold. Now, the world population keep increasing and will achieve 40-50% more population within the next fifty years. This population growth together with the urbanization and industrialization of the country also influence the increasing demand of clean water that also in the same time create serious consequences on of water resources (World Water Council, 2008). Although the earth covers by the water by 70%, but only 2.5% of the earth's water is freshwater and the balance of it is saline and ocean-based. Even then, only 1% of our freshwater easy to access with much of it trapped as snowfields and glaciers (National Geographic, 2018).

Wastewater is the water that has been affected by human use that came from combination of domestic, industrial, commercial or agricultural activities. It also came due to surface runoff or storm water and any sewer inflow or sewer infiltration. (Tilley *et al.*, 2014). There are several resources of wastewater including the domestic wastewater from households, municipal wastewater from the communities and also wastewater from industrial activities. Wastewater characteristics, which depend on wastewater source, are increasingly and becoming more toxic in recent times (Alade *et al.*, 2011).

One of the main sources that contribute to the water problem is caused by the present of oil and grease. Oil and grease is a measure of variety of sub-stances that

come from several different types of sources, for example: fuels, motor oil, cooking oil, animal-derived fats and oils, hydraulic oil, etc. It actually has become one of the critical components of the contaminant load especially in urban area which affect the quality of the water. These contaminants could cause many impacts towards the environment including clogging and fouling inside the sewer and drainage system.

To treat wastewater that contain oil and grease, the common treatment that been used is by using adsorbent such as activated carbon. However, due to the high price of activated carbon from the industrial market, it affects the effectiveness of the treatment in term of cost usage. Previous study by (Yakout and El-deen, 2016) , (Kouotou *et al.*, 2013) and (Bachrun *et al.*, 2016), reported that activated carbons can be produced also from virtually any type of carbonaceous materials such as sugarcane bagasse, coconut shell, palm shell, olive stones, oil-palm stones, agricultural wastes, and many others. This bio activated carbon not only can reduce the quantity of waste production but also give advantage in cost saving purposed.

Sugarcane bagasse is suitable for preparing activated carbons due to their excellent natural structure and low ash content. It is a byproduct of sugarcane industries obtained after the extraction of juice for production of sugar. Conversion of sugarcane bagasse into activated carbons which can be used as adsorbents, ion exchange, carbon molecular sieve, catalyst would add value to these agricultural commodities, help reduce the cost of waste disposal, and provide a potentially cheap alternative to existing commercial carbons for wastewater treatment purpose (Bachrun *et al.*, 2016).

1.2 Problem Statement

The major problem that usually occurs in the sewerage pipeline system is the high concentration of oil and grease that contain inside the wastewater that actually increase the possibility of clogging. Oil and grease enters the sewer system mostly comes from restaurants, residential area and also from industrial food facilities. It will continuously build up inside our sewer system when it release into the system and causes eventual blockage of sewer pipe (Husain *et al.*, 2014). At the same time, the present of grease traps may also fail to retain huge amount of dissolved and emulsified the oil and grease efficiently. Consequently, the oil and grease that not properly treated

by wastewater treatment process may enter the rivers and oceans that causing potentially detrimental environment impacts such as water pollutant (Peng, 2010).

One way to remove oil and grease from the wastewater is by using activated carbon as the wastewater treatment. Although it gives effective result as adsorption material for oil and grease but unfortunately the cost for activated carbon is expensive. There are many types or characteristic of activated carbon used in previous study such as sugarcane bagasse activation carbon as the alternative adsorbents for oil and grease removal because sugarcane bagasse is high available material in Malaysia (Thuan *et al.*, 2016). Most of the agricultural wastes including sugarcane bagasse are dump to the landfill instead of being used as other purposes.

Moreover, the different environmental parameters such as pH, sizes, adsorbent dosage, contact time, and the morphological analysis actually affect the optimum efficiency of the adsorbent to adsorb the oil and grease particles. This study was conducted by using agricultural residue as alternative adsorbents for oil and grease removal (Sa *et al.*, 2016). It significantly can help the agricultural industry to reduce the production of waste that been produced year by year. Besides, the efficiency of sugarcane bagasse activated carbon as natural adsorbent might help to reduce the cost that had been spend on the usage of existing activated carbon previously. Thus, it is significant to study on characterization and optimization of sugarcane bagasse activated carbon in both powder and granular forms towards the removal of oil and grease from the wastewater. The adsorbent sizes of powder and granular tends to give different performance towards the oil and grease removal.

1.3 Objective of Study

The main objective of this study is to investigate the capability of sugarcane bagasse activated carbon in removing oil and grease from the wastewater. Three correlative objectives were outlined to achieve the main aims.

1. To produce activated carbon from the sugarcane bagasse
2. To determine the effectiveness of activated carbon using sugarcane bagasse as oil and grease removal in wastewater.
3. To determine the different value of pH, adsorbent dosage, size, and contact time within the powdered sugarcane bagasse activated carbon, and granular sugarcane bagasse activated carbon with the adsorption isotherms.

1.4 Scope of Study

The study consists of field activities and laboratory work. Field activities carried out inside Universiti Malaysia Pahang (Gambang Campus), several water samples were collected from effluent domestic wastewater near the Café of Kolej Kediaman 3. Field activities were carried out during the early stage for characterization of wastewater, during preparation of activated carbon and last stage of batch study for powdered and granular activated carbon. While Laboratory work including preliminary study, preparation of activated carbon, adsorption test, optimization study, adsorbent characteristic before and after treatment of optimization study, removal efficiency of oil and grease via optimum study. The experiments were conducted in accordance with standard operations of Standard Method for the Examination of Water and Wastewater (2012) for collections and measurements will take about eight weeks.

The scope of the study includes the analyzation of water samples in Environmental Laboratory FKASA at Universiti Malaysia Pahang to determine their characteristic based on the water quality parameters; pH and the present of oil and grease inside the wastewater samples. Secondly, the production of powdered and granular activated carbon is produce using sugarcane bagasse by activation process. Then, the water samples are treated using both form of powdered and granular activated

carbon and identify the optimum effectiveness and performance for both of them. Compare the result which one gives more effective performance to remove the oil and grease inside the wastewater.

1.5 Significance of Study

This study significantly contributes to the cleanliness of our environment especially to our water resources, minimize the water pollutant and also to solve the problem regarding of the topic of study. Several significant contributions of this study are identified as follows:

1. The production of sugarcane bagasse activated carbon will adsorbs and removes the amount of oil and grease pollutant that been discharged so that clogging problem that happen in the sewerage pipeline system can be solved.
2. The quality of the wastewater that been discharged towards the river or stream can be improved and tendency of water pollution from happen will reduce. In fact, the quality of the water contributes huge difference towards the quality of life for human being in term of safe factor and economically beneficial towards our country.
3. By reusing the sugarcane bagasse waste as activation carbon can reduce the amount of wastes throw each day. The conversion of sugarcane bagasse to activated carbon would have dual advantages for our environment aspect, there are the production of low cost adsorbent material and at the same time reduce the need of land filling, disposal and the open burning. In Malaysia, sugarcane bagasse available abundantly and easy to be obtained with cheap, reasonable prices and in meanwhile it contains high carbon and low inorganics content that suitable for the production of activated carbon. Moreover, it has high potential to remove 90 % of pollutants in wastewater including oil and grease, than other local agricultural wastes.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

With the modernization in the development of economy and improvement in human life, unfortunately it also created some negative issues especially the increasing of wastewater production. Wastewater discharged by the municipal, industrial and commercial sectors have been adversely affected and threatening our environment. In fact, the wastewater that came from the kitchens, restaurants and commercial food service facilities give more impacts compared to the wastewater that came from residential area. Due to high concentration of oil and grease in our wastewater construction, it actually becomes the major pollutant that also reduces our water quality significantly. Specifically, the present of oil and grease frequently create problems that give negatives effects towards both public sewer system and on-site sewage disposal systems. Most problems happen when oil and grease liquefy at higher water temperatures used to wash dishes and later solidify in sewer lines or sensitive soil interfaces in the leaching facilities of on-site systems according to Barnstable County Department of Health and Environment (2011). It apparently became worse when high efficient detergent been uses to emulsify the oil and grease, keeping them in suspension until they reach the leaching field. Although conventional grease traps have the function to prevent the penetration of oil and grease into the sewer line or septic tank, but due to high loads of emulsified grease and surge wastewater, it often cause the polluters to passing through the trap and enter the leach field.

In current situation as the technology facing a lot of improvement, there are many available technologies that can solve the problem of oil and grease pollutant inside the wastewater by separating them before being discharge. For example, by using grease interceptor to trap grease from kitchen's wastewater that installed under the kitchen sinks mostly in restaurants. However, this technology apparently not the best options due to the cost through the maintenance and also take large space to be installed. Besides, there also another alternative to treat oily wastewater that used some type of treatment facilities to decomposed grease. Nevertheless, due to high cost and large space needed and at the same time required a skilled technician to maintain in long term of period, it became inefficient (Turunawarasu *et al.*, 2013)

As years passed, numerous meaningful research and experiments have been conducted to separate the oil and grease from the wastewater through adsorption by using adsorbents. The special properties and characteristic of oil absorbents have led to more efficient development of oil and grease removal treatment by having high oil absorption capability and at the same time inexpensive yet can be operated easily. In Malaysia, it is preferable to use natural adsorbents due to high production of byproduct from industries that have high properties of adsorbents such as sugarcane bagasse that can be converted to activated carbon that also help to reduce the amount of waste disposal.

2.2 Water Issues in Malaysia

Our country Malaysia known as the country that has rich of clean and safe water resources that mostly comes from stream, river and lake. Unfortunately, the water supply situation in the country has changed from one of relative abundance to one of scarcity. The increasing of demands and pressure of the water resources due to population growth, urbanization and industrialization are also contribute most of the pollution problems in the country. Despite Malaysia has been blessed with affluent of water supply, but it not will be impossible that the supply will sufficient enough to meet the demand in the future. The water pollution that come from industrial waste contribute up of 20 per cent of the total sources of pollutant while the remain of 80 percent of it come from other sources such as run-off, agriculture, farming, land

development and other activities that are not regulated under Environment Quality Act 1974 (EQA). From January to September 2016 shows that about 148 cases had been taken to court due to water pollution under the EQA's jurisdiction by the Department of Environment (DOE) (New Strait Times, 2016)

2.3 Wastewater and Treatment

Wastewater can be refers as the effluent that discharged from residential area, industrial sector, commercial establishments and institutions into water bodies such as stream or river. Apart of it, wastewater also contributed from storm water, urban runoff, agricultural and aquaculture effluents. In the most common usage, it can be refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the combination of wastewater that came from differences sources. The wastewater mixture usually contain large numbers or microscopic organisms, mostly bacteria that have capability to consume organic components such as fats, proteins, and carbohydrates from the mixture and bringing rapid changes to it. By chemically consideration, it shows that wastewater is a complex mixture of components that would be difficult to define completely (Iyyanki and Valli, 2017).

