Bamboo As Adsorbent For Removal of Methyl Orange Dye in Aqueous Solution

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DECLARATION

I hereby declare that the work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities of instituitions.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOL

%	Percentage
µm	Micrometre
BET	Brunauer–Emmett–Teller
cm^{-1}	Centimetre
COD	Chemical oxygen Demand
FTIR	Fourier-Transform Infrared Spectroscopy
G	Gram
HCL	Hydrochloric Acid
IUPAC	International Union of Pure and Applied Chemistry
KH_2PO_4	Monopotassium Phosphate
M	Molar
Mg/g	Milligram per gram
Mg/L	Milligram per litre
Mg/mL	Milligram per millilitre
mL	Millilitre
Mm	Millimetre
MO	Methyl Orange
$Na_2B_4O_7{\cdot}10H2O$	Borax
NaOH	Sodium Hydroxide
OH^-	Hydroxide
Ppm	Parts Per Million
SEM	Scanning Electron Microscopy
UV spectroscopy	Ultraviolet–visible spectroscopy

XRD	X-ray Diffraction
XRF	X-ray Florescence

Bamboo as Adsorbent for Removal of Methyl Orange Dye in Aqueous Solution

ABSTRACT

Bamboo is a multifunction plant because it can be used in construction, animal food, decoration landscape and any other usage. However, it become abundant and turns to be agriculture waste. Dyes are used in various types of industries such as textile, food, leather, paper and etc. Methyl Orange is one of dye that had been used in industry. As the industrial have develop and become more advance, the environment issues such as pollution become worse and need to be treated. The source of water supply usually had been polluted by the dye. Therefore, bamboos can be used as adsorbent for removal of Methyl orange (MO) dye. In this study, there are few parameters have been studied such as the effect of adsorbent particle size, adsorbent dosage, initial dye concentration, contact time and pH. The results showed that the adsorption of MO dye onto bamboo were optimum at adsorbent particle size of 0.125 mm, adsorbent dosage of 6 g, initial dye concentration of 150 mg/L, contact time of 24 hours and pH 7 with percentage removal of > 91 %. The equilibrium data was analysed using Langmuir and Freundlich adsorption isotherm model. The result showed that the equilibrium data was best fit to Langmuir adsorption isotherm model because the correlation coefficient is nearest to 1 and with maximum adsorption capacity was 1.688 mg/g. This study indicates that bamboo can be used as adsorbent for the removal of MO dye in water effluent.

Key word: Bamboo, Methyl orange, waste water treatment, Langmuir and Freundlich.

Buluh sebagai Penjerap untuk Peyingkiran Warna Metil Jingga dalam Larutan Akueus

ABSTRAK

Buluh merupakan tumbuhan pelbagai guna yang boleh digunakan untuk pembinaan, makanan haiwan, perhiasan landskap dan kegunaan yang lain. Walaubagaimanapun, lambakan buluh bertukar menjadi sisa pertanian. Pewarna digunakan dalam pelbagai jenis industri seperti tekstil, makanan, kulit, kertas dan lain-lain lagi. Metil Jingga adalah salah satu daripada pewarna yang digunakan dalam industri. Oleh kerana industri telah berkembang dan menjadi lebih maju, isu-isu alam sekitar seperti pencemaran semakin teruk dan perlu dirawat. Kebiasaanya punca bekalan air telah tercemar oleh pewarna. Oleh itu, buluh dapat digunakan sebagai penjerap untuk penyingkiran pewarna Metil jingga. Dalam kajian ini, terdapat beberapa parameter yang telah dikaji seperti kesan saiz partikel penjerap, dos penjerap, kepekatan awal pewarna, masa sentuhan dan pH. Keputusan menunjukkan bahawa penjerapan pewarna MO ke atas buluh adalah optimum pada saiz partikel penjerap 0.125 mm, dos penjerap 6 g, kepekatan pewarna awal 150 mg/L, masa sentuhan 24 jam dan pH 7 dengan peratusan penyingkiran > 91%. Data keseimbangan dianalisis menggunakan model isoterma penjerapan Langmuir dan Freundlich. Keputusan menunjukkan bahawa data keseimbangan adalah paling sesuai dengan model isoterma penjerapan Langmuir kerana pekali korelasi yang paling hampir dengan 1 dan kapasiti penjerapan maksimum ialah 1.688 mg/g. Kajian ini menunjukkan bahawa buluh boleh digunakan sebagai penjerap untuk penyingkiran pewarna MO dalam efluen air.

Kata kunci: Buluh, Metil jingga, rawatan air, Langmuir and Freundlich.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The high usage of dyes in industries become something serious due to global demand of textile products that can cause environmental problem and the pollution of dyes in aqueous solution is getting higher day by day. Basically, all industrial that used dye, will discharge toxic effluent without any treatment to nearest river, pond or water stream. The effect of dye effluent is highly toxic in nature as it contains high suspended solid, dye, and chemical that has heavy metals. Usually, the contamination of the surface and ground water can be dangerous, carcinogenic or mutagenic to living organisms (David Noel, 2014).

There are several techniques of dye removal that had been classified by chemical, physical and biological methods. The adsorption technique is included in physical methods had been chosen because of this technique is cheap and environment friendly. Technique of adsorption takes place when molecules in a liquid bind themselves to the surface of a solid substance. Adsorbents have a very high internal surface area that permits adsorption. This technique has more benefits compared to chemical and biological methods that involve of high investment and functional costs. Adsorption technique is the most common technique because of the treatment of material can be in many sources such as natural sources, agriculture waste and others (Ravi V. K., 2016).

There are so many dyes pollution of water such as methylene blue, reactive orange, congo red and others. However, one of the common dyes that had been used is Methyl Orange. The IUPAC name of Methyl Orange is Sodium 4-[[4-(dimethylamino)phenyl] diazenyl] benzene sulfonate. The presence of Methyl Orange can cause of toxicity and persistence. The discharge of methyl orange in water stream can cause a threat to physic-chemical properties of fresh water and to aquatic life (Munagapati, 2016).

Bamboo is one of economically plantation can be found in Malaysia. This is because of it is low cost and sustainable which is it can be harvested without damaging the original plant and grow faster than a tree. It has been reported as inexpensive and effective adsorbents for removal of dyes. The efficiency of low-cost adsorbents depends on the characteristics and particle size of the adsorbent, and the characteristics and concentration of the adsorbate (Thuy, 2012). Any part of bamboo can be applied as adsorbent in removal process because of their ability to adsorb particular dye in solution.

The studies of bamboo raw as adsorbent will be observed by few parameters such as the particle size of adsorbent, initial dye concentration, contact time, adsorbent dosage and pH. The adsorption isotherm that has been used in this study is Langmuir and Freundlich to determine the adsorption favourability for the assumption for monolayer and multilayer adsorption. Lastly, the characterisation of bamboo was studied by using Fourier-Transform Infrared Spectroscopy (FTIR) and Scanning Electron Microscopy (SEM).

1.2 Problem Statement

Bamboo is sustainable plant growth in Malaysia since it is grown without pesticides or chemical fertiliser. It also type of grass that grows from its root so it is quickly grows and only takes a few years to mature. Nowadays, bamboo is one of agriculture waste and it became abundant and no value since it is fast growing. So that, in this study bamboo raw has been used as a raw material to remove dye since it is one of a good adsorbent. Dye can contribute to water pollution which is a small quantity of dye in water that less than 1 ppm can be highly visible. Methyl orange dye had been used in textile industry, food industry and biopharmaceutical industry. It is acidic dye that can cause vomiting and diarrhea and do not fit for human consumption. However, methyl orange must be removing from aqueous solution since the high level of exposure to methyl orange can cause to death (Azlan Kamari, 2017).

1.3 Objectives

The objectives of this study are;

i. To study the potential of bamboo raw as adsorbent for removal of methyl orange dye in aqueous solution.

ii. To determine the optimum parameters and suitable adsorption isotherm for the removal of methyl orange using bamboo raw as an adsorbent.

iii. To determine the functional groups and surface morphology of the bamboo using FTIR and SEM, respectively.

1.4 Scope of Study

Bamboo raw was collected from Agropark of Universiti Malaysia Kelantan and then was grinded to become powder form. Several parameters were studied such as the effect of particles size, the effect of adsorbent dosage, the effect of initial dye concentration, the effect of contact time and the effect of pH. The suitable of Langmuir and Freundlich adsorption isotherm were used to determine the adsorption favourability. Bamboo powder was characterised using Fourier-Transform Infrared Spectroscopy (FTIR) to determine the functional groups and Scanning Electron Microscopy (SEM) to study the surface morphology.

1.5 Significance of Study

The removal of dye is needed because dye is one of the causes of environment pollution. There are so many types of dyes such as organic dye and synthetic dye that had been used. Based on the journal referred about 10-15% dyes are released since the percentage of synthetic dye does not bind and went into the environment during dyeing. Dyes usually have potential hazard to living organisms and undergo degradation to form products that are highly toxic and carcinogenic. The effect of dye to environment such as reduction in dissolved oxygen level and thus affects the aquatic microorganisms. The carcinogenicity of azo dyes has been linked to bladder cancer in humans and cause of chromosomal aberration in mammalian cells (Selva Raj et al., 2011).

The techniques of adsorption had been chosen since it is low cost and more effective than other methods such as chemical methods and biological methods. Since other techniques produce large volume of sludge and the waste must be reduce due to avoid environmental pollution. The bamboo is readily available material and it is sustainable. Therefore, it is a good adsorbent to be used for removal of methyl orange in aqueous solution.

