Removal Of Benzene and Toluene from Artificial Wastewater with Adsorbents Developed from Rice Husk

by

ABDUL AZIZ BIN ABDUL WAHED

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Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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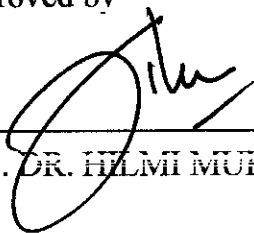A project dissertation submitted to the

Chemical Engineering Department

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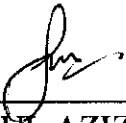
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TRONOH, PERAK

AUGUST 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work in my own except as specified in the references and acknowledgements and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(ABDUL AZIZ BIN ABDUL WAHED)

Abstract

Rice husk has a very large potential to be developed in an absorbent. The aim of this study is to develop rice husk into an adsorbent for the removal of benzene and toluene from artificial wastewater. Rice husk is an abundant source of agricultural waste that can be found all over the world. Rice husk was treated by burning it in a furnace at certain temperature for one and three hours. Properties of the treated rice husk was examined by using characterization equipments such as Scanning Electron Microscope and Fourier Transform Infrared Resonance. The performance was found through a batch experiment where 100ppm of artificial wastewater containing benzene and toluene respectively were mix with the developed adsorbent. It was found from the experiment that the highest removal efficiency for the removal of benzene is 80% while toluene is 85%. It is concluded that this experiment was able to developed rice husk into an adsorbent for the removal of benzene and toluene from artificial wastewater.

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ABDUL AZIZ BIN ABDUL WAHED

Chemical Engineering

Universiti Teknologi PETRONAS

Table Of Contents

Content	Page

List of Figures

List of Tables

Abbreviations

RH   Rice Husk

FTIR   FTIR Fourier Transform Infrared Resonance

UV-VIS   Ultra Violet Visible Spectroscopy

SEM   Scanning Electron Microscope

CHAPTER 1

Introduction

1.1 Project Background

Rice husk is one such widely available agricultural waste product generated in rice producing countries. The annual world rice production is approximately 500 million mectric tons of which 20% of it are rice husk. Rice husk contains cellulose (35%), hemicelluloses (25%), lignin (20%) and the rest is silica by Nasim A.K. et. al, (2004).
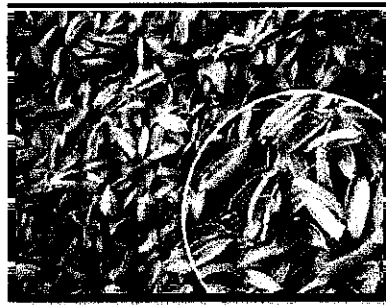
Figure 1.1: Rice Husk

In recent years, study has been done on utilizing rice husk as an adsorbent for the removal of lead, copper and heavy metals. It was reported by Kardivelu et. Al, (2003) that modified rice husk is a potentially useful material for the removal of these effluents.

Wastewater is any water that has been adversely affected by anthropogenic influence. It comprises of liquid waste discharged by domestic residences, commercial properties and industry. It encompasses a wide range of potential contaminants and concentrations. Wastewater can classed as domestic, commercial and industrial.

Industrial effluents are one of the major causes of environmental pollution. Effluents discharged from gas processing industries are highly coloured, of low BOD and high COD. Disposal of this coloured water into receiving water can be toxic to aquatic life. These effluents may pose a problem because they may be mutagenic and carcinogenic and can cause severe damage to human beings such as dysfunction of kidney, reproductive system, liver, brain and central nervous system.

Benzene and toluene are toxic chemicals that can be found in wastewater. Each have different limit of release where it is stated in Malaysia Environmental Quality Act 1974 that benzene has a limit of 5ppm while toluene has a limit of 1ppm. Benzene can be formed from coal tar, paint strippers, industrial solvent, etc. While toluene can be found in paints, thinners, synthetic fragrance, etc. These two chemicals are very dangerous and have very dangerous effects on human health such as myelocytic anemia, leukimia, dizziness, nausea, tremor and many more.

1.2 Problem Statement

Benzene and toluene are considered as very dangerous or carcinogenic chemicals. As such, they cannot be released to the river or sewage system without prior treatment to reduce the content of benzene and toluene in the wastewater. However, the technologies available to treat or adsorb benzene and toluene from wastewater are expensive and suitable for a big operation. It might occupy a large treatment area and high power to operate. Therefore, there is a need for a new but cheap and efficient treatment process.