Treatment for wastewater is essentially required before it released back into the water sources to prevent any pollution to happen. In sewage treatment plant, it contains three general phases of treatment that are primary, secondary, and tertiary. In Figure 2.1 shows more detail about the flow treatment of wastewater system. The wastes that come will pass through a series of screens, chambers, and chemical processes along the phases to reduce bulk and toxicity of the water. Almost all suspended solids and inorganic material will removed from the sewage during the primary treatment by the screening and sedimentation process. For the secondary treatment, it focuses more on removal of biodegradable organic and suspended solids by using biological unit processes. Disinfection also involve inside the secondary treatment. While tertiary treatment is the removal process of nutrients, toxic substances including heavy metal and further removal of suspended solids and organic. The effluent product from this treatment is high standard and can be reuse but unfortunately, the tertiary treatment does not been built in Malaysia (Indah Water Portal)

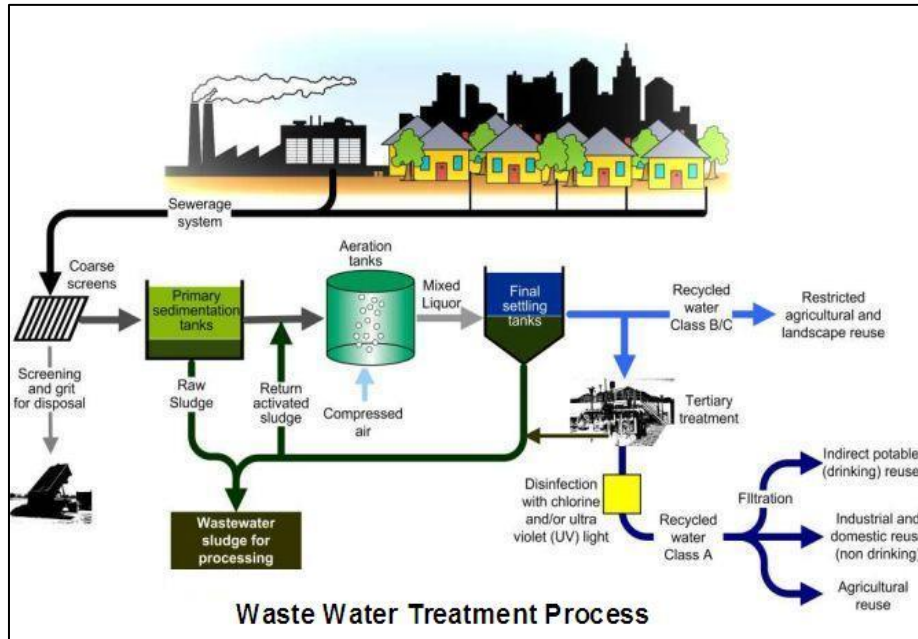


Figure 2.1: Flow treatment of wastewater systems

2.3.1 Domestic Sewage

Domestic wastewater commonly generated from household activities and mainly distributed into two types of them, there are grey water and black water. Grey water generally excludes toilet wastewater while the black water is the wastewater that including the toilet sewage. A research that been conducted in India stated that the production of grey significantly contributes about 80% from the total domestic wastewater and from that percentage, 44% of it is come from the kitchen household (Vakil *et al.*, 2014). Approximately about 12 liter of kitchen wastewater has been produced per person in one day from residential area in India (Edwin *et al.*, 2014). Although domestic wastewater especially that come from kitchen household activities do not contains harmful substances and less concentration of heavy metals comparing to other types of wastewater such as industrial wastewater, but the presence of oil and grease, and other contaminants also plays a significance factors toward the pollution of water bodies if not treated carefully.

2.3.2 Oil and Grease

Oil and grease are commonly found in kitchen waste water and have poor solubility in water that always cause serious problem during the wastewater treatment. During peak operating hours, the commercial kitchen produces more volume of wastewater that consists of high level oil and grease composition compared to residential wastewater. Mostly, because of the characteristic of oil and grease that have low specific gravity and insoluble in water, it tends to float on the water surface. In worst condition, this situation can cause clogging if large amount of oil and grease wastewater flow through the pipe. Based on previous study, it shows that the initial concentration of oil and grease in wastewater were quite high range from 101.37mg/l to 248.3 mg/l that been recorded at Parit Raja in Batu Pahat District, Johor (Rahmat *et al.*, 2017). Therefore, it is important to reduce the concentration of oil and grease composition in wastewater and maintained at acceptable levels to avoid problems happen inside the pipeline and sewerage treatment plant.

2.4 Sugarcane Bagasse

Modern agricultural industries produce a million tons of waste and by-product per year that have incredible potential as useful alternative resources. These agro-industrial residues actually can become promising alternative to replace the traditional adsorbents due to low cost, readily available, highly sorptive and insensitive to toxic substances (Thuan *et al.*, 2016). Sugarcane bagasse is an agricultural residue that come as fibrous matter after sugarcane been crushed to extract their juices that shown in Figure 2.2. It has been widely used as a biofuel and burnt to produce steam to generate electricity.

Currently, sugarcane bagasse is one of the most cost-effective and available agro-industrial residues, especially in tropical regions (Sarker *et al.*, 2017). Brazil is the world's top producer of sugarcane plant or *Saccharum Officinarum* followed by India, China, and Bangladesh (Ferreira *et al.*, 2015), and bagasse is produced in large quantities as a by-product of the sugar and bioethanol mills in each of these countries. The Figure 2.3 shows the sugarcane plant inside the plantation.



Figure 2.2: Sugarcane bagasse



Figure 2.3: Sugarcane Plant

2.4.1 Sugarcane Bagasse Composition

The sugarcane bagasse as any of lignocellulosic material mostly constituted by the present of hemicellulose, cellulose and lignin with chemical composition analysis showed that untreated bagasse has approximately 50% cellulose and similar amounts of hemicellulose (25%) and lignin (25%)(Huang *et al.*, 2012). From all sugar production factories, there are produce quite amount of sugarcane waste fiber residues, and it typically about 30% of bagasse. It contains about 12–16% fiber and also 10–15% sucrose (Arni and Converti, 2012). This composition of sugarcane bagasse actually makes it relatively resistant to biodegradation. Besides that, due to high activated carbon content, sugarcane bagasse is well-known as good adsorbent. The ash percentage for untreated bagasse was quite high approximately about 20 % (Rezende *et al.*, 2011). Sugarcane bagasse also consists of 90.22 % of carbon and the remaining of 9.78 % content comes from the existence of silica. This is the major reason why sugarcane bagasse contains high activated carbon in it.

Table 2.1: Analysis of chemical content of sugarcane bagasse

Content	Percentage (%)
Carbon	90.22
Silica	9.78

2.5 Activated Carbon

Activated carbon or known as activated charcoal that shown in Figure 2.4 is a form of carbon processed that contains small and low volume pores that can increase the surface area that actually help the adsorption or chemical reactions happen at optimum rate. It has been an ideal material for wastewater treatment due to the high surface area, contain with well-organized macro and micro-pores to increase the adsorption purpose, and a wide range of chemical functional groups presents on it. The pores of sugarcane bagasse activated carbon can be shown in Figure 2.5. Activated carbon naturally come as positively charged and because of that it also have capability to remove negative ions that come from the water such as ozone, chlorine, dissolve organic substances and fluorides by the absorption reaction between the activated carbon and the water. Unfortunately, activated carbon is not effective for heavy metal treatment but often used as a filter for organic material for water treatment system (Atabaki, 2014).

Due to having high porosity, high specific surface area and favorable pore-size distribution, activated carbon has become good adsorbent to treat wastewater especially as oil and grease removal. Activated carbon can be produced from agricultural bio-waste or food production industry such as sugarcane bagasse, rice husk, nut shell and wood that easily to get and at the same time the price is cheaper than existing activated carbon. Thuan *et al.*, (2016) reported that a thousand of tons of sugarcane bagasse has been disposed yearly in Vietnam by the sugar manufacturing factories from surrounding sector that actually can be process to produce natural activated carbon. But in term of other production processes, a good quality activated carbon that have high surface area and pore size actually involve the balancing of all condition during the process to get certain desired characteristic of activated carbon (Danish and Hashim, 2014).



Figure 2.4: Activated Carbon

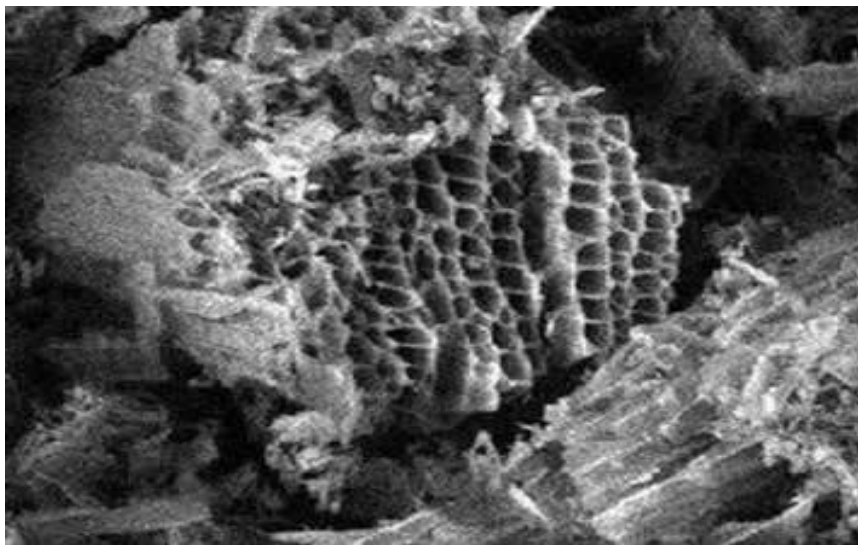


Figure 2.5: The pores of activated carbon under microscope

2.5.1 Types of Activated Carbon

In the production of activated carbon, normally there are three types of activated carbon that commonly used which are granular activated carbon (GAC), powder activated carbon (PAC) and also extruded activated carbon (EAC) shown in Figure 2.6. For GAC, the size is ranging from 0.2 to 5.0 mm with irregular shaped particles and usually be used in both liquid and gas phase application. Meanwhile, PAC is a pulverized carbon with a size predominantly not more than 0.18mm and mainly used in liquid phase applications together with flue gas treatment. Unlike GAC and PAC, EAC is the activated carbon that being shaped as cylindrical pellets with diameters range between 0.8mm to 5 mm. This type of activated carbon commonly used for gas phase application due to their low pressure drop and low dust content but have high mechanical strength characteristics (Chemviron Portal, 2019).