CHAPTER 2

LITERATURE REVIEW

2.1 Bamboo as Adsorbent

In Malaysia, bamboo is one of beneficial products in rainforest hardwoods. Bamboo is not a wood but bamboo is from the grass family Gramineae and sub family of Bambusoidae (Figure 2.1). It is sustainable plant since it is a quick-growing plant on Earth. However, the growth rate is dependent on soil and climatic condition even though it can be grown in most of climates. The common cultivated bamboo’s typical growth rate in temperate climates is in range 3-10 centimetres during their growing period. Usually, based on the species the lifespan of a bamboo is only about 20 years while it flowers once every 7 to 120 years. There are over 1200 species of bamboo over the world except Europe which is divided in geographically into Asia-Pacific zone, the America zone, and the African zone and some of them are still undeveloped places to discover. However, it also has a greater yields of raw material to use and can be utilize for many purpose (Essay, 2013).

Figure 2.1: Bambusoidae

Bamboo consist their own of chemicals such as 40-44% of cellulose, 21-23% of pentosans, 26-28% of lignin, 1.7-1.9% of ash and 0.6-0.7% of silica. Bamboo is a composite material's structure because it has long and aligned cellulose fibers that immersed in a ligneous matrix. The distribution of the fibers is based on the cross section of a bamboo culm. The higher height of the culm represents the decrease of the thickness of wall. Fibers also can contribute between 60-70% of the weight of the bamboo for the density of bamboo (Jie, 2017). The mechanical properties of bamboo, it has specific gravity that measure of the density of a substance which is varies between 0.4-0.8. Usually heights of bamboo culms can achieved from 10-15 cm which is about 4-6 inches in the smallest species. However, bamboos produce seeds by their flower only after 12-120 years of it growth which is once in their lifetime and their reproduction is largely vegetative.

The seeds can be eaten as grain while the young bamboos of some species are eaten as vegetable. In addition, the shoots of bamboo are edible. Lastly, the bamboo raw that known for its hard stems can be used for a variety applications such as building constructions, furniture, flooring, flute, and even bicycle frame and others (Adam Augustyn, 2018). For example, bamboo can be used as construction because of the bamboo's tensile is stronger than steel and it withstands compression better than concrete. Chinese medicine is still using bamboo in treating and healing a disease since ancient time. It also a primary use to treat coughs and mucous in children (Rahul Shukla, 2012). Every part of bamboo can be used as adsorbent such as leaves, raw, shoot, and dust. For example, the removal of methylene blue is using bamboo shoot as an adsorbent (Hongmei, 2014). There are many studies that used parts of bamboo as adsorbent based on Table 2.1.

Table 2. 1: Summary of adsorption studies using the parts of the bamboo

No.	Adsorbate	Adsorbent	Adsorption capacities (mg/g)	Authors
1.	Bamboo in batch and in continuous system	Methyl Green dye	15.5	Atshan, (2014)
2.	Bamboo biochar	Metal-complex dye	19.51	Yang et al., (2014)
3	Bamboo sawdust	Direct red 81 dye	DR81-BSD (6.43) DR81-TBSD (13.83)	Khan, (2012)

2.2 Dye

Dyes are the most demanding raw material in all industries such as food, textile, leather, paper and others industrial to colour the products (Khan, 2012). Function of dye is provide bright and lasting when binding with fabric or surface because of it is a coloured substance that been used widely in all industries. There are some 9 000 colorants with more than 50 000 trade names are used. Dyes are known as the organic compounds that give colour because of it have at least one chromophore that colour-bearing group and visible spectrum at 400-700 nm. The characterisation of dye also when they have conjugated system for example structure with alternating double and single bonds and stabilizing force in organic compound which it actually to exhibit resonance of electrons. Auxochrome have a few functional groups such as hydroxyl (-OH), amino (-NH2), nitro (-NO2), akyl (-R) so that it can increase the color of compound. However, the chromophore has functional groups which are unsaturated and the compound to become coloured for example, -N=N-, -C=C-, -C=N- and –C=O. (Suthagar, 2015). Dyes give negative effects due to the discharge of dye-containing effluents. Those effluents are characterized by strong colours, high pH variations, high chemical oxygen demand (COD) and increased biotoxicity against bacteria (Porwal, 2015).

2.2.1 Classification of Dyes

There are so many ways that can classify all dyes because each of dye has their own unique chemistry, structure and particular way of bonding. The classification based on the source of materials, nuclear structure, industrial and chromophores that can produce the colour. Based on the chemical structure, dye can be classified to readymade dye and ingrain dyes. Readymade dyes are divided to water soluble dye such as direct dyes, acid dyes, basic dyes, reactive dyes and water insoluble dyes such as vat dyes, sulphur dyes, and disperse dyes while ingrain dyes such as azoic colors, oxidation colors and mineral colors (Puvaneswari, 2012).

However, generally dyes that had been used in textile industry also have been classifies according to their chemical structural such as azo dyes, nitro dyes, indigo dyes, anthraquinone dyes, phthalein dyes, triphenyl methyl dye, nitroso dyes. More specific information details of each dye class are based on the chemistry of the dye and the most common mode application (Benkhaya, 2017).

2.2.2 Azo Dyes

There are two types of dyes which are natural dyes and synthetic dyes. However, synthetic azo dyes are commonly used in industrials such as textile industry, pharmaceutical industry, plastic industry and others and represent over 60% of the total dye. The usage of azo dyes is due to their ease and cost effectiveness for synthesis as compared to natural dye. There are many different structures that possible but the azo dyes contain at least one nitrogen-nitrogen (N=N) double bond. When a diazonium ion reacts with either a phenol or an amine, which it is the coupling component is the way of an azo group is formed (Kiernan, 2009). The break down and metabolized of azo dye known as azo dyes.

Besides that, azo dyes can give bad effect to environment since they are carcinogenic, allergenic and mutagenic characteristics. Most azo dyes are carcinogenic due to their byproduct such as benzidine which it can cause to human and animal tumours. Next, the direct action of the agent itself or of the aryl amine derivatives generated during reductive biotransformation of the azo bond can give the toxic effect of the azo dyes (Chequer, 2013). Regulation, prevention and research due to azo dye must be done because of the spread pollution of azo dyes and their toxic aromatic amines in our environment to reduce the incidence of human disease and bad environment (Chung, 2016). The release of these synthetic azo-dyes in the environment has detrimental effect on all forms of life. The methyl orange dye is classified as azo dye because azo dye is a class of synthetic nitrogen-based dyes that produce bright reds, oranges and yellow.

2.3 Methyl Orange

The molecular formula of methyl orange is $C_{14}H_{14}N_3NaO_3S$ while the IUPAC Name of methyl orange is sodium; 4-[[4-(dimethylamino)phenyl]diazenyl]benzenesulfonate (Figure 2.3). The molecular weight of methyl orange is 327.334 g/mol. The physical description of methyl orange is orange-yellow powder or appears in crystalline scales. The chemical properties such as the solubility of methyl orange in water are less than 1 mg/mL at $64^{o}F$ (Pub Chem). Usually the function of methyl orange acts as pH indicator that used in titration since its clear and distinct colour variance at different pH values. At pH value less than 3.1, the colour of methyl orange become red and a pH values greater than 4.4, it will become yellow because of it changed due to indicator. The solution will be appearing orange in the range of pH between 3.1 and 4.4 (Mlsiasebs, 2012).

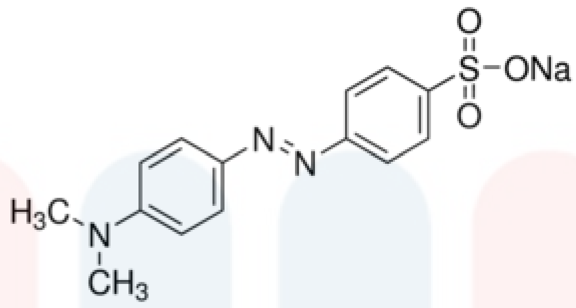


Figure 2. 2: Structure of Methyl Orange (Tapan et al., 2010)

Methyl orange will give bad effects to human health environment, clinical and laboratory. The expose of methyl orange can cause the bad effects to human health through inhalation and dermal contact. The common bad effect of irritation such irritation of the eyes. It also may be harmful if it absorbed through the skin and it also may cause irritation of the digestive tract if the toxic swallowed. Lastly, methyl orange that release to water streams will affect the ionic state of it make the compound essentially non-volatile and it cannot be degraded over several days in an aqueous BOD screening test. Compound of methyl orange is can resistant to aerobic biodegradation in both soil and water. However, under anaerobic conditions methyl orange should readily biodegrade because it may adsorb to clay sediments and particulate matter in the water due to ion-exchange processes. Table 2.2 shows the removal of methyl orange using different adsorbent.

Table 2.2: Summary of studies that used methyl orange as an adsorbate

No	Adsorbent	Equilibrium data model	Authors
1.	Calcium Alginate	Langmuir	Yujin Lia et al., (2012)
2.	Modified Local Clay (Kaolinite)	Freundlich	Fortunate Phenyo Sejie et al., (2016)
3.	Dragon Fruit (Hylocereusundatus) Foliage	Freundlich	Zahra Haddadian et al., (2013)
4.	Pumpkin seed powder.	Langmuir	Subbaiah, (2016)
5.	Date Stones Activated Carbon	Tempkin	Alqaragully, (2014)

2.4 Adsorption

Bind of molecules by the external surface or internal surface of solids or by the surface of liquids are known as a technique of adsorption. However, IUPAC define adsorption as the "Increase in the concentration of a substance at the interface of a condensed and a liquid or gaseous layer owing to the operation of surface forces." (Helmenstine, 2018). The adsorption occurs because due to unbalanced forces that has ability to attract and retain the molecular species (Adsorption, 2009). Inside the adsorbent, the forces acting between the particles are mutually balanced while on the surface area, the particles are not surrounded by similar atoms. Hence, they possess residual attractive forces. The molecular species that gets adsorbed on the surface is known as adsorbate and the surface on which adsorption occurs is known as adsorbent. Adsorbate gets adsorbed. This technique will be depending on nature of adsorbate and nature of adsorbent. It also is friendly to environment that avoid from making a large volume of sludge that rich in dye. In adsorption, adsorption can be divided into two types of adsorption which is physical and chemical adsorption. The physical adsorption is involved of the force of attraction, van der Waals between the solid adsorbent and the adsorbate molecules. Activation energy is not required because it is exothermic process. In the chemical adsorption, it is irreversible and usually occurs when gases are held to solid surface by chemical forces that are specific for each surface and each gas. The activation energy is needed due to chemical bond formation enthalpy of chemical adsorption is high and it can result in unimolecular layer. However, the chemical adsorption is slower process than physical adsorption. As we know methyl orange is dye that containing high concentration of azo dye and difficult to remove by biological method such as enzymatic treatment, function of survival anaerobic biomass and others (Bazrafshan, 2014).