Rice husk is an agriculture waste that can be found vastly in Malaysia. The waste resources can be easily be converted to adsorbent via physical, chemical or activation treatment. This adsorbent has a great potential to be used for removal of benzene and toluene from wastewater.

1.3 Objective and Scope of Study

This project will be focusing on the effects of treatment to the rice husk and its effects on the adsorption performance. Below are the objectives of this project:

i. Develop adsorbent from rice husk for the removal of benzene and toluene from artificial wastewater

ii. To study the performance for the removal of benzene and toluene from artificial wastewater

1.4 Significance of the Project

Rice husk is a vast agricultural waste throughout the map. It is very easy to find and it can be process to be something useful from waste. Rice husk can be prepared into and absorbent for many purposes. This project will emphasize on the importance of preparing the rice husk into and adsorbent to adsorb benzene and toluene from artificial wastewater. The artificial wastewater will represent the general wastewater produce by any chemical plants. As such, this project will be very useful to give an insight to create a more efficient adsorbent for adsorption of benzene and toluene in the wastewater in any future project.

CHAPTER 2

Literature Review

2.1 Overview of Wastewater

Wastewater, also spelled waste water, is any water that has been adversely affected in quality by anthropogenic influence. It comprises liquid waste discharged by domestic residences, commercial properties, industry, and/or agriculture and can encompass a wide range of potential contaminants and concentrations. In the most common usage, it refers to the municipal wastewater that contains a broad spectrum of contaminants resulting from the mixing of wastewater from homes, businesses, industrial areas and often storm drains, especially in older sewer systems.

Sewage is the subset of wastewater that is contaminated with feces or urine, but is often used to mean any wastewater. Sewage includes domestic, municipal, or industrial liquid waste products disposed of, usually via a pipe or sewer.

2.1.1 Wastewater Characterization

Wastewater is domestic, municipal, or industrial liquid waste products. Depending on their origin, wastewaters can be classed as sanitary, commercial, industrial, or surface runoff.

Sanitary sewage is the spent water from residences and institutions, carrying body wastes, ablution water, food preparation wastes, laundry wastes, and other waste products of normal living, are classed as domestic or sanitary sewage.

Commercial wastes is liquid-carried wastes from stores and service establishments serving the immediate community, termed commercial wastes, are included in the sanitary or domestic sewage category if their characteristics are similar to household flows.

While Surface runoff, also known as storm flow or overland flow, is that portion of precipitation that runs rapidly over the ground surface to a defined channel. Precipitation

absorbs gases and particulates from the atmosphere, dissolves and leaches materials from vegetation and soil, suspends matter from the land, washes spills and debris from urban streets and highways, and carries all these pollutants as wastes in its flow to a collection point. Discharges are classified as point-source when they emanate from a pipe outfall or non-point-source when they are diffused and come from agriculture or unchanneled urban land drainage runoff.

2.2 Rice Husk

Rice husk is an agricultural waste generated in rice producing countries, especially Asia. The annual world rice production is approximately 500 million metric tons, of which 20% is considered as rice husk. Rice husk contains 70-85& organic matters such as lignin, cellulose, sugars, etc. while the remaining consists of silica which is present in the cellular membrane. (Khan et al, 2004) In recent years, studies have been conducted to utilize rice husk as an adsorbent. Rice husk will be modified for the removal of pollutants. (Wong et al, 2003)

Basically, an adsorbent can be produce from many organic materials. In this study, adsorbent is produce from rice husk which is an agricultural waste. The activated carbons are adsorbent which is widely used in industry for separation, purification and recovery process. It was previously reported that treated rice husk was effective in adsorbing pesticides and organochlorine compounds such as chloroform, dichloromethane and benzene. Analytical and laser microscopic data have confirmed that removal of organochlorine compounds and benzene is dependent on the uptake of these compounds into intracellular particles called spherosomes. (Adachi et. Al, 2001)

Figure 2.1: Raw Rice Husk

2.3 Adsorption

Adsorption phenomena are operative in most natural physical, biological and chemical systems. Adsorption operation which employs solids such as activated carbon and synthetic resins for purification of waters and wastewaters are widely used in industrial applications.

Adsorption involves separation of a substance from one phase accompanied by its accumulation or concentration at the surface of another. The adsorbing phase is the adsorbent and the material concentrated or adsorbed at the surface of that phase is the adsorbate. (Slejko F. Et. Al, 1985)

2.3.1 Types of Adsorption

Forces of attraction exist between adsorbate and adsorbent. These forces of attraction can be due to Van der waal forces of attraction which are weak forces or due to chemical bond which are strong forces of attraction. On the basis of type of forces of attraction existing between adsorbate and adsorbent, adsorption can be classified into two types, physical adsorption or chemical adsorption.