Figure 2.6: Forms of activated carbon

2.5.2 Physicochemical Properties of Activated Carbon

Activated carbon is an excellent adsorbent due to its capability to remove most of the pollutants from the wastewater effectively. It has strong affinity in binding organic substances together but in order to have great active sites during adsorption process, the activated carbon need to have good properties in term of both physical and chemical. The physical and chemical or can called by physicochemical properties was described as surface chemistry of activated carbon consisting of ash content, iodine number, yield test, particle density test and others (Yusufu, Ariaahu and Igbabul, 2012).

Eventually, the ash formed during the production of activated carbon and it can becomes as indicator of the quality of each activated carbon that been produced. In most situation, ash forms due to the high burning of activated carbon and longer contact time during production. The effectiveness of activated carbon as adsorbent tends to decrease if the ash content too high that cause the blockage of pores and resulting saturated diffusion towards active binding site of activated carbon. Hence, to achieve good activated carbon the content of ash value must be lower but at same time it must contains high carbon to ensure its produce optimum results during adsorption process (Chowdury *et al.*, 2012)

2.5.3 Type of Activation Techniques

In production of activated carbon, there are two major processes that are involved; the first one is the carbonization of precursor material and then the activation of activated carbon. The choice of precursor mostly depending of its availability, purity and eventually the cost of it too, however the manufacturing process and the application of the product also may take into consideration. Activation process that happened during carbonization creates the pore volume and significantly increases the diameter size of the pores (Bringle, 2009). There are two activation techniques that commonly used to produce activated carbon; the physical activation and chemical activation. Both of activation techniques have different flow of process and required certain conditions to be followed significantly to produce good quality of activated carbon.

2.5.3.1 Physical Activation

The physical or known as dry activation involves two step of thermal processes that conducted at temperature of 700°C and below with the present of oxidizing gases like Oxygen (O₂) then Carbon dioxide (CO₂) and hot water vapour are involves as second step after pyrolysis (Sekirifa *et al.*, 2013). During the process, porous structure of activated carbon will be creates and it actually increases the adsorption capacity of the activated carbon materials. The oxidant agents convert the carbon material inside the wastes to form carbon monoxide (CO) and carbon dioxide (CO₂) opening pores.

2.5.3.2 Chemical Activation

Different from physical activation, chemical activation process is one stage process only that consist of carbonization and activation of the precursor occur synchronously with the presence of oxidative chemical reagent such as phosphoric acid (H₃PO₄) ,magnesium chloride (MgCl₂), zinc chloride (ZnCl₂), potassium hydroxide (KOH), sodium hydroxide (NaOH). From all chemical oxidizing reagents that been stated above, phosphoric acid (H₃PO₄) and zinc chloride (ZnCl₂) are commonly used as activation reagent to impregnated the raw material (Alzaydien, 2016) .

However, phosphoric acid usage is more preferable compared to zinc chloride because the zinc chloride give more environmental impact because of the contamination of zinc (Zn) compound (Bringle, 2009) , at the same time the product of activated carbon that use it as reagent is practically not safe to be used in food and pharmaceutical industries. Besides, enhance adsorption capacity only can be reach by using phosphoric acid as chemical activation because it can easily open up the pores and cavity of activated carbon. Moreover, compared to physical activation that required high temperature to produce activated carbon, the heating process of chemical activation usually required less heat because of the existence of oxidizing reagent that help to improve the surface area or size of porous structure of the activated carbon material. Because of the simplicity, lower temperature required and shorter activation time, chemical activation more preferable being used instead of physical activation process (Ahmed and Theydan, 2012).

2.5.4 Factors Affecting Production of Activated Carbon

In production of activated carbon, several aspects need to be followed in order to ensure that the product had been made achieve the standard quality that can produce optimum performance for any significant usage. The major factors that can affect the production of activated carbon includes the type of impregnating agent, the carbonization temperature and the time taken during the carbonization of activated carbon. All of these parameters significantly affect the developments of pore volume and pore size distribution during reaction take place.

2.5.4.1 Impregnating Agent

Impregnating agent or called as activating agent generally functions as hydrating materials and promotes the crosslinks formation. Both of physical and chemical activation use activating agent to activate the properties of the carbon. In physical activation, it shows that the presence of steam and air as activating agents perform really well in term of reaction time because it has been proved that the reaction of steam and air together with carbon are 8 and 10 times respectively faster compared to reaction between carbon dioxide (CO₂) and carbon (Chowdury *et al.*, 2013). However in some condition, the activated carbon tends to burnout inside of the pore structure and also on the external surface due to aggressive reaction between air and the carbon. Consequently, dropping of yield strength of carbon might happen. Therefore, carbon dioxide (CO₂) is more preferable to overcome the problem and at the same time it also easier to be handled and cleaned.

In chemical activation, there are several types of reagents that commonly use to activate the carbon such as Zinc Chloride (ZnCl₂), Phosphoric acid (H₃PO₄), Sodium Hydroxide (NaOH), and Potassium Hydroxide (KOH). Each of the chemical activating agents gives different effect to the raw materials. For example in previous research on derivation of activated carbon from Holk oak acorn stated that Potassium Hydroxide (KOH) produces the highest percentage of micro-pore (Tezcan *et al.*, 2015).

In the other hand, chemical activation that using phosphoric acid (H_3PO_4) does not only affect the surface area and pore volume of activated carbon but also tailor the pore nature and size distribution (Örkün, Karatepe and Yavuz, 2012). Liou (2010) reported that there are some difference results occur after production of activated carbon using phosphoric acid (H_3PO_4) and Zinc Chloride ($ZnCl_2$). It was found that activated carbon that produced by using phosphoric acid had a mesopore structure but both heterogeneous micropores and mesopores was found at the surface of activated carbon that been produce by zinc chloride. Besides, activated carbon that impregnated by phosphoric acid has higher fixed carbon content than raw material but contain low fixed carbon content if it again be compared to the activated carbon that impregnated by zinc chloride. In a research by Yahya *et al.*, (2018) stated that *Hura Crepitans Linn* seed shell were using phosphoric acid and zinc chloride as activating agent, then the results obtained from the experiments showed that the percent yield of phosphoric acid zinc chloride activated carbon was 44.9% and 31.94% respectively.

2.5.4.2 Carbonization Temperature

Generally, temperature is one of the crucial factors during carbonization of activated carbon to produce high pore structure activated carbon. Basically, higher carbonization temperature leads to lower the yield production of activated carbon meanwhile it actually change the composition of activated carbon in term of lowering the moisture content and volatile matter content.

A study by Yorgun and Yıldız (2015) show the preparation of activated carbon from Paulownia wood by using several degree of temperature in range of 300°C to 600°C respectively with the present of phosphoric acid as activating agent. It also shows that increasing of BET surface area and pore volume during carbonization temperature at the range of 300°C to 400°C. However, it started to decrease when the temperature reaching from 400°C to 600°C. The temperature inside this range might have induced the shrinkage towards the structure of activated carbon itself.

2.5.4.3 Carbonization Time

Carbonization time is time taken for an organic substance to convert into carbon through pyrolysis process or destructive distillation. The period of time to produce activated carbon is actually important aspect because the adsorption rate quality of the activated carbon might be affected. If the carbonization time is too longer, the BET surface of activated carbon tends to decrease due to shrinkage of pores. Ünner and Bayrak (2018) in their study reported that during production of activated carbon from *Arundo donax* stated that when the carbonization time increases from 30 to 60 minutes with constant impregnation ratio show the surface areas of activated carbon increase linearly. However, the different trends are observed after it reached 60 minutes and more when the adsorption started to decrease.

Another research by Hosney *et al.*, (2015) shows that dehydration, decarboxylation and complete carbonization process during increasing of carbonization time usually produce carbon and non-condensable gases until it achieve the limit. After certain limit had been achieved, increasing of carbonization time does not effective anymore since the production of carbon dioxide also increase that actually lead to decreasing of carbon content during the production of the carbon.

2.6 Adsorption

Adsorption can be defined as the adhesion of atoms, ions or molecules from gaseous, liquid or any dissolved solid towards a surface. When this process occurs, a film of adsorbate creates on the surface of the adsorbent. Generally, adsorption process is differs from the absorption process which absorption happen when the absorbate is dissolved by or permeates the absorbent. Besides, the adsorption process only occurred and reaction took place at the surface of material while absorption process involves the reaction of whole volume of the material.

Similarly with the surface tension, adsorption also is a consequence of the surface energy. In a bulk material, all the bonding requirements including ionic, covalent or metallic bond of the constituent atoms are filled by other atoms. However,

the atom on the surface of the adsorbent usually not fully surrounded by the other atom therefore it actually can attract the adsorbate particularly. According to Ferrari *et al.*, (2010) stated that the adsorption process is generally classified as physisorption that show the characteristic of weak van der Waals forces or chemisorption that characterize as covalent bond. Both types of sorption might occur due to attraction of ions electrostatic. However, the exact nature of bonding only depends on the properties or characteristic of the species that involve in the adsorption process. In the other hand, adsorption can be presented in many natural, physical, chemical and biological systems and widely used in many applications especially in industrial industry like water purification, heterogeneous catalyst activated carbon, synthetic resins, increasing the storage capacity of carbide-derived carbons and others (Czelej *et al.*, 2016).

2.6.1 Adsorption Mechanism

The term of adsorption is firstly used by Kayser in 1881 in order to explain the condensation of gases on surfaces that actually contradict with the phenomena of gas absorption. It happens when the gas molecules penetrate the bulk phase of the absorbing solid. The mechanism of adsorption is an exothermic process that produces liberation of energy during adsorption. When one mole of adsorbate is adsorbed on adsorbent, it will evolve certain amount of heat known as enthalpy. The change in enthalpy is denoted to be negative due to the reason when adsorbate molecules are adsorbed on top of the surface, the molecules cannot move freely and become restricted due to limitation of space. Therefore, the entropy becomes decrease.

According to Bushra and Shahadat (2017) stated that the mechanism of adsorption involves the sorption of the sorbate molecules on the surface of the sorbents through molecular interactions, and penetration of sorbate molecules from the surface into the interior of the sorbent materials, either by monolayer or multilayer that can be shown in Figure 2.7. The phenomenon of adsorption commonly depended by various parameters or factors such as pH value, temperature, size or dosage of adsorbent and the surface morphology. At the same time, the sorbate concentration and structure also give significant affect toward the adsorption process.