2.5 Adsorption as Basis Dye Removal

Dye removal is needed to save the environment and human health. Nowadays, there are many kind presence of pollution that affects the quality of water. So, removal of dye materials becomes more important. The reason of removal dye is because a small quantity of dye does cause high visibility and undesirability. The techniques that can be used had been classified to physical, chemical, and biological. In biological of techniques, the major challenge associated with the treatment of wastewater containing dyes is related to degradation process. As the degradation capability is dependent on the different physical properties such as concentration and class of dye, pH, salinity and production of the end product that can be toxic. Different types of microbes have been employed under anaerobic environment for decolorizing the azo dyes and their compounds. It may be high cost other than techniques even though is economically feasible, environmental-friendly and generates less volume of sludge. Adsorption, ion-exchange, oxidation process and irradiation are the commonly used few of the physical methods that have been used for treating wastewater and have provided valuable results. Therefore, the adsorption that involve of physical and chemical techniques or both of the combination may provide effective technologies in removing dye because it can be cost effective and eco-friendly (Williams, 2006). The most applicable techniques of remove dye are adsorption because of the adsorbent in dye removal from wastewater as it is the most economical, the cheapest and effective method. For example, the materials that had been used widely like agricultural waste and industrial waste can be used with parameters factors such as particle size of adsorbent, contact time, adsorbent dosage, pH solution and initial dye concentration that will affect the process in removing dye (Razi, 2017).

2.6 Adsorption Isotherm

In this study an adsorption isotherm is a plot of solute adsorbed by a solid at a given temperature, against pressure, in the case of adsorbing on a solid or against concentration in the case of adsorption from solution. There a many types of adsorption types can be used such as Langmuir, Freundlich, Temkin and BET theory, but in this study Langmuir and Freundlich models are used.

Equation of Langmuir model is based on the relationship between the number of active sites of the surface by adsorption and pressure. Langmuir model have few assumption based of it theory such as adsorption is monolayer. There is no interaction between adsorbed molecules and adsorbed molecules immobile. However, this applicable on low pressure condition, since high pressure condition break down as gas can molecules attract more and more molecules towards each other.

The Equation 2.1 is Langmuir's isotherm model with its linear form respectively (Dada et al., 2012);

$$\frac{c_e}{q_e} = \frac{1}{q_{max}K_L} + \frac{1}{q_{max}}\ C_e \tag{2.1}$$

where,

q_e = amount of dye adsorbed at equilibrium (mg/g)

C_e = equilibrium concentration of the adsorbate (mg/L)

q_{max} = monolayer adsorption capacity of sorbent (mg/g)

K_L = Langmuir constant (L/mg)

C_e is the equilibrium is the equilibrium concentration (mg/L) of dye in solution while q_e is the absorbed amount of dye per specified amount of absorbent (g), K_F is the Langmuir equilibrium constant related to the free energy of adsorption and q_{max} is the monolayer adsorption capacity that required. A graph plot of Langmuir isotherm with C_e/q_e versus C_e should be form in a straight line.

The Freundlich isotherm is the most important multilayer adsorption isotherm for rough surfaces. It is a curve relating the concentration of a solute on the surface of adsorbent to the concentration of the solute in a liquid with which it is in contact. It gave an empirical expression representing the isothermal variation of adsorption of a quantity of gas adsorbed by unit mass of solid adsorbent with pressure. Freundlich adsorption equation also adsorption processes occur on heterogonous surfaces. Though Freundlich Isotherm correctly established the relationship of adsorption with pressure at lower values, it failed to predict value of adsorption at higher pressure. It also can be used for the surface heterogeneity and the exponential distribution of active sites and their energies with their Equation 2.2 (Aishah, 2010);

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \tag{2.2}$$

where,

K_F = constant value which related to adsorption capacity (mg/g)

$\frac{1}{n}$ = empirical parameter related to the adsorption intensity which depends on heterogeneity.

K_F is the Freundlich equilibrium constant relating to the adsorption capacity and 1/n is empirical parameter relating the adsorption intensity, which varies with the heterogeneity of the material. So that, the graph were plotted for both of parameter contact time and pH of log q_e versus log C_e should formed a straight line with slope 1/n and an intercept of log $K_{F.}$

2.7 Factor Affecting the Adsorption

The factor that effecting the adsorption of dye removal such as the particle size of adsorbent, the adsorbent dosage, the initial dye concentration, the contact time of adsorption and the pH. Parameter of adsorption can be used on a treatment process for degradation of dye. Based on the theory of affecting of removal dye, in contact time term, the dye removal rate increase with an increase in contact time to a certain extent. However, there is no more increment in increasing of contact time due to deposition of dyes on the available site on adsorbent material. It reached state of equilibrium as the amount of dye adsorbed at the equilibrium time reflects, the maximum adsorption capacity of the adsorbent under those operating conditions contact time between adsorbent and adsorbate significantly affecting the performance of dye removal (Atshan, 2014).

Next is the dosage of adsorbent in order to identify the capacity for amount of adsorbate in adsorption. Usually, the increase in dye removal along the increasing of adsorbent will be result to the increase of dye removal percentage. The control parameter must be given when carried out the effect of adsorbent dose on the adsorption process because of as the adsorbent dosage is higher, the more amount of sorption site at the adsorbent surface.

In particle size, the smaller particles size of adsorbent would be the higher percentage of dye removal due to surface area concept. The smaller size of adsorbent has more surface area for adsorption of dye. However, the effecting of dye adsorption based on the pH solution determines by the surface charge of adsorbent and degree of ionization and specification of adsorbate. For example, dye removal percentage for cationic dye will decrease at a low pH, while increment in percentage of dye removal for anionic dyes adsorption. In contrast, cationic dye that contains negative charge ion adsorption density preferred for high solution of pH and dye adsorption for efficiency of anionic dye will be lower due to electric repulsion increases (Mohammad Shafiqul Alam et al., 2015).

Lastly, the parameter that effect percentage of dye removal is the initial dye concentration. The increasing of in initial dye concentration will increase the adsorbent loading capacity due to the driving force of mass transfer become large. Therefore, it can be conclude that the adsorption is depends on the initial concentration of dye. Table 2.3 shows the factors that affecting adsorption studied based on the adsorbent and the type of removal.

Table 2.3 : Summary of factors that affecting adsorption studied based on various of adsorbent and adsorbate

Adsorbent	Type of removal	Parameter Factors					References
		pH	Contact Time	Initial dye Concentration	Adsorbent Dosage	Particles Size Adsorbent	
Natural clay	Methylene blue	pH 2	20 Minutes	_	1 g	_	(Mahammedi Fatiha, 2016)
Coconut fronds	Malachite green	pH 1	16 hours	50 mg/L	0.5 g	0.125 mm	(Rosmawani Mohammad, 2017)
Apricot stone activated carbon	Malachite green	pH 7	40 minutes	50 mg/L	_	0.300 mm	(Abbas, 2017)
calcined Lapindo volcanic mud	Methyl orange	pH 3	30 minutes	300 mg/L	0.25 g	_	(Aishah, 2010)
Thermally treated egg shell	Methyl orange	_	20 minutes	12.5 mg/L	2 g	5 mm	(Belay K., 2014)

CHAPTER 3

METHODOLOGY

3.1 Preparation of Bamboo Raw

The bamboo raw from Agropark, Universiti Malaysia Kelantan were collected and washed by distilled water to make sure all dust, dirt or any unwanted matters remove from bamboo raw. Then, the bamboo raw was dried had been put under sunlight to make sure it fully dry and unwanted moisture was removed in it. Bamboo raw were cut into smaller size so that it was easier for grinded and turned to powder.

3.2 Preparation of Adsorbate and Stock Solution

0.5 g of Methyl orange powder were being weighed and dissolved in 500 mL of distilled water so that methyl orange at concentration of 1000 mg/L were obtained.

3.3 Preparation of Calibration Curve

The stock solution of Methyl orange were diluted at concentration of 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0 mg/L with distilled water in 50 mL volumetric flask. Then, all the solutions of methyl orange at different concentrations were measured with UV spectrometer at wavelength of 464 nm (Mahsa Azami, 2012). Lastly, the absorbance reading was plotted to produce calibration curve and the final concentration of methyl orange were calculated based on the calibration curve.

3.4 Adsorption studies

3.4.1 Effect of Particles size

The bamboo raw powder was sieved at different particles size. There were three sizes of particles that were being used 0.71, 0.3, and 0.125 mm. Each of different sizes of particles samples were mixed with 100 mL of methyl orange at concentration 100 mg/L. Then, stirred it manually at beginning and kept at room temperature. The observations were taken after 24 hours.