Physical adsorption or physiosorption occurs when the force of attraction existing between adsorbate and adsorbent are weak Van der waal forces of attraction, the process is called physical adsorption or physisorption. Physical adsorption takes place with formation of

multilayer of adsorbate on adsorbent. It takes place at low temperature below boiling point of adsorbate. As the temperature increases in, process of physisorption decreases.

Chemical adsorption or chemicsorption occurs when the force of attraction existing between adsorbate and adsorbent are chemical forces of attraction or chemical bond, the process is called chemical adsorption or chemisorption. Chemisorption takes place with formation of uni layer of adsorbate on adsorbent. It has high enthalpy of adsorption. It can take place at all temperature. With the increases in temperature, chemisorption first increases and then decreases.

2.3.2 Adsorption isotherm

In the process of adsorption, adsorbate gets adsorbed on adsorbent.

$$\text{Adsorbate} + \text{Adsorbent} \underset{\text{desorption}}{\overset{\text{Adsorption}}{\rightleftharpoons}} \text{Adsorption}$$

$$A + B \rightleftharpoons AB$$
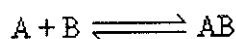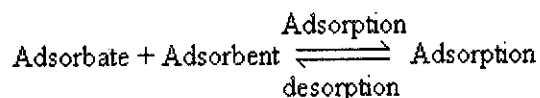
According to Le-Chatelier principle, the direction of equilibrium would shift in that direction where the stress can be relieved. In case of application of excess of pressure to the equilibrium system, the equilibrium will shift in the direction where the number of molecules decreases. Since number of molecules decreases in forward direction, with the increases in pressure, forward direction of equilibrium will be favoured.
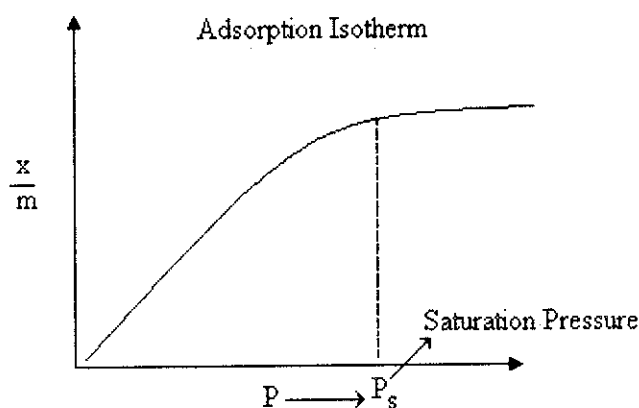

Figure 2.2: Basic Adsorption Isotherm

From the graph, we can predict that after saturation pressure Ps, adsorption does not occur anymore. This can be explained by the fact that there are limited numbers of vacancies on the surface of the adsorbent. At high pressure a stage is reached when all the sites are occupied and further increase in pressure does not cause any difference in adsorption process. At high pressure, Adsorption is independent of pressure.

2.3.2.1 Freundlich Adsorption Isotherm

In 1909, Freundlich gave an empirical expression representing the isothermal variation of adsorption of a quantity of gas adsorbed by unit mass of solid adsorbent with pressure. This equation is known as Freundlich Adsorption Isotherm or Freundlich Adsorption equation or simply Freundlich Isotherm.

$$\frac{x}{m} = kP^{\frac{1}{n}}$$

Where x is the mass of the gas adsorbed on mass m of the adsorbent at pressure p and k, n are constants whose values depend upon adsorbent and gas at particular temperature. Though Freundlich Isotherm correctly established the relationship of adsorption with pressure at lower values, it failed to predict value of adsorption at higher pressure.

2.3.2.2 Langmuir Adsorption Isotherm

In 1916 Langmuir proposed another Adsorption Isotherm known as Langmuir Adsorption isotherm. This isotherm was based on different assumptions one of which is that dynamic equilibrium exists between adsorbed gaseous molecules and the free gaseous molecules.

$$A(g) + B(S) \underset{\text{desorption}}{\overset{\text{Adsorption}}{\rightleftharpoons}} AB$$
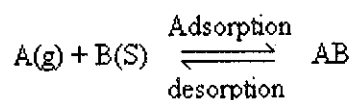
Where A(g) is unadsorbed gaseous molecule, B(s) is unoccupied metal surface and AB is Adsorbed gaseous molecule.