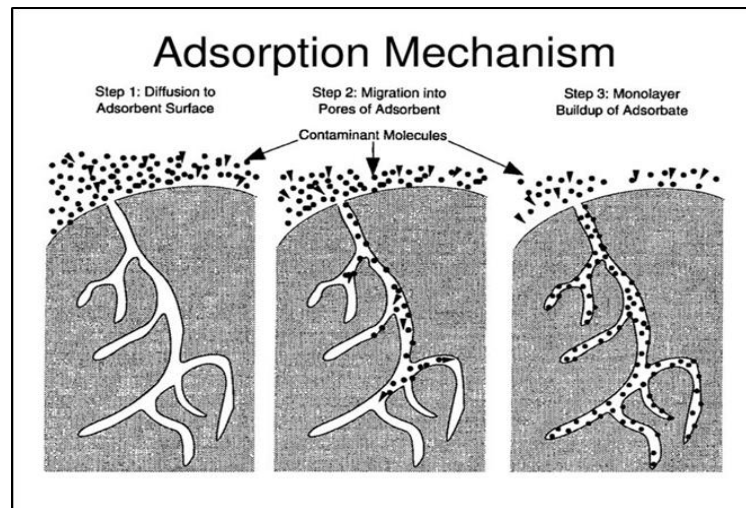


Figure 2.7: Adsorption mechanism

2.6.2 Adsorption Isotherm

A study by Patiha *et al.*, (2016) describe that adsorption isotherm is the process that create a thin layer or a film on the surface of the adsorbent whether in solid or liquid state by the adhesion of an adsorbate such as fluid, liquid or gasses. The reaction or called as bonding between the adsorbent and adsorbate can be happen either in physical or chemical bonding. In comparison, the physical bonding provides weaker bonding than the bonding from chemical reaction, and the film that been produced might in condition of single or multiple layers. In adsorption process, after saturation pressure has been achieved, it will slowly stop from making reaction anymore due to limited numbers of vacancies on the surface of adsorbent itself.

For developing an equation which represents the results accurately and which could be used as design purposes, it is important to analyze the adsorption data correctly. The linear regression was used in determination of most fitted models among all written isotherms (Gupta *et al.*, 2010). The equilibrium modelling of adsorption system have been widely used in term of isotherm equation, one of the equation that commonly used is Langmuir equation.

2.6.2.1 Langmuir Adsorption Isotherm

The Langmuir adsorption isotherm (Langmuir, 1918) is comes from the form of equation (2.1) as below:

$$\frac{C_e}{q_e} = \frac{C_e}{Q_o} + \frac{1}{Q_o b} \quad (2.1)$$

Where C_e (mg/ L) is the equilibrium concentration and q_e (mg/g) is the equilibrium adsorption capacity. The value of Q_o (mg/g) come from the maximum amount of pollutant per unit weight of adsorbent that present as complete monolayer at the top of the surface while and b (L/mg) is a constant that related to the affinity of binding sites with the pollutant.

2.6.3 Advantages of Adsorption

According to Rashed (2013) the adsorption process by using the solid adsorbents shows good potential among the possible techniques for the water treatments due to the high effectiveness in removal of organic contaminants from wastewater treatment process. Besides, adsorption has advantages compared to the other method due to the simplicity of the design that easy to be build and at the same time it involve low investment not only in term of cost but also it required small space area of land. Due to the effectiveness of the process, the adsorption process has been widely used to treat the organic and inorganic pollutants from the wastewater. In recent year, the trend to used low-cost absorbent that produce from natural materials, agricultural wastes and industrial wastes become more applicable due to cheaper price compared to expensive existing activated carbon. In fact, activated carbon that been produced from these waste not only have good pollutant-binding capacities but also can reduce the amount of waste that been dumped to the landfill.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter presents the methodology applied to carry out the experiments and analysis on performance of sugarcane bagasse activated carbon in removing oil and grease from wastewater. In section 3.2, description of materials and equipment are provided while in section 3.3, the further explanation is presented about the analytical method. Finally, in section 3.4 illustrated about the experiment set up throughout the study.

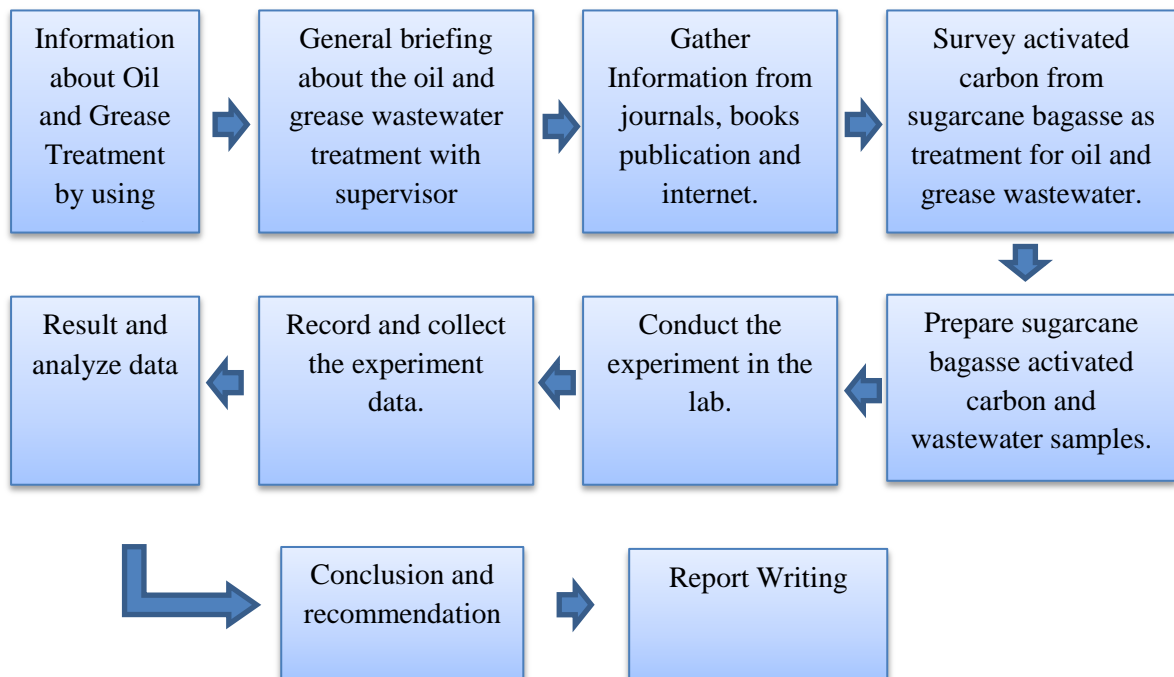


Figure 3.1: Research framework of the experimental work of study

3.2 Materials and Equipment

3.2.1 Wastewater

There are several types of wastewater that had been discharged everyday by human and the characteristic of the wastewater vary depending on the sources that it comes from. The types of wastewater include: the domestic wastewater that commonly discharged from the household kitchen, municipal wastewater that comes from residential or community area and last but not least the industrial wastewater that comes from industrial activities. In this study, the type of wastewater sample that been used was came from domestic wastewater. It had been taken from the Cafeteria Kolej Kediaman 3 located inside Universiti Malaysia Pahang (Gambang Campus). The reasons why the samples was taken from Cafeteria's discharged is to ensure that the oil and grease particles was exists in there before proceed for further experiment. Table 3.1 shows the initial properties of raw wastewater sample before it has been preserved.

Table 3.1: The Properties of Wastewater Samples

Parameter	Value	EQA 1974	
		Standard A	Standard B
Oil and Grease	26.0 mg/L	1.0 mg/L	10 mg/L
pH	5.06	6.0 – 9.0	5.5 – 9.0
Temperature	25.7 °C	40 °C	40 °C

3.2.2 Sugarcane Bagasse Activated Carbon

In this study, the adsorbent that been used as adsorbent to remove oil and grease from the wastewater was sugarcane bagasse activated carbon. Sugarcane bagasse was collected before the experiment begins and it had been taken from the agricultural waste product. Estimation of sugarcane bagasse that been used approximately about 2-3 kg. Then, the sugarcane bagasse that been collected was stored in room temperature before the experiment started to minimize any changes that might occur later. The bagasse that

came from the sugarcane was used to produce activated carbon in the laboratory for this study is shown in Figure 3.2.



Figure 3.2: Production of sugarcane bagasse activated carbon in laboratory

3.2.3 Chemical and Reagents

The chemical and reagents that had been used in the experiment are Sulfuric acid (H_2SO_4), Phosphoric acid (H_3PO_4), Hexane and Isopropyl alcohol (IPA). Sulfuric acid (H_2SO_4) and Phosphoric acid (H_3PO_4) were used to produce activated carbon from the sugarcane bagasse while Hexane and Isopropyl alcohol (IPA) were the chemical reagent that used to detect the present of oil and grease inside the wastewater sample that been taken. Besides, to adjust the pH value of the sample for the experiment regarding the effect of pH towards the adsorption rate, the acid and alkali that had been used were Sulfuric acid (H_2SO_4) and Sodium Hydroxide (NaOH). All of the chemical solutions had already been inside the environmental laboratory for the experiment purpose. However, due to the properties of the acid that has high corrosive reactions and the effects of getting cancer from the usage of hexane for this experiment, all of this reagent must be handled carefully with supervision of the lab technician. Table 3.2 below shows the list of reagent used in this study and their applications.

Table 3.2: List of reagent used in the study

Reagents	Application
Sulfuric acid	Used to separate the impurities such as dirt from the bagasse and also used to adjust the pH value of the samples.
Sodium Hydroxide	To adjust the pH value of the wastewater samples.
Phosphoric acid	Used as activation agent in activated carbon production.
Hexane	Used to extract oil and grease from the sample. It evaporates and the remaining residue left behind is defined as oil and grease.
Isopropyl alcohol	Used as cleaning solvent to clean the oil and grease residue that stick at the wall of the beaker and it totally evaporates without having any remaining residue.
Sodium sulphate	To separate the impurities clump from the oil and grease.