3.4.2 Effect of Adsorbent Dosage

The optimum size of adsorbent obtained from previous experiment was used in this study. The study effect of adsorbent dosages used was studied at 0.5 g, 1 g, 2 g, 3 g, 4 g, 5 g, 6 g and 7 g. The adsorbent with different dosage were mixed with 100 mL of methyl orange at concentration of 100 mg/L. Then, the adsorption of methyl orange using bamboo powder was conducted at room temperature and being observed after 24 hours.

3.4.3 Effect of Initial Dye Concentration

Optimum adsorbent dosage and particles sizes that were obtained in previous experiment were used to study the effect of initial dye concentration. It proceed by mixed with 100 mL volume for each initial dye concentration at 30 mg/L, 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, and 300 mg/L. Next, the adsorption of adsorbate and adsorbent was conducted at room temperature for 24 hours and observation was recorded.

3.4.4 Effect of Contact Time

To study the effect of contact time, the samples were filtered for first 30 minutes, 1 hour, 2 hours, 4 hours, 8 hours, 16 hours, 20 hours, 24 hours and 28 hours.

This experiment was conducted by using the optimum adsorbent dosage, particle sizes and initial dye concentration that were obtained from previous experiment. The mixtures of adsorbent and adsorbate were being stirred at the beginning of the experiment and the observations were taken according the contact time.

3.4.5 Effect of pH

To study the pH effect, the buffer solutions were prepared according to delloyd.50megs.com. The optimum parameter from previous experiment had been used in this study. The effect of pH was studied started at pH 3, 4, 6, 7, 8, 9 and 10. The observations were recorded at optimum contact time that was obtained from the previous experiment.

Buffer solutions for pH 3-6 were prepared using the combination of 0.1 M sodium citrate and 0.1 M citric acid. Next to get the desired pH from pH 3-6, the volume of 0.1 M citric acid was adjusted. For pH 7 and 8 the mixture of 0.1 M potassium dihydrogen phosphate (KH_2PO_4) and 0.1 M sodium hydroxide (NaOH) were used; the volume of 0.1 M of NaOH was adjusted to get pH 7 and pH 8. Lastly, for pH 9 and pH 10 the mixture of 0.025 M of borax ($Na_2B_4O_7{\cdot}10H2O$) and 0.1 M of hydrochloric acid (HCL) were used and the volume of NaOH and HCL was adjusted to get pH 9 and pH 10.

3.5 Characterisation of Bamboo Powder

3.5.1 Fourier-Transform Infrared Spectroscopy (FTIR)

FT-IR uses an incandescent source of light to emit a bright ray in the IR wavelength range (Alawam, 2014). The importance of FTIR is to identify the functional groups of bamboo. 0.1 g of bamboo powder and the bamboo powder after adsorption process were analysed using FTIR to observe its functional group properties.

3.5.2 Scanning Electron Microscope (SEM)

SEM is function to determine the morphology of bamboo structure. 0.2 g of bamboo powder and bamboo powder after adsorption process were analysed using Jeol JSM – IT100 SEM. There are three different scales to be observed for both samples which is x100, x200, x300, x400 (Swapp, 2012).

3.6 Data Analysis

3.6.1 T-test

The use of t-test is to determine result between two data, so that it is statistically significant (Martin Krzywinski, 2013). T-test was performed under the confidence level of 95%. In this study, the result of t-test value must be less than 2.78 at degree of freedom t_4=2.78 which mean there is no significance different.

The Equation 3.1 is to find the t-test by comparing two sample means $\bar{x}_1$ and $\overline{x_2}$ test are needed whether ($\bar{x}_1$-$\bar{x}_2$) differs significantly from zero. If the two samples have standard deviations which are not significantly different, a pool estimated, s, of the standard deviation can be calculated from the two individual standard deviations s_1 and s_2 in Equation 3.2

$$t = \frac{mean_1 - mean_2}{s \times \sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \tag{3.1}$$

where s is calculated from:

$$s^2 = \frac{(n_1 - 1)s_1{}^2 + (n_2 - 1)s_2{}^2}{n_1 + n_2 - 2} \tag{3.2}$$

And t has $n_1 + n_2 - 2$ degrees of freedom. This method assumes that the sample are drawn from the population with equal standard deviations (Miller and Miller, 2005)

3.6.2 Adsorption Isotherm

The result of the equilibrium data were analyzed with Langmuir isotherm and Freundlich isotherm to determine the most appropriate correlation coefficient value that were nearest to 1. The linear regression was used to determine the suitable isotherm and the capability of the adsorption capacity based on the both of Langmuir isotherm and Freundlich isotherm (Meroufel et al., 2013). The equation for Langmuir isotherm and Freundlich isotherm as stated in Section 2.5.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

The experiment was started with calibration curve and it had been carried out by studying the effect of parameters such as particles size (0.710, 0.300, 0.125 mm), adsorbent dosage (0.5, 1, 2, 3, 4, 5, 6, 7 g), initial dye concentration (30, 50, 100, 150, 200, 250, 300 mg/L), contact time (0.5, 1, 2, 4, 8, 12, 16, 20, 24, 28 hours) and pH (3, 4, 5, 6, 7, 8, 9).

The purpose of studying all those parameters is to find out the optimum condition for removal of methyl orange dye using bamboo as adsorbent. The adsorption isotherm also had been use for effect of contact time and pH. There are two adsorption isotherm that were used which are Langmuir and Freundlich isotherm.

4.2 Standard Calibration Curve

For preparing calibration curve, the various concentrations of methyl orange (MO) (0.5, 1, 2, 3, 4, 5, 6 mg/L) were measured at wavelength of 464 nm using UV-Visible spectrophotometer.

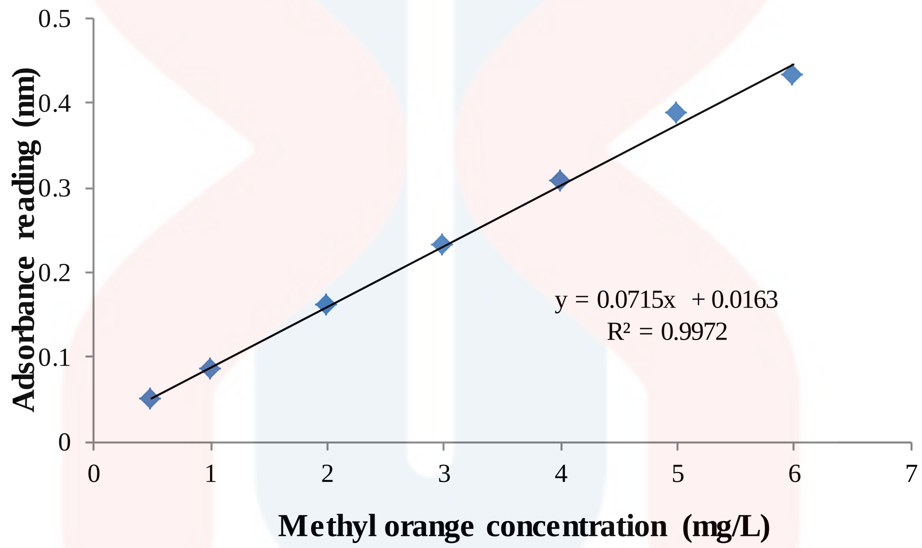


Figure 4.1 : Calibration curve for MO. Conditions: volume of the solution 50 mL; room temperature; wavelength 464 nm.

4.3 Effect of Particle Size

According to Figure 4.2 the percentage of dye removal for adsorbent size of 0.125, 0.300, 0.710 mm were 89.29%, 86.94%, 82.85% respectively. It can be seen that the highest percentage of dye removal was obtained at the smallest size (0.125 mm) while the lowest percentage removal was obtained at the biggest size (0.710 mm). Even though the difference between 0.125 mm and 0.300 mm are very small, but it shows significance difference based on the t-test at confidence level of 95% as shown in Table 4.1 (Miller and Miller, 2005).

The smallest particle sizes of adsorbent have the largest surfaces area, so that can absorb more of MO dye. This is due to relationship of changes of adsorption capacity and particle size depends on two criteria which are the chemical structure of the dye molecule ionic charge and the intrinsic characteristic of the adsorbent. For example, the bamboo raw has good porosity to adsorb the MO due to the criteria that had mentioned (Ip. et al., 2009). Data for effect of particle size can be obtained in Appendix A.

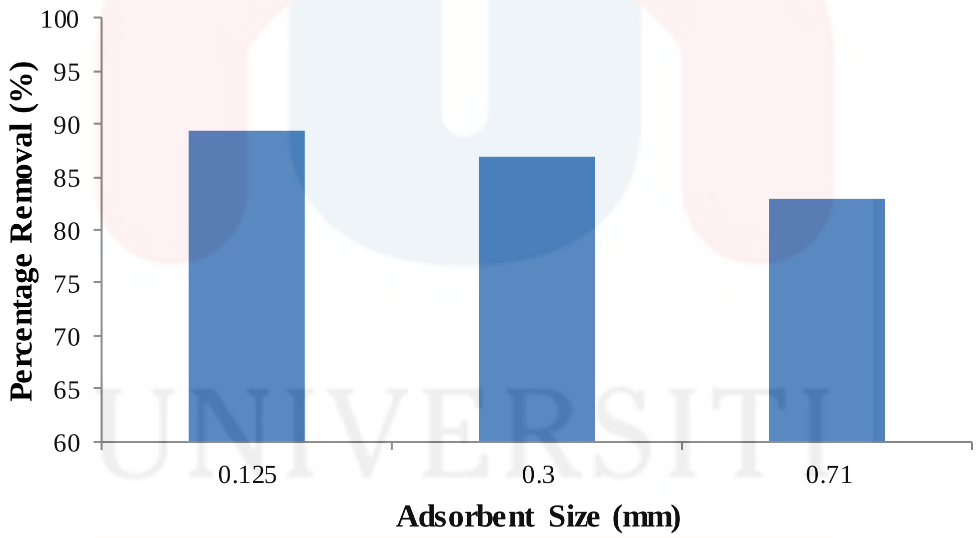


Figure 4.2 : Effect of adsorbent size on removal of MO using bamboo raw. Conditions: MO concentration 100 mg/L; contact time 24 hours; volume 100 mL; adsorbent dosage 3 g; wavelength 464 nm.