Based on his theory, he derived Langmuir Equation which depicted a relationship between the number of active sites of the surface undergoing adsorption and pressure.

$$\theta = \frac{KP}{1 + KP}$$

Where θ the number of sites of the surface which are covered with gaseous molecule, P represents pressure and K is the equilibrium constant for distribution of adsorbate between the surface and the gas phase .The basic limitation of Langmuir adsorption equation is that it is valid at low pressure only.

At lower pressure, KP is so small, that factor (1+KP) in denominator can almost be ignored. So Langmuir equation reduces to

$$\theta = KP$$

At high pressure KP is so large, that factor (1+KP) in denominator is nearly equal to KP. So Langmuir equation reduces to

$$\theta = \frac{KP}{KP} = 1$$

2.3.2.3 BET adsorption Isotherm

BET Theory put forward by Brunauer, Emmett and Teller explained that multilayer formation is the true picture of physical Adsorption.

One of the basic assumptions of Langmuir Adsorption Isotherm was that adsorption is monolayer in nature. Langmuir adsorption equation is applicable under the conditions of low pressure. Under these conditions, gaseous molecules would possess high thermal energy and high escape velocity. As a result of this less number of gaseous molecules would be available near the surface of adsorbent.

Under the condition of high pressure and low temperature, thermal energy of gaseous molecules decreases and more and more gaseous molecules would be available per unit surface area. Due to this multilayer adsorption would occur. The multilayer formation was explained by BET Theory. The BET equation is given as

$$V_{total} = \frac{V_{mono} \cdot c\left(\frac{P}{P_0}\right)}{\left(1 - \frac{P}{P_0}\right)\left(1 + c\left(\frac{P}{P_0}\right) - \frac{P}{P_0}\right)}$$

2.4 Types of Adsorption Isotherm

Five different types of adsorption isotherm and their characteristics are explained below.

Type I Adsorption Isotherm

Figure 2.3: Type I Adsorption Isotherm
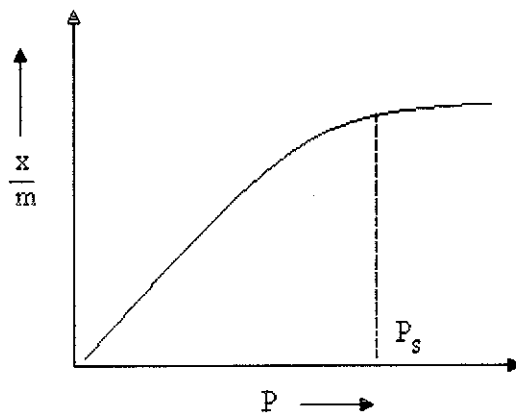
- The above graph depicts Monolayer adsorption.

- This graph can be easily explained using Langmuir Adsorption Isotherm.

- If BET equation, when $P/P0 \ll 1$ and $c \gg 1$, then it leads to monolayer formation and Type I Adsorption Isotherm is obtained.

- Examples of Type-I adsorption are Adsorption of Nitrogen (N2) or Hydrogen (H) on charcoal at temperature near to -1800C.

Type II Adsorption Isotherm

Figure 2.4: Type II Adsorption Isotherm

Type II Adsorption Isotherm

- Type II Adsorption Isotherm shows large deviation from Langmuir model of adsorption.

- The intermediate flat region in the isotherm corresponds to monolayer formation.

- In BET equation, value of C has to be very large in comparison to 1.

- $\Delta H^0_{des} > \Delta H^0_{vap.L}$

- Examples of Type-II adsorption are Nitrogen (N2 (g)) adsorbed at -1950C on Iron (Fe) catalyst and Nitrogen (N2 (g)) adsorbed at -1950C on silica gel.
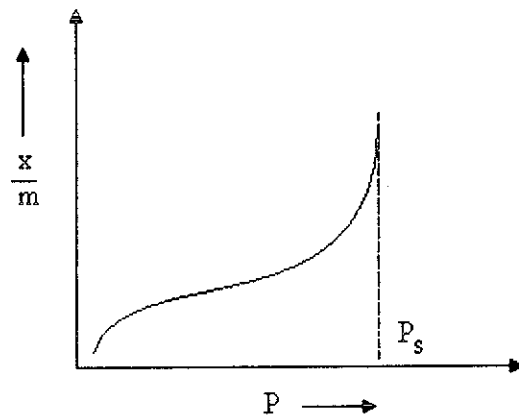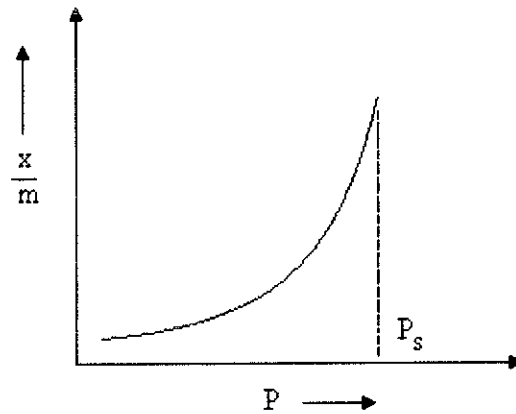
Type III Adsorption Isotherm