3.2.4 Equipment

In this study, the equipment that been used is as below:

Table 3.1: List of equipment and apparatus use for oil and grease adsorption experiment

Equipment	Application
Drying oven	Use to dry out the moisture from the raw bagasse for few hours at certain temperatures.
Furnace	A device that produce heat and have variety of functions such as melting steel and also as a heat treating to change the molecular structure of the things.
Analytical weight	A device that use to weight the material that will use for the experiment. It gives more accurate reading compared to manual weight balance.
Laboratory sieve	A metal utensil that use to separate the size of the particle depending on the opening size of the hole. The sieve size that be used for this experiment are 1.18mm and 600 μ m.
Desiccators	To absorb the water moisture of the sample in vacuum state so that the result that will record will more accurate.
pH meter	To detect the pH value of the sample solution either it acidic, neutral or alkaline condition.
Electrical shaker	A piece of laboratory equipment used to mix, blend, or agitate substances in tube or flask by shaking them to ensure that the reaction occur at optimum state.
Fume Hood	Designed as a ventilation device to limit the exposure of hazardous or toxic fumes, vapours or dusts towards the human respiratory system.
Water bath	To incubate the samples in water over long period of time at constant temperature and allow the evaporation of vapour to occur.

3.3 Analytic Method

Samples were collected prior to and after infiltration to compare the concentration of oil and grease that have passed through the medium of activated carbon in term of size of activated carbon, pH value effect and also the effect of contact time. Water samples were analysis within 24 hours after sampling. The laboratory analysis followed the Standard Methods for the examination of water and wastewater. The value of oil and grease that been filtered can be calculated by using equation 3.1: -

$$\text{Concentration of Oil and Grease} = \frac{(A-B) \times 1000}{\text{ml sample}} \quad (3.1)$$

Where,

A = weight of flask plus residue (mg)

B = weight of flask (mg)

The percentage of adsorptivity of the bagasse is calculated using equation 3.2: -

$$\text{Adsorptivity} = \frac{\text{Weight of sorbent containing fluid}}{\text{Initial weight of sorbent}} \times 100 \quad (3.2)$$

The equilibrium modelling of adsorption system have been widely used in term of isotherm equation, one of the equation that commonly used is Langmuir equation. The Langmuir adsorption isotherm (Langmuir, 1918) is comes from the form of equation 3.3 as below:

$$\frac{C_e}{q_e} = \frac{C_e}{Q_o} + \frac{1}{Q_o b} \quad (3.3)$$

Where C_e (mg L^{-1}) is the equilibrium concentration and q_e (mg g^{-1}) is the equilibrium adsorption capacity. The value of Q_o (mg g^{-1}) come from the maximum amount of pollutant per unit weight of adsorbent that present as complete monolayer at the top of the surface while and b (L mg^{-1}) is a constant that related to the affinity of binding sites with the pollutant.

3.4 Experimental Procedures

3.4.1 Activated Carbon

The process of preparing activated carbon was started by washing the bagasse with the diluted sulfuric acid (5%) to remove the adhered dirt. Then, the bagasse was washed again with distilled water to remove the soluble materials until it achieved natural effect. After that, the bagasse was put inside the oven with the temperature of 80°C for about 4 hours. After the bagasse completely dry, the bagasse was impregnated with phosphoric acid solution with the ratio of 25.0 gram of sugarcane bagasse with 100 ml of acid (85%). The impregnated sugarcane bagasse then subjected to carbonization inside the furnace at temperature of 550°C for about 3 hours. When the carbonization process was done, the bagasse became activated carbon and cooled in room temperature before it washed again with distilled water and dried in the oven at 100°C for about 4 hours until it reach constant weight. Finally, the activated carbon was grounded and sieved with the size of 1.18mm and 600µm for experimental used.



Figure 3.3: The process of sugarcane bagasse activated carbon

3.4.2 Domestic Wastewater Sampling

The sample of wastewater that been used for this study came from the kitchen household wastewater at student cafeteria of Kolej Kediaman 3 in Universiti Malaysia Pahang (Gambang Campus). The quantity of the kitchen wastewater was about 25 liter and the sampling was done during the peak hour of cafeteria operation because at that particular hour, the cafeteria produced the discharge which contained high concentration of oil and grease. Then the wastewater sample had been taken to environment laboratory and preserved by using sulfuric acid (H_2SO_4) to maintain the properties inside the wastewater. For preservation, the 1:1 sulfuric acid (H_2SO_4) been used with the ratio of 2.5ml of acid for every 500ml of wastewater sample. The samples were stored inside the chiller until it ready to be used for experimental purposed. However, the sample valid for 28 days only after the preservation was done.



Figure 3.4: The wastewater sample from Cafeteria Kolej Kediaman 3, UMP Gambang

3.4.3 Oil and Grease

The concentration of oil and grease was determined by using appropriated method that can be used to test all type of water and wastewater. For the oil and grease experimental procedures, the conical flask was washed and dried inside the oven for an hour before been put into desiccator for about 24 hours to ensure that no presence of moisture inside the conical flask. Then, the initial weight of conical flask was weighted and the reading was recorded. After that, 500ml of wastewater sample was poured into the conical flask and 2.5ml of 1:1 ratio of sulfuric acid was put into the sample. Then, the procedure was proceed by pouring 30ml of Hexane in the sample and it was shaken rigorously for two minutes. For every 30 second within the two minutes of shaking, the gas vapour of the sample was released to allow the evaporation of Hexane from the sample. After few minutes, a layer of oil was formed separately at the top of the sample, before the bottom part of water sample was allowed to flow out slowly until only the layer of oil was remained. After that, small amount of isopropyl alcohol (IPA) was added to detect the visibility of oil and also to separate it from the impurities that contains inside the oil layer.

The same steps were repeated for three times starting from the addition of Hexane. A spoon of Sodium sulphate was put inside the conical flask to clod the excess impurities then the sample was filtered by using filter paper. Then the flask was put inside the water bath at temperature of 80°C for an hour before dried inside the oven with temperature of 103°C for two hours. Finally, the flask was allowed to cool down for couple of minutes before put inside the desiccator for between 30 minutes until 24 hours. The final weight of conical flask with residue was taken and recorded. Figure 3.7 show the experimental set up for oil and grease extraction from the wastewater sample.

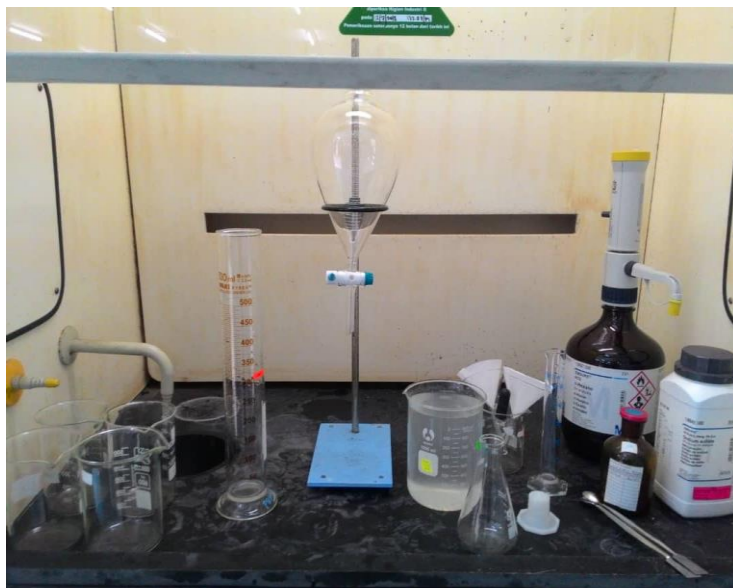


Figure 3.5: Oil and Grease experimental set up

3.4.3.1 Determination of Optimum Dosage

In order to determine the optimum dosage of adsorbent for oil and grease removal, there were two sizes of sugarcane bagasse activated carbon that had been used, which were 1.18mm and 600 μ m. For every size, different dosages of activated carbon need to be prepared and weighted, which were 0.6g, 1.0g, 3.0g and 5.0g by using analytical weight scale for accurate reading. The initial weight of conical flask was weighted and recorded before 0.6g of activated carbon was added into 500ml of wastewater sample. Then, the solution was put inside the electrical shaker with agitation speed of 150rpm for an hour to ensure constant reaction occurred.

After that the experiment was proceed with the oil and grease experimental process. The beaker then was put inside water bath for an hour to allowed evaporation to occur before it was dried in oven for another two hours. Finally, the conical flask was weighted using analytical balance and the reading was recorded. To determine the optimum dosage, both weight of initial and final weight of conical flask were recorded. The experiment was repeated with the same step for 1.0g, 3.0g and 5.0g of each size of activated carbon respectively. Figure 3.7 shows the sugarcane bagasse activated carbon been weighted according to dosage.

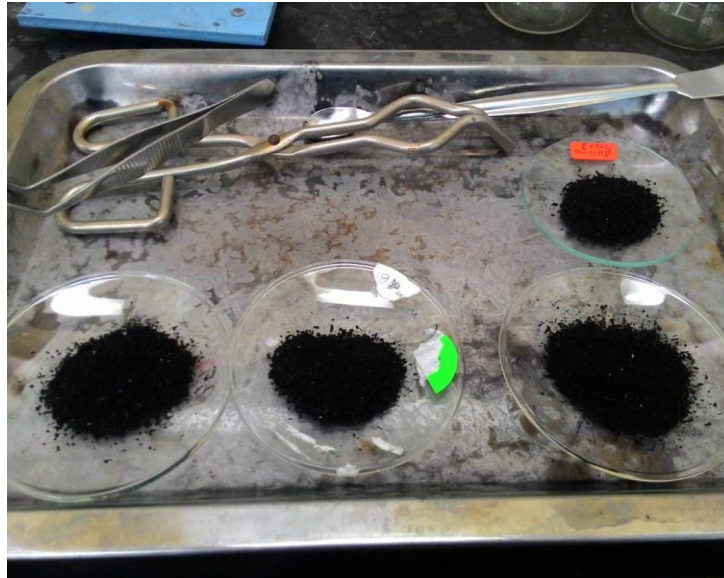


Figure 3.6: The sugarcane bagasse activated carbon been weighted according to dosage

3.4.3.2 Determination of Optimum pH Effect

For the effect of pH value towards the percentage of adsorption experiment, firstly the blank conical flask is weighted and the reading was recorded before 500ml of wastewater samples was put into conical flask. Then, the pH meter was used to detect the pH value of the samples. The pH values that were used for this experiment were pH 2.0, pH 4.0, pH 6.0 and pH 8.0. To adjust the pH value, sulfuric acid (H_2SO_4) and alkaline solution sodium hydroxide (NaOH) was used. After the pH value has been achieved, the optimum dosage of 3.0 g was added into the samples. Then the sample was put into the electrical shaker for an hour with agitation speed of 150 rpm to ensure the optimum adsorption occurred.

The experiment was proceed with the procedure of oil and grease detection to extract the oil and grease pollutant from the wastewater sample. The beaker then put inside water bath for an hour to allowed evaporation to occur before it was dried in oven for another two hours. After that, the conical flask with oil and grease residue was

weighted again and the reading was recorded. The value of optimum pH required was shown by the highest percentage of adsorption that been calculated. The experiment had been continued and repeated by using other pH values that were pH 4.0, pH 6.0 and pH 8.0.