From Figure 4.2, it can be clearly seen that the percentage of MO removal was increasing as the size of particle became smaller. The similar trend by Belay and Hayelom (2014) in removal of MO from aqueous solution using thermally treated egg shell. This is because from the observation, the constant decrement on the removal efficiency because of the surface area of adsorbent material decreases at the largest particle of size.

Table 4.1: Result of t-test for the effect of particle sizes

Particle size	Value of t-test (t_4=2.776)	Notes
0.125 mm and 0.300 mm	21.385	Have significant difference
0.125 mm and 0.710 mm	23.534	Have significant difference

4.4 Effect of Adsorbent Dosage

There are no obvious change at 0.5, 1, 2 g where the percentage of dye removal were 60.62%, 60.10%, 60.61%. The percentage of dye removal started to increase at adsorbent size of 3 to 6 g (68.90% to 87.58%). The percentage of dye removal increased with the increasing of adsorbent dosage. The optimum adsorbent dosage was obtained at 6 g. After 6 g, the percentage of dye removal became constant. Based on the t-test in Table 4.2, there was no significance difference in percentage removal of adsorbent at 6 and 7 g. The constancy of the graph due to the fixed mass can be used to adsorb certain amount of the dye. So that it can be concluded, the more the adsorbent dose the larger the volume of effluent can purify (Ahmad et al., 2015).

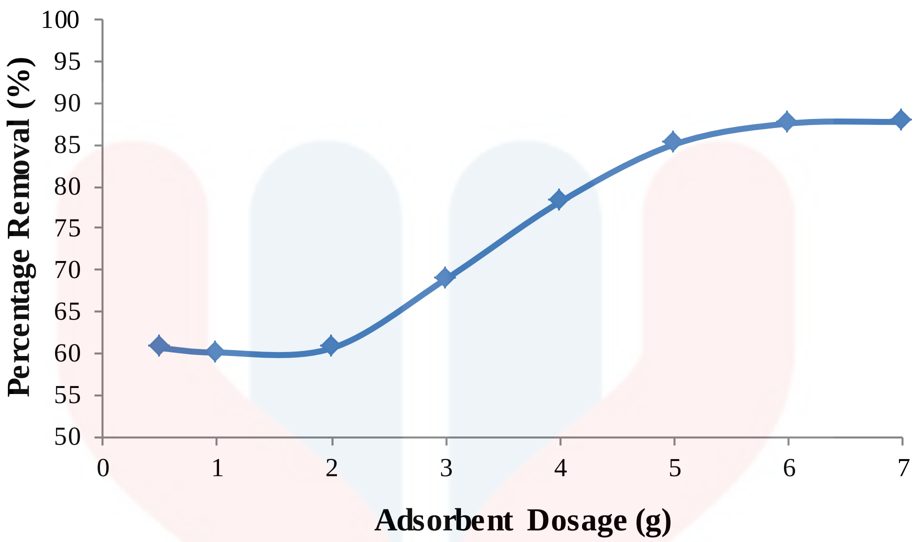


Figure 4.3 : Effect of adsorbent dosage on removal of MO using bamboo raw. Conditions: MO concentration 100 mg/L; contact time 24 hours; volume 100 mL; adsorbent size 0.125 mm; room temperature; wavelength 464 nm.

Figure 4.3 shows that as the adsorbent dosage increases, the percentage removal increase. It similar to study by El Maghraby (2010) in removal of a basic dye from aqueous solution by adsorption using rice hulls as adsorbent. The higher the adsorbent dosage used lead to the increasing of percentage removal. This is because as increase in adsorbent dose attributed to increase adsorbent surface area and availability of more adsorption sites.

The similar trend was reported in adsorption of MO using tree bark powder by Egwounwu (2013) where the increase in adsorbent dose at constant dye concentration lead to unsaturation of adsorption sites through the adsorption process and thus increased in percentage of dye removal.

Table 4.2 : Result of t-test for the effect of adsorbent dosage

Adsorbent Dosage	Value of t-test (t_4=2.776)	Notes
6g and 5g	13.820	Have significant difference
6g and 7g	1.887	No significance difference

4.5 Effect of Initial Dye Concentration

The effect of initial dye concentration was optimum at 150 mg/L (92.87%) as shown in Figure 4.4. The initial dye concentration at 30, 50, 100 mg/L were increased smoothly with percentage removal of 68.42%, 77.37%, 88.54% respectively. There were slightly changes in colour into light orange as it can be as a proved that amount of MO absorbed per unit mass of adsorbent from previous study increased with increasing of dye concentration. This is because of increase in the driving force of the concentration gradient with the increase in the initial dye concentration. (Hameed et al., 2008). Similar trend was reported by Mahammedi Fatiha (2016) in the removal of methylene blue from aqueous solutions using natural clay. The adsorption capacity of dye increases as the increase in initial dye concentration due to higher of methylene blue molecule is available in higher initial dye concentration. The adsorption also occurred because of the role of initial concentration is driving force to overcome the resistance to the mass transfer of adsorbate between aqueous and the solid phases.

However, the percentage removal remains constant at initial dye concentration of 200-300 mg/L. The constancy of percentage removal is due to the repulsive forces between the dyes molecules on the surface and the un-absorbed dye molecules as well as the structure of the adsorbent (Fortunate, 2016). There was study about the increasing of initial concentration also lead to decrement of percentage removal that was reported by Nagarethinam Kannan (2001). This indicates that there exist reductions in immediate solute adsorption, owing to the lack of available active sites required for the high initial concentration of adsorbate (Nagarethinam Kannan, 2001).

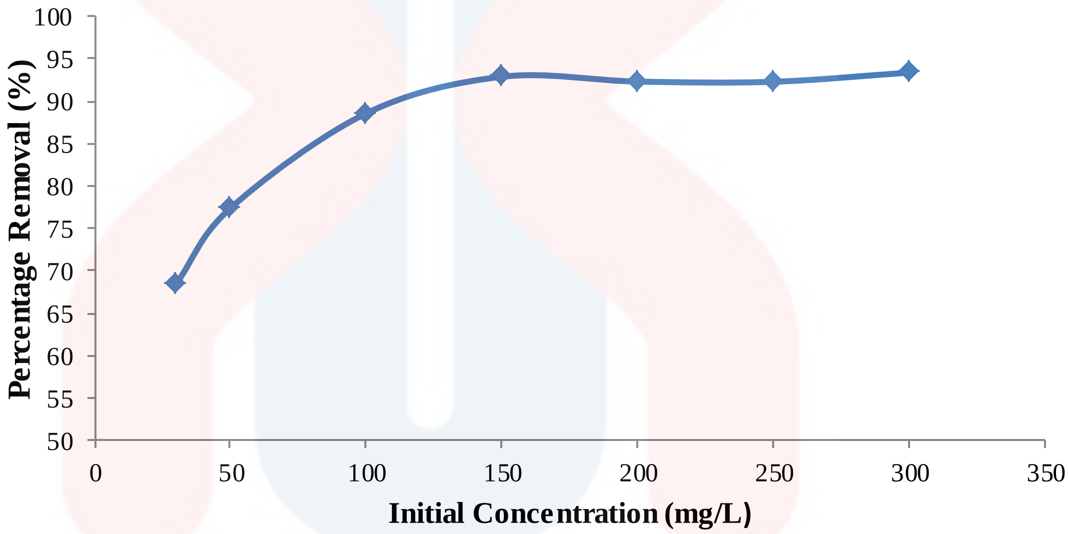


Figure 4.4 : Effect of initial dye concentration on removal of MO using bamboo raw. Conditions: adsorbent dosage 6 g; adsorbent size 0.125 mm; contact time 24 hours; volume 100 mL; room temperature; wavelength 464 nm.

4.6 Effect of Contact Time

Based on Figure 4.5, at the first 30 minutes until 16 hours the percentage of removal remains constant. The changes of percentage removal were slightly difference because of the short of the time taken for the adsorption process for the active site of adsorbent to bind with the adsorbate. The significance increase was obtained at 20-24 hours due to rapid attachment of dye to the surface of the adsorbent. The changes in the rate of removal with time might be due to the fact that initially all adsorbent sites were vacant and the solute concentration gradient was high (Belay, 2014).

However, the percentage removal decreased with increase in contact time at 28 hours because the adsorbent was reached its equilibrium state at 24 hours. It showed that there was no any increment will occur after the optimum contact time since it was already reached equilibrium state. This decrement result also might be occurred when there is no more available external site and lead to the diffusion into the porous structure of an adsorbent (Senthikumaar et al., 2005). This study showed the same result for effect of contact time by Bello (2012) for malachite green dye removal by using activated carbon of banana stalked where adsorption was achieved optimum contact time at 24 hours. From the result showed that 24 hours is the best result because of the rate removal of dye increase with an increase in contact time until it reached the equilibrium point.

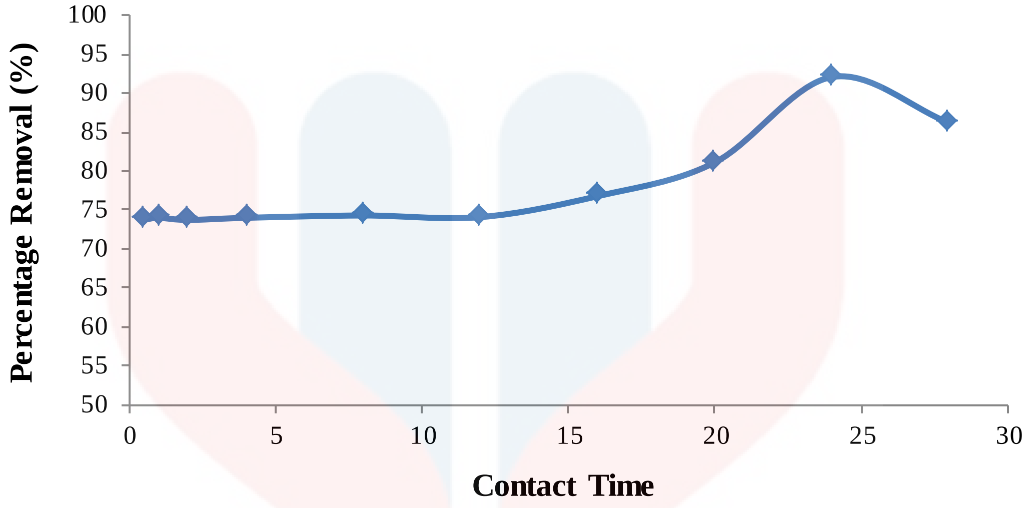


Figure 4.5 : Effect of contact time on removal of MO using bamboo raw. Conditions: MO concentration 100 mg/L; volume 100 mL; adsorbent size 0.125 mm; adsorbent dosage 6 g; room temperature; wavelength 464 nm.

4.7 Effect of pH

Based on Figure 4.6, the effects of pH were studied started from pH 3 until pH 10. There were three conditions of pH which were acidic, neutral, and alkaline. It showed that the percentage removal were almost constant at acidic condition because of the repulsion of the dye due to excess cation in the solution, positive charged have been neutralized (Fortunate, 2016). Graph slightly increased at pH 7 with percentage removal of 91.53%. The optimum pH for methyl orange was at pH7 where it is neutral condition.

The percentage removal drastically decreased starting at pH 9 with (73.25%) because MO is anionic dye molecules. The decrement of the removal percentage in the effect of pH may be because of the competitive effects of OH^- ions and the electrostatic repulsion between the anionic dye molecules and the negatively charged active adsorption sites (Ai Lunhong et al., 2011). Due to the excess anions in the solution of MO, there will be repulsion of the dye by the raw material of bamboo that had been used as adsorbent that need to compete for adsorption sites, increase in pH which resulted in lower percentage removal.

In the previous study, the effect of pH of adsorption MO by calcined Lapindo volcanic mud showed the adsorption capacities decreased because at the higher pH reduced the number positively charged sites and raised the number of negatively charged sites. It created the electrostatic repulsion between the negatively charged of adsorbent surface and adsorbate (Aishah, 2010).

The effect of pH in adsorption process can be affected the surface charge of the adsorbent, the ionization degree of the different pollutants, the dissociation of functional groups on the active site of the adsorbent and the structure of dye molecule (Ai Lunhong et al., 2011).

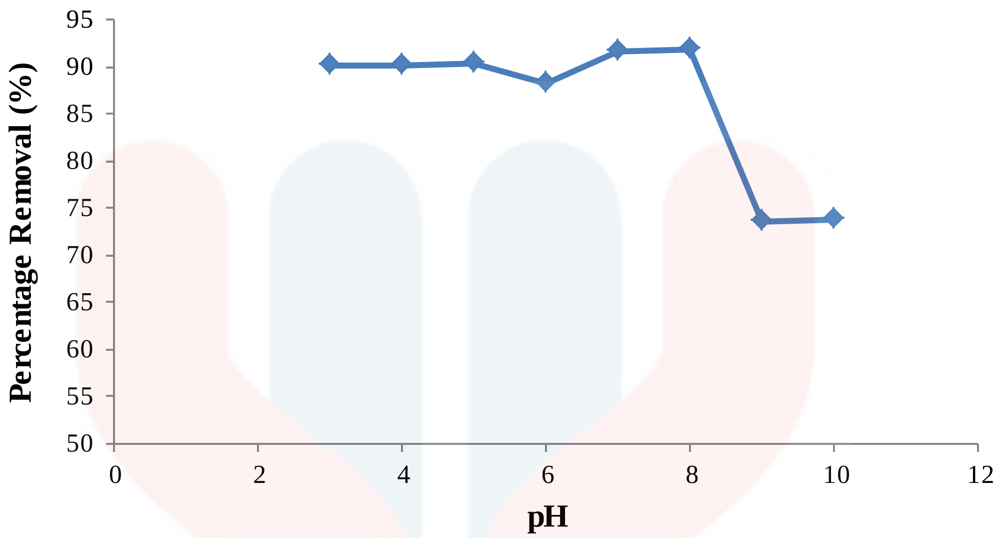


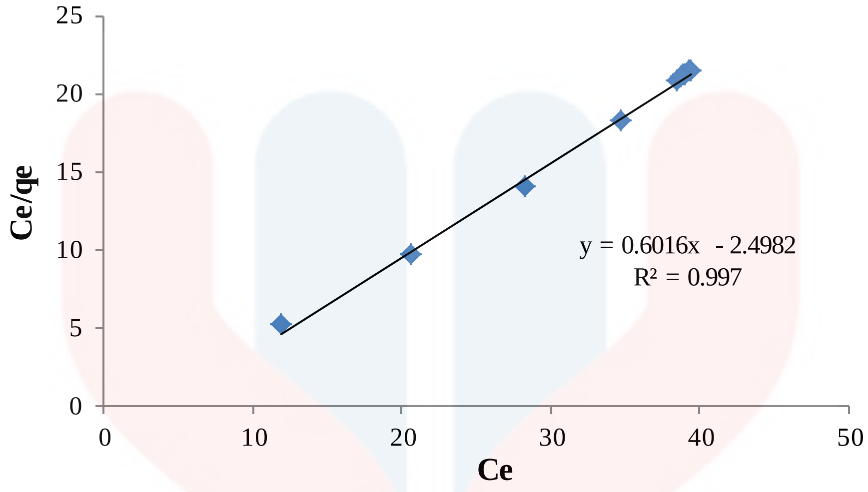
Figure 4.6 : Effect of pH on removal of MO using bamboo raw. Conditions: MO concentration 100 mg/L; contact time 24 hours; volume 100 mL; adsorbent dosage 6 g; adsorbent size 0.125 mm; room temperature; wavelength 464 nm

4.8 Adsorption Isotherm

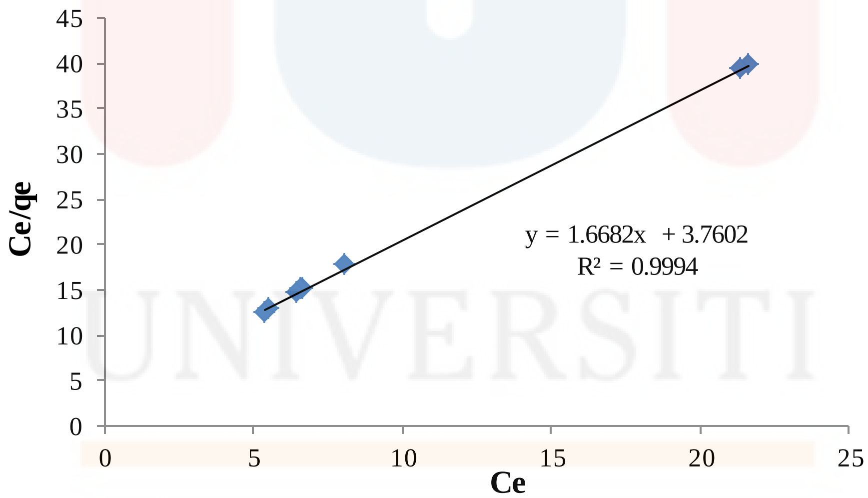
There are so many types of isotherm with their own advantage such as Langmuir, Freundlich, Tempkin, Multisite and other. In this study, there were two types of adsorption isotherm that have been used for the effect of contact time and the effect of pH. Langmuir was chosen at the best adsorption isotherm since the correlation coefficient (R^2) value was nearest to value 1. Figure 4.7 and 4.8 showed a graph plot for both isotherm which are Langmuir isotherm and Freundlich isotherm should be form in a straight line.

Based on Table 4.3, the data of the adsorption isotherm for both effect of contact time and pH were best fitted to Langmuir isotherm due to the correlation coefficient

(R^2) nearest to 1. In addition, since the value of n in Freundlich isotherm is negative, therefore it is not favourable to Freundlich isotherm. It can be concluded that, the adsorption of MO dye onto bamboo is a monolayer adsorption and the adsorption capacity was 1.66 mg/g. Similar result was also reported by Atshan (2014), whereby the adsorption of methyl green dye onto bamboo in batch and continuous system was best fitted to the Langmuir adsorption isotherm with the adsorption capacity was 20.41 mg/g.