3.4.3.3 Determination of Optimum Contact Time

For the effect of contact time towards the percentage of adsorption experiment, there were 5 different ranges of contact time that were used starting from 15 minutes, 30 minutes, 60 minutes, 90 minutes and 120 minutes. At first, the initial concentration of oil and grease was detected using the same procedure method from the optimum dosage and optimum pH experiment previously. Then, this time the optimum dosage of activated carbon was put into each of all 5 beakers that contain 500ml wastewater samples. After that, all of 5 beakers were put inside the electrical shaker with agitation speed of 150 rpm. 15 minutes later, took one of the beakers to proceed with oil and grease experiment. The beaker then was put inside water bath for an hour to allowed evaporation to occur before it was dried in oven for another two hours. The weight of conical flask with the oil and grease was weighted and been used to calculate the percentage of adsorption. Finally, the procedure was repeated with another sample after 30 minutes, 60 minutes, 90 minutes and 120 minutes of contact time respectively. The same procedure was repeated again by using granular activated carbon. Figure 3.8 shows the samples of wastewater before the different dosage of activated carbon was added.



Figure 3.7: The samples of wastewater

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This research is to determine the performance of sugarcane bagasse activated carbon in removing oil and grease from the domestic wastewater. To determine the performance of sugarcane bagasse activated carbon in removing oil and grease, the size, dosage, pH value of the samples and the contact time have been manipulated. This chapter will discuss about the result and the data analyzation from the research to accomplish the objectives of the study.

4.2 Optimum Dosage

In order to find the optimum percentage of adsorption for both sizes of sugarcane bagasse activated carbon (SBAC) which are 600 μm and 1.18mm, the dosage value of adsorbent has been manipulated into 4 different values of dosage. At the same time, the values of contact time, temperature, agitation speed, initial pH value and volume of wastewater already been fix to a constant values of 60 minutes, $29 \pm 2^\circ\text{C}$ or room temperature, 150rpm, pH 5.0 and 500ml respectively to ensure that the result that been got is more accurate. Table 4.1 shows the result on effect of dosage towards the percentage of adsorption. While table 4.2 indicates the Langmuir isotherm result in term of adsorbent dosage.

Table 4.1: Effect of dosage towards the percentage of adsorption

Size	Dose (g)	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
600 μ m	0.6	45.0	25.0	44.44
	1.0	32.0	14.0	56.25
	3.0	64.0	24.0	62.50
	5.0	21.0	9.0	57.14
1.18mm	0.6	66.0	48.0	27.27
	1.0	38.0	22.0	42.11
	3.0	28.0	13.0	53.57
	5.0	32.0	15.0	53.13

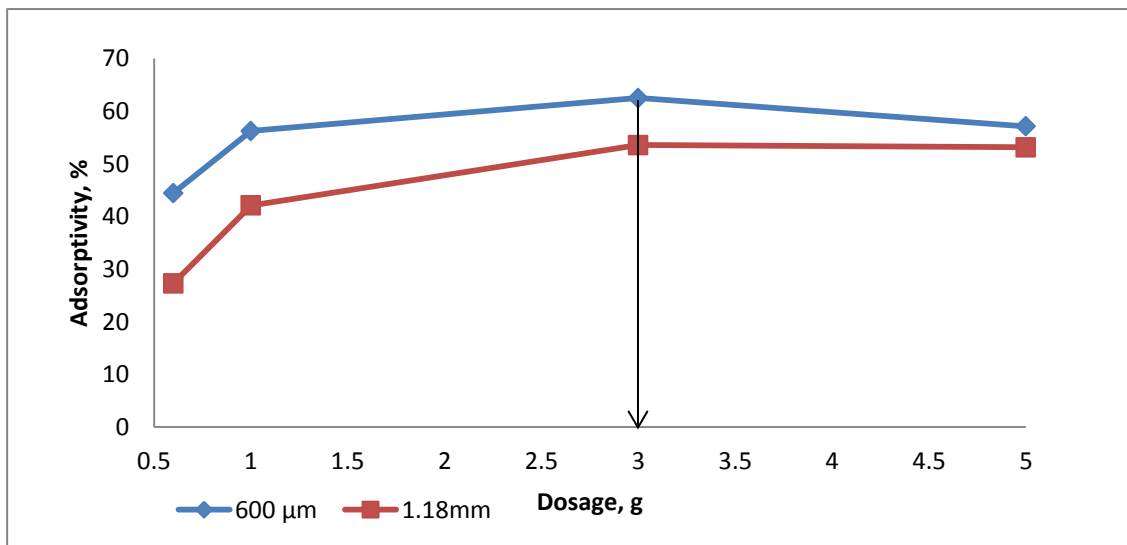


Figure 4.1: Comparison of percentage of adsorption between the two sizes of adsorbent in term of dosage.

As shown in Figure 4.1, the dosage weight and size of sugarcane bagasse activated carbon (SBAC) affect the percentage of adsorption. 600 μm of SBAC has higher percentage of adsorption compare to 1.18mm of SBAC. This is because 600 μm of SBAC have larger surface area that can absorb and react with more oil and grease molecules at top surface of SBAC compare to 1.18mm of SBAC that contain limited surface on top of the adsorbent. Based on the graph obtained, the sizes of 600 μm and 1.18 mm of SBAC have achieved optimum percentage of adsorption when 3.0g of both sizes been added into wastewater samples. The result suggests that all SBAC have an ability to absorb the oil and grease from the wastewater samples. Moreover, the effectiveness of the SBAC is depends on the surface area of the adsorbent that can absorb the oil and grease molecules from the wastewater samples.

Table 4.2: Langmuir isotherm result in term of dosage (g)

Size	Dose (g)	C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	C_e / q_e	Q_o	b (L /mg)	R^2
600 μm	0.6	45.0	25.0	16.67	1.50	-0.2286	7.6518	0.3994
	1.0	32.0	14.0	9.00	1.55			
	3.0	64.0	24.0	6.67	3.60			
	5.0	21.0	9.0	1.20	7.50			
1.18mm	0.6	66.0	48.0	15.00	3.20	-0.0964	7.3536	0.3163
	1.0	38.0	22.0	8.00	2.75			
	3.0	28.0	13.0	2.50	5.20			
	5.0	32.0	15.0	1.70	8.82			

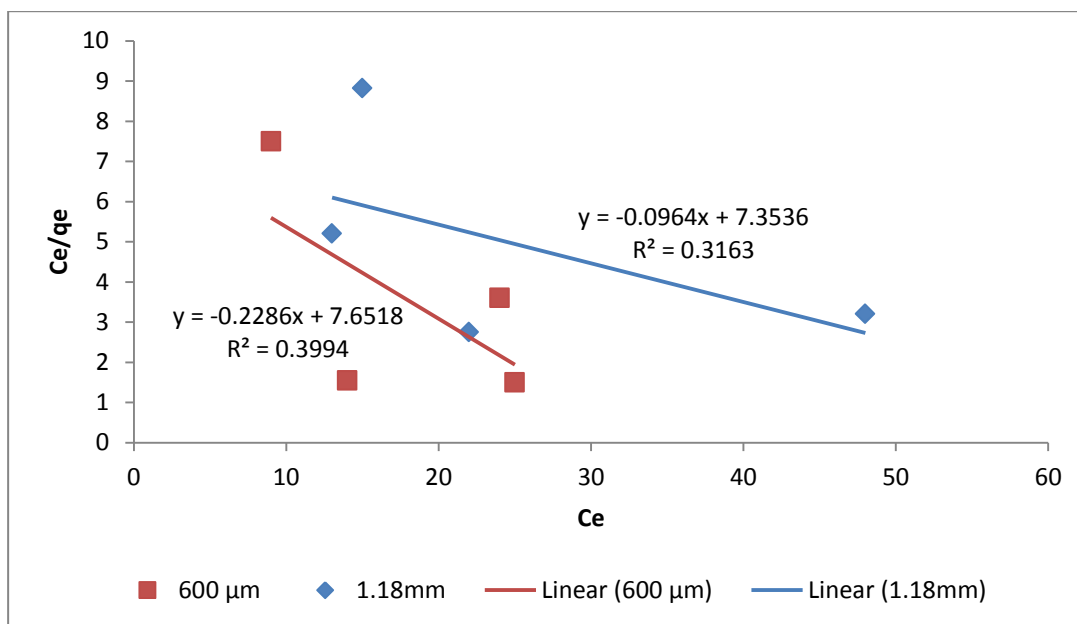


Figure 4.2: Langmuir isotherm plots for the two sizes of adsorbent in term of dosage

Figure 4.2 shows the trend of graph and value of R^2 using Langmuir Isotherm approach. For both sizes of SBAC, the graph shows inversely proportional trend respectively. Although the value of equilibrium parameter, R^2 for 600 μm is 0.3994 larger than the value of R^2 from the size of 1.18mm that is 0.3163 but both values of R^2 still favourable for Langmuir isotherm studies. By comparing the values of R^2 between 600 μm and 1.18mm of SBAC in term of optimum dosage, the most suitable and best fitted Langmuir isotherm model is the graph plotted by 600 μm size of adsorbent.

4.3 Optimum pH Value

In term of pH value study, different pH levels were used to get the optimum percentage of adsorption. Meanwhile, the values of contact time, temperature, agitation speed and volume of wastewater already fixed to a constant values of 60 minutes, $29 \pm 2^\circ\text{C}$ or room temperature, 150rpm and 500ml respectively. The value of dosage that been used was 3.0g for both size of SBAC which were 600 μm and 1.18mm that had been got from previous experiment. Table 4.3 indicated the result that showed the effect

of pH value of samples towards the percentage of adsorption. Table 4.4 shows Langmuir isotherm result in term of pH value.