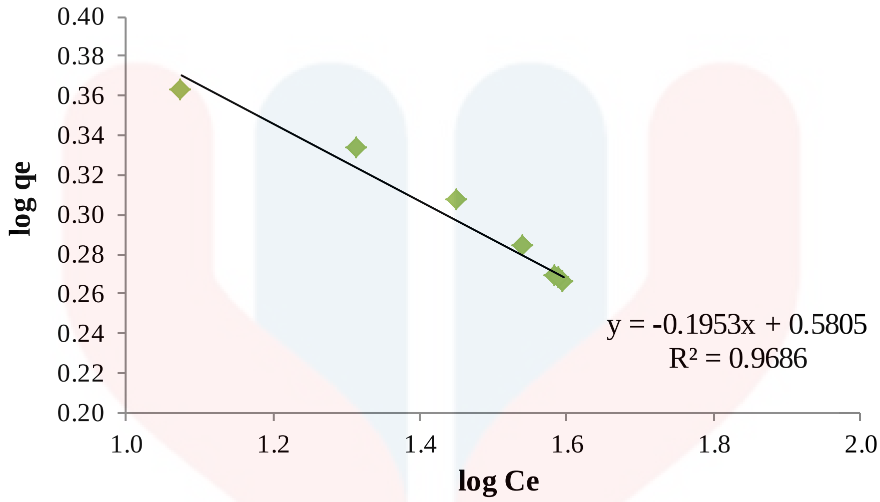


(a)

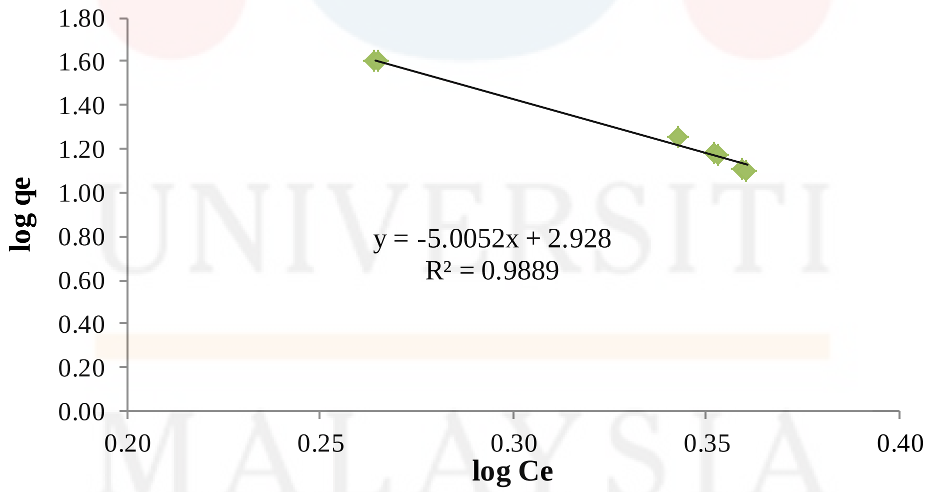


(b)

Figure 4.7 Langmuir isotherm for (a) contact time and (b) pH



(a)



(b)

Figure 4.8 Freundlich isotherm for (a) contact time and (b) pH

Table 4.3 : Isotherm parameter for adsorption of MO using bamboo raw as adsorbent based on contact time and Ph

Isotherm Model	Contact time		pH	
	Parameter	**Value**	**Parameter**	**Value**
Langmuir	K_L (L/mg)	-0.2408	K_L (L/mg)	0.4437
	q_{max} (mg/g)	1.6622	q_{max} (mg/g)	1.6822
	R^2	0.997	R^2	0.9994
Freundlich	K_F (mg/g)	3.8063	K_F (mg/g)	847.2274
	n	-5.1203	n	-0.1998
	R^2	0.9686	R^2	0.9889

4.9 Characterisation

4.9.1 Fourier-Transform Infrared Spectroscopy (FTIR)

In this study, the characterisation of bamboo before adsorption and bamboo after adsorption by using Fourier-Transform Infrared Spectroscopy (FTIR) was shown in Figure 4.9. The wavelength to identify the functional groups of bamboo before and after adsorption was in range 500-3500 cm^{-1}. In the bamboo before adsorption, the functional groups that had shown are inorganic phosphates in range wavelength 2600–3500 cm^{-1}, alkynes monosubstituted in range wavelength 3250-3350 cm^{-1} and aliphatic hydrocarbon 2810-2950 cm-1. This result is similar to bamboo after adsorption. Besides that, the FTIR spectra do not have many differences and cannot recognize the difference between before adsorption and after adsorption FTIR due to the small amount of the adsorbate.

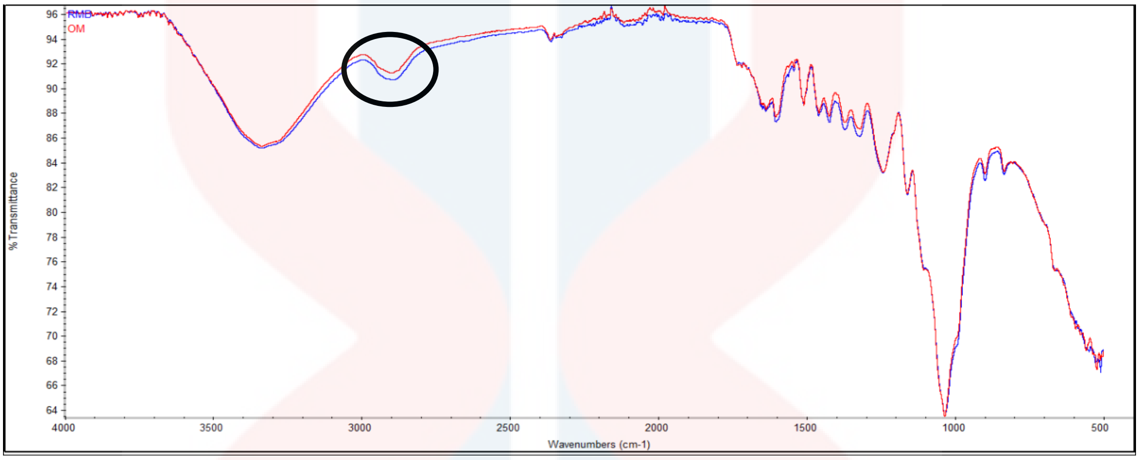


Figure 4.9 : FTIR spectra of : before adsorption; : after adsorption

The frequencies of the bamboo before adsorption and bamboo after adsorption show a broad band present between 3300 and 3400 cm^{-1}, which can assigned to the O-H stretching mode of hydroxyl group. The intensity at peak 2800-3000 cm^{-1} of bamboo after adsorption is slightly increased from bamboo before adsorption (Tomak et al., 2013). The obvious broad peak also showed for the both sample at 2800 cm^{-1} and 3000 cm^{-1} which is strong broad peak which is N-H stretching mode of amine salt. Next is strong peak at between 1070 cm^{-1} and 1030 cm^{-1} which assigned to the S=O stretching mode of sulfoxide. From the FTIR spectra, it can be clearly seen that, there is no new or diminish peak were observed. Therefore, it can be suggested that the adsorption of MO dye onto raw bamboo powder is based on physical adsorption. For improvement in the future study, FTIR spectra for MO dye alone should be included in study.

4.9.2 Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy in this study was used to investigate the surface morphology of bamboo powder before adsorption and after adsorption. Based on the Figure 4.10 it showed the magnification x1500 on the bamboo powder before and after adsorption. The images of bamboo before adsorption showed more pores and holes than the images of bamboo after adsorption. The reducing of pores and holes after adsorption is due to diffusion of dye molecules onto the surface of the adsorbent (Djilani et al., 2015). The pores and holes that had been observed before adsorption can be probability that dye become trapped and absorbed.

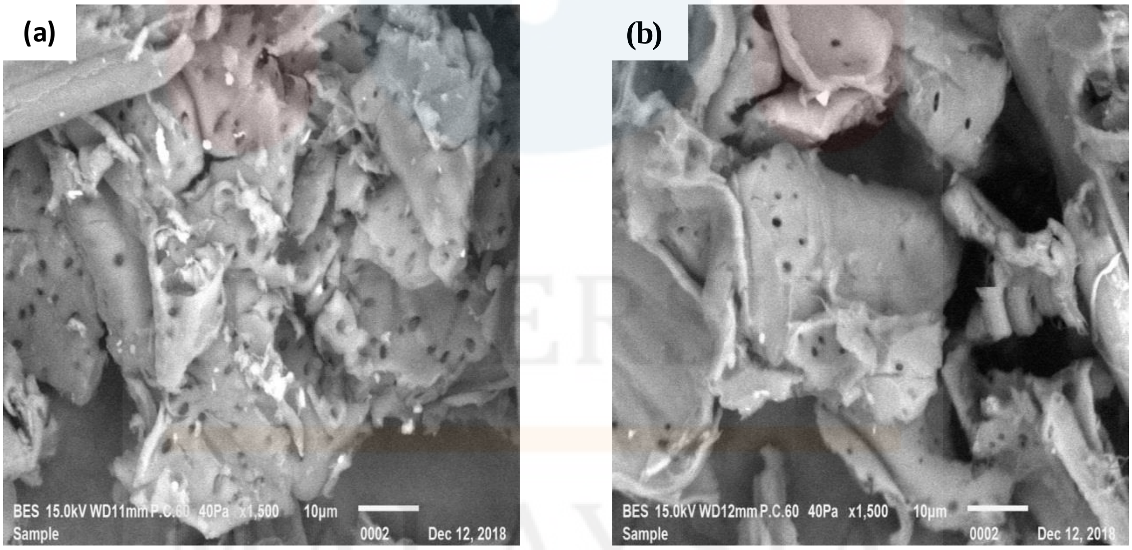


Figure 4.10 : The Scanning Electron Microscopy (SEM) images (x1500) for bamboo powder before adsorption (a) and after adsorption (b)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The adsorption of methyl orange using the bamboo raw had been carried out by a few parameters. The parameter that used in this adsorption are the effect of particle size, the effect of adsorbent dosage, the effect of initial dye concentration, the effect of contact time and the effect of pH solution. All of the parameters are important to study the potential of bamboo as adsorbent for removal of dyes.

In this adsorption process, the first observation that had been carried out is the effect of particle size. It showed that percentage of dye removal increased the smallest particle size. This is because of the smallest particle size has the largest surface area. The optimum particle sizes obtained was 0.125 mm with percentage removal of 89.29%. Next is the effect of adsorbent dosage that reached optimum result at 6 g with 87.58% of the percentage removal. There are no significance difference based on the t-test of adsorbent dosage of 6 g and 7 g but the optimum dosages that were chosen is 6 g because it already reached the equilibrium point.