Table 4.3: Effect of pH value of samples towards the percentage of adsorption

Size	pH value	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
600 μ m	2.0	24.0	18.0	25.00
	4.0	52.0	28.0	46.15
	6.0	114.0	68.0	40.35
	8.0	142.0	92.0	35.21
1.18mm	2.0	31.0	27.0	12.90
	4.0	57.0	35.0	38.59
	6.0	103.0	48.0	53.39
	8.0	89.0	40.0	55.10

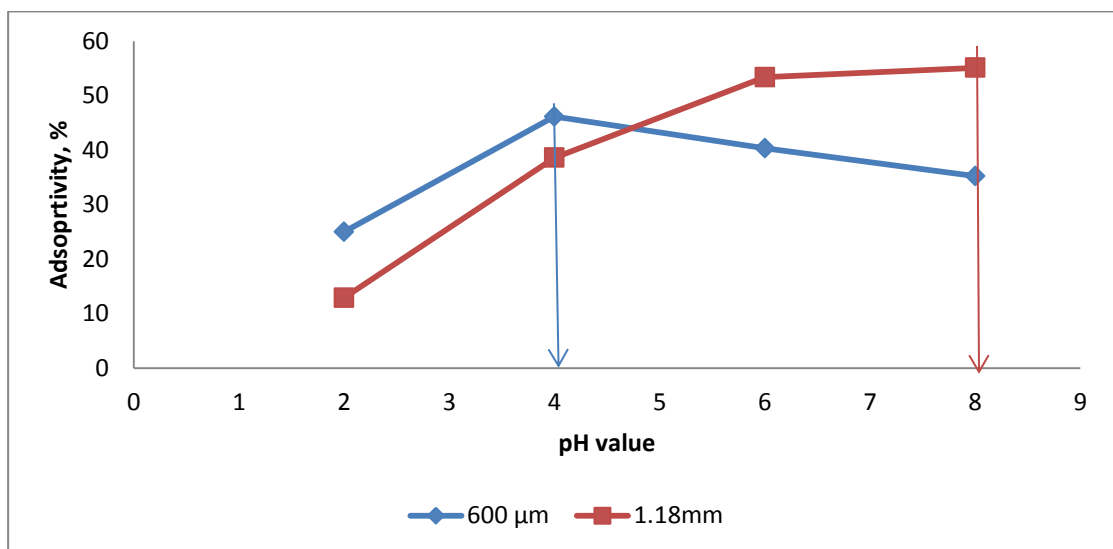


Figure 4.3: Comparison of percentage of adsorption between the two sizes of adsorbent in term of pH value of samples

Figure 4.3 compares the percentage of adsorption between sizes at different initial pH values of wastewater samples. The dosage value that been used was 3.0 g for both SBAC sizes. It was observed that the size of 600 μm achieved the highest value of percentage of adsorption at 46.15 % when the adsorbent reacted with the wastewater sample that had pH value of 4.0 and constantly decreasing when the value of pH is increased. However, 1.18mm of SBAC graph shows different trend when the increasing in percentage of adsorption happened simultaneously with the increasing of pH value. The highest percentage is achieved at 55.10 % during the adsorbent reacted with pH 8.0 of wastewater sample. From the result shows in graph, we can conclude that the pH value of the sample also effect the percentage of adsorption.

Table 4.4: Langmuir isotherm result in term of pH value

Size	pH	C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	C_e / q_e	Q_o	b (L /mg)	R^2
600 μm	2.0	24.0	18.0	1.00	18.00	-0.0485	13.726	0.1218
	4.0	52.0	28.0	4.00	7.00			
	6.0	114.0	68.0	7.67	8.87			
	8.0	142.0	92.0	8.33	11.04			
1.18mm	2.0	31.0	27.0	0.67	4.03	0.0043	5.7641	0.0002
	4.0	57.0	35.0	3.67	9.54			
	6.0	103.0	48.0	9.17	5.23			
	8.0	89.0	40.0	8.17	4.90			

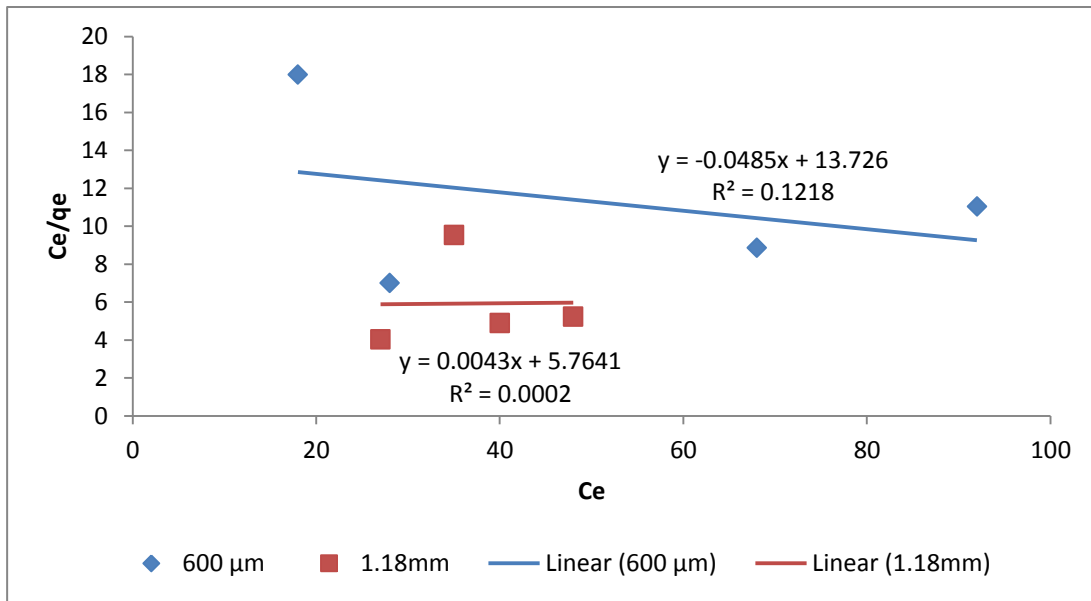


Figure 4.4: Langmuir isotherm plots for the two sizes of adsorbent in term of pH value of the sample

Figure 4.4 shows the value of R^2 using Langmuir Isotherm approach. It shows that the value of R^2 for 600 μm is 0.1218 larger than the value of R^2 from the size of 1.18mm that is 0.002. Although both R^2 values are favourable in term of equilibrium parameter, but in term of graph pattern it obviously shows different trend. For 600 μm of adsorbent shows inversely proportional graph pattern while for 1.18mm of adsorbent shows linearly proportional trend. By comparing both values, the most suitable and best fitted Langmuir isotherm model in term of pH value is the graph plotted on 600 μm size of adsorbent.

4.4 Optimum Contact Time

For this study, the value of contact time had been manipulated to determine the effect of contact time towards the percentage of adsorption. In order to achieve the result, some of variables need to be constant such as pH value and volume of wastewater sample, temperature, agitation speed and the adsorbent dosage. The values of the constant variables were pH 5.0, 500ml, $29 \pm 2^\circ\text{C}$ or room temperature, 150rpm and 3.0 g of adsorbent respectively for both sizes of SBAC. Table 4.5 shows the effect of contact time towards the percentage of adsorption while table 4.6 shows Langmuir isotherm result in term of contact time between adsorbent and wastewater sample.

Table 4.5: Effect of contact time towards the percentage of adsorption

Size	Contact Time (mins)	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
600 μ m	15	38.0	34.0	10.53
	30		30.0	21.05
	60		24.0	36.84
	90		18.0	52.63
	120		26.0	31.58
1.18mm	15	26.0	24.0	7.69
	30		16.0	38.46
	60		14.0	46.15
	90		14.0	46.15
	120		18.0	30.77

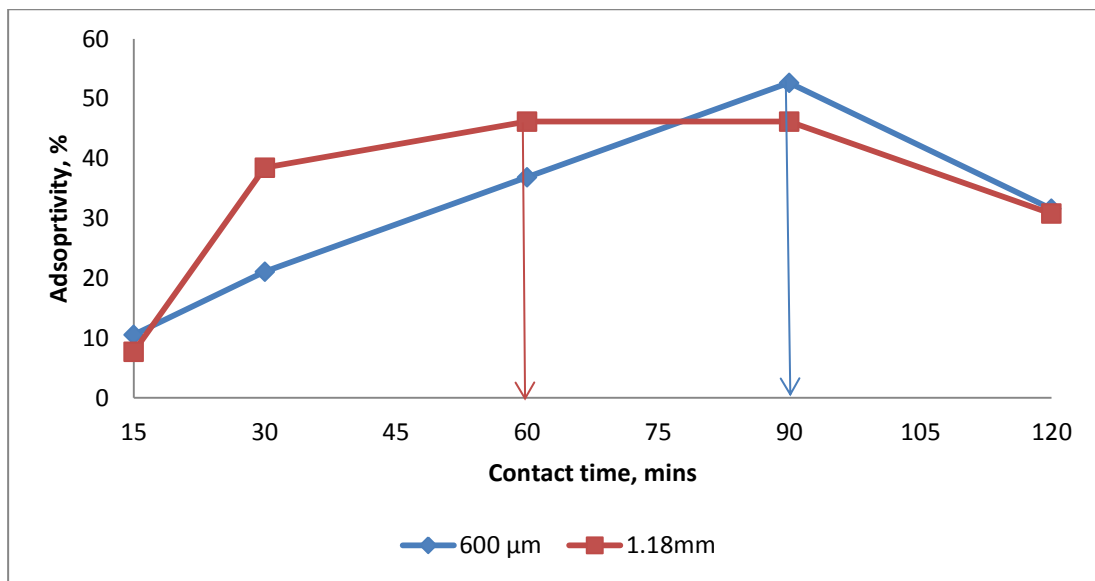


Figure 4.5: Comparison of percentage of adsorption between the two sizes of adsorbent in term of contact time

Figure 4.5 illustrates the contact time between the wastewater sample and the adsorbent affect the percentage of adsorption. It shows that adsorbent size of 600 μm gradually increase of adsorption capability and achieve the optimum percentage of adsorption during 90 minutes of contact time with value of 52.63%. Then, it drastically decreases until 120 minutes of contact time. Meanwhile, the percentage adsorption of adsorbent size 1.18 mm show the same trend but it reaches the optimum percentage of adsorption with the value of 46.15% during 60 minutes and remains until 90 minutes of contact time. However it decreases along the 90 minutes until 120 minutes of contact time.