Besides that, for the effect of initial dye concentration, the optimum result was at 150 mg/L with percentage removal 92.87%. Based on the graph, the increasing of initial dye concentration has increased the percentage of dye removal and it became constant until it reached the equilibrium. The optimum of contact time is at 24 hours with percentage removal 92.08%. This showed that as the contact time increased, the percentage removal increased.

From the result of the effect of pH, the optimum pH was obtained at pH 7 with percentage removal 91.53% where it is at neutral condition. Based on the graph the percentage of dye removal was slightly increase until it reached at pH 7 and become decrease at ph 8, pH 9, pH 10. This showed that, the percentage of removal was decreased when the pH of solution increased (alkaline medium).

In this study there were two types of adsorption isotherm that had been used which are Langmuir isotherm and Freundlich isotherm. Based on the isotherm graph, the value of correlation coefficient (R^2) that nearest to 1 was showed by Langmuir isotherm for both effect of contact time and the effect of pH. It can be concluded that adsorption of methyl orange using bamboo raw was made up from homogeneous surface and monolayer adsorption.

5.2 Recommendation

In the conclusion, bamboo can be used as one of the adsorbent to adsorb of dyes that can give the bad effect for environment and living organisms. The bamboo showed the great potential for dye removal because of there is many of abundant bamboo that have been left and become agriculture waste. The recommendation for the next study in the removal of dye is to do bamboo as activated carbon or using phosphoric acid to give the effect of the burn of build of pores. As bamboo acts as adsorbent for removal dyes there will be more parameters can be added such as the effect of temperature and the effect of agitation rate. The more characterisation of bamboo powder can be investigated such as Scanning Electron Microscopy (SEM) to study the surface morphologies of adsorbent to that the porosity will be detected, X-ray Diffraction (XRD) to determine the crystallinity or amorphous nature, X-ray Florescence (XRF) to study interactions between electron beams and x-rays with samples and Brunauer-Emmett-Teller (BET) to explain the physical adsorption of gas molecules on a adsorbent.

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APPENDIX A

Table A.1 : Calibration curve data

Concentration	1	2	3	4	Average	Standard Deviation
0.5	0.048	0.049	0.054	0.049	0.05	0.002708
1	0.086	0.088	0.085	0.083	0.0855	0.002082
2	0.148	0.162	0.163	0.164	0.15925	0.007544
3	0.236	0.237	0.226	0.227	0.2315	0.005802
4	0.311	0.306	0.303	0.306	0.3065	0.003317
5	0.384	0.381	0.401	0.381	0.38675	0.009605
6	0.432	0.434	0.432	0.431	0.43225	0.001258

Table A.2 : Data of effect of particle size

Particle Sizes	1	2	3	4	Average	Final Concentration	Percentage removal (% R)
0.71	1.247	1.239	1.243	1.24	1.242	17.146	82.854
0.3	0.948	0.954	0.951	0.948	0.950	13.062	86.938
0.125	0.785	0.772	0.777	0.795	0.782	10.713	89.287

Table A.3 : Data of effect of adsorbent dosage

Adsorbent Dosage	1	2	3	4	Average	Final Concentration	Percentage Removal (%R)
0.5	2.824	2.835	2.834	2.836	2.832	39.384	60.616
1	2.879	2.864	2.863	2.872	2.870	39.905	60.095
2	2.826	2.831	2.836	2.838	2.833	39.391	60.609
3	2.234	2.23	2.239	2.256	2.240	31.097	68.903
4	1.584	1.586	1.579	1.561	1.578	21.835	78.165
5	1.079	1.089	1.088	1.079	1.084	14.929	85.071
6	0.908	0.905	0.906	0.899	0.905	12.422	87.578
7	0.887	0.889	0.891	0.892	0.890	12.216	87.784

Table A.4 : Data of effect of initial dye concentration

Initial concentration	1	2	3	4	Average	Final Concentration	Percentage Removal (%R)
30	0.694	0.695	0.692	0.694	0.694	9.475	68.417
50	0.899	0.799	0.802	0.802	0.826	11.317	77.365
100	0.84	0.837	0.834	0.831	0.836	11.457	88.543
150	1.026	1.006	0.106	0.986	0.781	10.695	92.870
200	1.111	1.118	1.117	1.119	1.116	15.384	92.308
250	1.396	1.39	1.391	1.406	1.396	19.293	92.283
300	1.432	1.437	1.451	1.445	1.441	19.929	93.357

Table A.5 : Data of effect of contact time

Contact time	1	2	3	4	Average	Final Concentration	Percentage Removal (%R)
30	2.801	2.898	2.809	2.810	2.830	39.345	73.770
1	2.809	2.803	2.806	2.797	2.804	38.985	74.010
2	2.828	2.831	2.833	2.839	2.833	39.391	73.739
4	2.806	2.804	2.798	2.806	2.804	38.982	74.012
8	2.77	2.773	2.771	2.772	2.772	38.534	74.310
12	2.798	2.799	2.79	2.787	2.794	38.842	74.105
16	2.504	2.508	2.503	2.507	2.506	34.814	76.791
20	2.044	2.032	2.044	2.046	2.042	28.324	81.117
24	0.866	0.868	0.867	0.863	0.866	11.884	92.077
28	1.492	1.499	1.491	1.500	1.496	20.688	86.208

Table A.5 : Data of effect of pH

pH	1	2	3	4	Average	Final Concentration	Percentage Removal (%R)
3	1.083	1.085	1.088	1.082	1.085	14.940	90.040
4	1.085	1.087	1.085	1.077	1.084	14.926	90.049
5	1.059	1.06	1.062	1.061	1.061	14.604	90.264
6	1.282	1.287	1.286	1.281	1.284	17.730	88.180
7	0.928	0.921	0.922	0.929	0.925	12.709	91.527
8	0.9	0.899	0.901	0.898	0.900	12.352	91.765
9	2.853	2.857	2.86	2.853	2.856	39.713	73.525
10	2.832	2.834	2.835	2.834	2.834	39.405	73.730

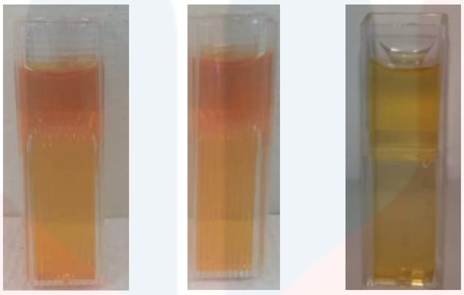
Table A.6 : Data of Langmuir and Freundlich for contact time

contact time	Final Concentration (C_e)	q_e	C_e/q_e	Log q_e	Log C_e
30	39.345	1.844	21.334	0.266	1.595
1	38.985	1.850	21.070	0.267	1.591
2	39.391	1.843	21.368	0.266	1.595
4	38.982	1.850	21.068	0.267	1.591
8	38.534	1.858	20.742	0.269	1.586
12	38.842	1.853	20.966	0.268	1.589
16	34.814	1.920	18.134	0.283	1.542
20	28.324	2.028	13.967	0.307	1.452
24	11.884	2.302	5.163	0.362	1.075
28	20.688	2.155	9.599	0.333	1.316

Table A.7 : Data of Langmuir and Freundlich for pH

pH	Final Concentration (C_e)	q_e	C_e/q_e	Log q_e	Log C_e
3	14.940	2.251	6.637	0.352	1.174
4	14.926	2.251	6.630	0.352	1.174
5	14.604	2.257	6.472	0.353	1.164
6	17.730	2.204	8.043	0.343	1.249
7	12.709	2.288	5.554	0.359	1.104
8	12.352	2.294	5.384	0.361	1.092
9	39.713	1.838	21.605	0.264	1.599
10	39.405	1.843	21.378	0.266	1.596

APPENDIX B



0.710 mm 0.300 mm 0.125 mm

Observation on dye removal of effect of particle sizes

0.5 g 1 g 2 g 3 g 4 g 5g 6 g 7 g

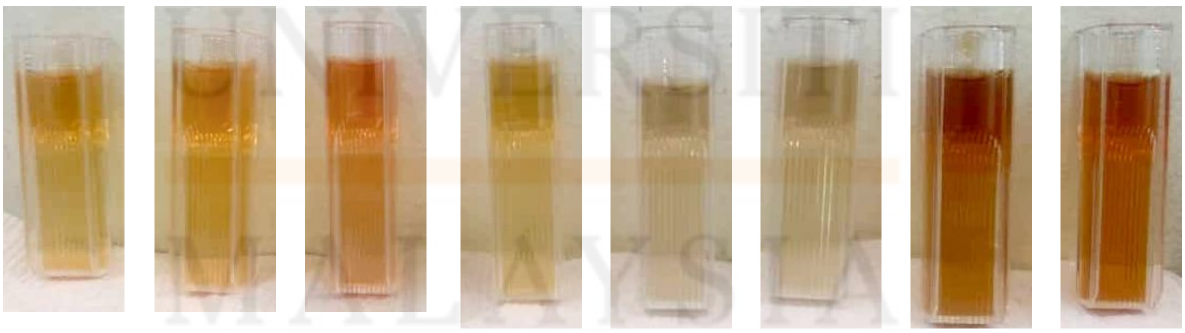
Observation on dye removal of effect of adsorbent dosage

30 mg/L 50 mg/L 100 mg/L 150 mg/L 200 mg/L 250 mg/L 300 mg/L

Observation on dye removal of effect of initial dye concentration

30 minutes | 1 hour | 2 hours | 4 hours | 8 hours | 16 hours | 24 hours | 28 hours

Observation on dye removal of effect of contact time



pH 3 | pH 4 | pH 5 | pH 6 | pH 7 | pH 8 | pH 9 | pH 10

Observation on dye removal of effect of pH