Table 4.6: Langmuir isotherm result in term of contact time (mins)

Size	Contact time (mins)	C_o (mg/l)	C_e (mg/l)	q_e (mg/g)	C_e / q_e	Q_o	b (L/mg)	R^2
600 μm	15	38.0	34.0	0.67	50.75	2.6600	-49.8200	0.7967
	30		30.0	1.33	22.56			
	60		24.0	2.33	10.30			
	90		18.0	3.33	5.41			
	120		26.0	2.00	13.00			
1.18mm	15	26.0	24.0	0.33	72.73	6.5640	-90.3050	0.9251
	30		16.0	1.67	9.58			
	60		14.0	2.00	7.00			
	90		14.0	2.00	7.00			
	120		18.0	1.33	16.67			

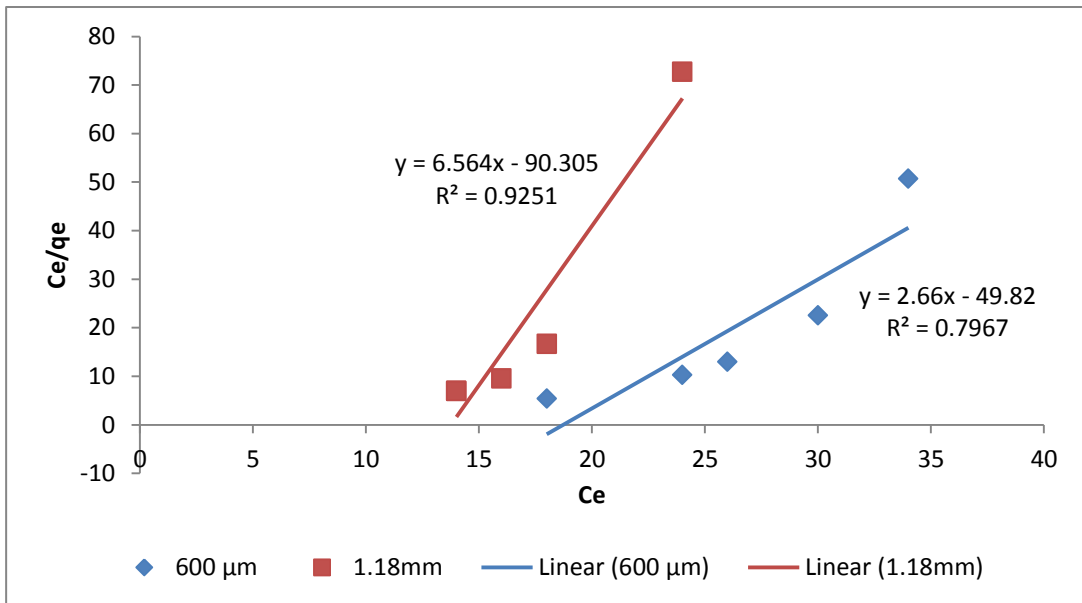


Figure 4.6: Langmuir isotherm plots for the two sizes of adsorbent in term of contact time

Figure 4.6 show the value of R^2 using Langmuir Isotherm approach. From the graph plotted show that the value of R^2 for 1.18mm size of adsorbent is 0.9251 larger than the value of R^2 from the size of 600 μm that is 0.7967. By comparing both values, the most suitable and best fitted Langmuir isotherm model is the graph plotted on 1.18 mm size of adsorbent. Both of the line graph show similar trend which are linearly proportional.

4.5 Discussion

The study was basically to determine the performance of sugarcane bagasse activated carbon in removing oil and grease from wastewater by manipulating the size, dosage weight, pH value and contact time. The different sizes of activated carbon which was granular size 1.18mm and powdered size 600μm happened to give different result in percentage of adsorption capability. For both sizes of 600μm and 1.18mm as stated in the section 4.2 shows that the highest percentage of adsorption gave by the dosage weight of 3.0g. This is due to adsorption of oil towards the surface of adsorbent. In fact, the amount of oil adsorption increase linearly with the increasing of adsorbent, however the adsorption was stop when the surface of the adsorbent be fulfilled with the oil molecules. In addition, the sugarcane bagasse chemically modified with the presence of

phosphoric acid as the activating agent that caused the structure of the bagasse changes. One of the characteristic of carbon that affects the percentage of adsorption is the pore texture.

The pH value of the wastewater samples also been manipulated to determine the performance of sugarcane bagasse activated carbon in removing oil and grease molecule. From the result that obtained in section 4.3, the comparison that show between the effect of pH value towards the adsorption percentage by using powdered and granular activated carbon were the percentage of adsorption for powdered activated carbon (600 μm) reached the maximum of 46.15% adsorption capacity when it reacted with pH 4.0 wastewater samples, while 53.39% of adsorption percentage was reached when the granular activated carbon (1.18mm) reacted with pH 6.0 of wastewater sample. However, this does not mean that oil and grease adsorption is effective for both pH values because during the studying the effect of pH, sulfuric acid (H_2SO_4) and sodium hydroxide (NaOH) was added into the wastewater samples to adjust the pH value. The addition of sodium hydroxide results in changes of chemical structure of the oil and grease molecules that affect the adsorption reaction. Therefore, when determining the oil concentration in the treated sample using petroleum ether, the oil concentration was to be less at pH 9.0 since the oil and grease was hydrolysed inside the wastewater sample and was not being extracted to the solvent. Hence, this gives advantage to the treatment process whereby the final discharge after adsorption will have a neutral pH. For this reason, no further adjustment of pH would require after this adsorption before the effluent could be discharged.

In term of effect of percentage of adsorption due to contact time, both powdered and granular activated carbon show the increasing of percentage adsorption along the contact time. The difference between the results can be show in section 4.4 where powdered activated carbon reached the maximum percentage of adsorption after 90 minutes of time contact with the sample with 52.63%. In meanwhile, the granular activated carbon that reacted with the sample reached the maximum percentage of 46.15% during the range of 60 to 90 minutes. After both of them reach the maximum adsorption percentage, the trend shows the decreasing affect. The reason of this phenomena happens is because when the adsorption percentage reached the maximum, it actually show that the surface of the adsorbent have been fully covered by the oil and

grease particle that form a layer on top of it. Hence, the adsorption rate became slower due to limited space of adsorbent that can adsorb the oil and grease particles.

For Langmuir isotherm studies, only the graph of optimum contact time shows the best fitted and most suitable to represent the isotherm reaction that effect the percentage of adsorption. It was due to highest value of equilibrium parameter, R^2 . Moreover, to get the best fitted Langmuir isotherm model, there are a lot of isotherm that must be followed. Since the oil and grease chemical compound is a bit complex due to the presence of multiple organic components, the use of Langmuir isotherm might be difficult (Sa *et al.*, 2016).

Sugarcane bagasse is a great material to adsorb oil, heavy metal, gas or dye because of its carbon content. The sugarcane bagasse that converted to activated carbon works most effectively as the adsorbent material. As to separate oil and water, method of adsorption is applied in this research. The combination of cellulose, hemicelluloses and lignin inside the bagasse is actually can adsorb hydrophilic and hydrophobic materials (Behnood *et al.*, 2016). Bagasse can attract both of them but it more effectively adsorb more hydrophobic material which is oil and grease compared to water adsorption. All of the performance will increase and more effective when the bagasse is chemically modified to produce activated carbon.

CHAPTER 5

CONCLUSION

5.1 Conclusion

In the present study, the performance of sugarcane bagasse in removing oil and grease from wastewater was explored. The usage of by product from production of sugar which was sugarcane bagasse was used to produce bio adsorbent activated carbon. In fact, the sugarcane bagasse has high carbon content with strong fibrous components in its structure that can be used for many other environmental purposes such as oil and grease removal. The sugarcane bagasse activated carbon or called as SBAC actually can replace the existing production of activated carbon due to the similar absorption performance that have been showed. Therefore, the cost to buy the activated carbon can be reduce significantly by using the bio adsorbent that produce from the sugarcane bagasse. The bio-adsorbent activated carbon can be used to absorb the oil and grease that comes from the wastewater that produce from residential area, commercial area or industrial area.

The following conclusions are drawn from the results obtained from the study:

1. Sugarcane bagasse can be used in production of activated carbon that has adsorption capability to absorb oil and grease particle.
2. Activated carbon that produced from sugarcane bagasse is effective in adsorbing the oil and grease molecules from the wastewater samples because it have high porosity characteristic that can absorb oil and grease particle.

3. The small particle size shows higher adsorption capacity compared to larger size particle because it provides more surface area that can absorb the oil and grease molecules.
4. The comparison between the percentages of adsorption that affected by pH values of wastewater sample for both size particles show different adsorption trend. This experiment actually did not give significant accurate reading. This was happened due to addition of acid and base solution inside the samples that changed the oil and grease particle composition that effect the concentration of oil and grease inside the sample.
5. In term of contact time, the result for both sizes of SBAC show increasing trend for a certain period of time before it became slower after it reached the optimum percentage of adsorption. Although, the powdered SBAC with 600 μ m size shows the higher percentage of adsorption compared to granular SBAC with size of 1.18mm but in term of contact time granular SBAC achieved the optimum contact time faster than powdered SBAC.

5.2 Recommendation

From this research, a lot of aspect must be taken to improve the result of the experiment. There are some recommendations that can be taken for further studies which are:

1. Varies adsorbent size, adsorbent dosage, pH value, and contact time to find more accurate optimum condition and discover the best performance for sugarcane bagasse activated carbon.
2. Use different isotherm model for isotherm studies to find the best fitted isotherm for sugarcane bagasse activated carbon
3. The sugarcane bagasse can be activated using many type of impregnating agents not only by using phosphoric acid but also zinc chloride, sodium hydroxide, potassium hydroxide and more.

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APPENDIX A
TEMPLATE OF DATA COLLECTION

OPTIMUM DOSAGE

Size of adsorbent : 600 μm Contact time : 60 mins
 Volume of wastewater: 500ml pH value : 5.0
 Temperature : 29 \pm 2°C (room temperature)

Dose (g)	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
0.6			
1.0			
3.0			
5.0			

Size of adsorbent : 1.18 mm Contact time : 60 mins
 Volume of wastewater: 500ml pH value : 5.0
 Temperature : 29 \pm 2°C (room temperature)

Dose (g)	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
0.6			
1.0			
3.0			
5.0			

PH VALUE

Size of adsorbent : 600 μ m Contact time : 60 mins
Volume of wastewater: 500ml Dosage : 3.0 g
Temperature : 29 \pm 2°C (room temperature)

pH value	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
2.0			
4.0			
6.0			
8.0			

Size of adsorbent : 1.18 mm Contact time : 60 mins
Volume of wastewater: 500ml Dosage : 3.0 g
Temperature : 29 \pm 2°C (room temperature)

pH	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
2.0			
4.0			
6.0			
8.0			

CONTACT TIME

Size of adsorbent : 600 μm pH value : 5.0
Volume of wastewater: 500ml Dosage : 3.0 g
Temperature : 29 \pm 2°C (room temperature)

Contact Time (mins)	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
15			
30			
60			
90			

Size of adsorbent : 1.18 mm pH value : 5.0
Volume of wastewater: 500ml Dosage : 3.0 g
Temperature : 29 \pm 2°C (room temperature)

Dose (g)	Concentration of Oil & Grease before adsorption C_o (mg/l)	Concentration of Oil & Grease after adsorption C_e (mg/l)	Percentage of adsorption (%)
15			
30			
60			
90			