Figure 2.5: Type III Adsorption Isotherm

- Type III Adsorption Isotherm also shows large deviation from Langmuir model.
- In BET equation value if $C \lll 1$ Type III Adsorption Isotherm obtained.
- This isotherm explains the formation of multilayer.
- There is no flattish portion in the curve which indicates that monolayer formation is missing.
- Examples of Type III Adsorption Isotherm are Bromine (Br2) at 790C on silica gel or Iodine (I2) at 790C on silica gel.

Type IV Adsorption Isotherm
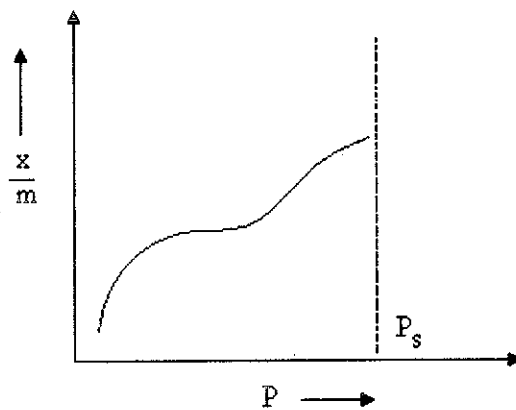
Figure 2.6: Type IV Adsorption Isotherm

- At lower pressure region of graph is quite similar to Type II. This explains formation of monolayer followed by multilayer.

- The saturation level reaches at a pressure below the saturation vapour pressure .This can be explained on the basis of a possibility of gases getting condensed in the tiny capillary pores of adsorbent at pressure below the saturation pressure (PS) of the gas.

- Examples of Type IV Adsorption Isotherm are of adsorption of Benzene on Iron Oxide (Fe2O3) at 500C and adsorption of Benzene on silica gel at 500C.

Type V Adsorption Isotherm
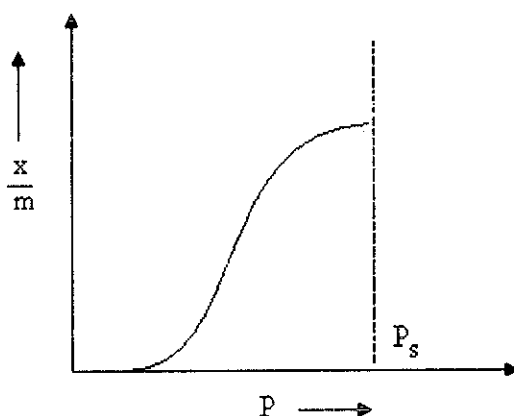
Figure 2.8: Type V Adsorption Isotherm

- Explanation of Type V graph is similar to Type IV.

- Example of Type V Adsorption Isotherm is adsorption of Water at 1000C on charcoal.

- Type IV and V shows phenomenon of capillary condensation of gas.

2.5 Overview of Benzene

Benzene is an organic chemical compound. It is composed of 6 carbon atoms in a ring, with 1 hydrogen atom attached to each carbon atom with the molecular formula C_6H_6. Benzene is a natural constituent of crude oil and is one of the most basic petrochemicals. Benzene is an aromatic hydrocarbon. Benzene is colorless and highly flammable liquid with a sweet smell. Benzene is present in crude oil, and this provides the

main source of a chemical which is used as a raw material for a wide range of products. It is mostly used as a precursor to heavy chemicals, such as ethylbenzene and cumene. Benzene has a high octane number, as such; it is an important component of gasoline. Its carcinogenic properties though has limited its use in non-industrial applications. (Dixon et al., 2000) The typical concentration of benzene allowed in wastewater is at 5ppm according to EQA 1974.

Benzene is mainly used as an intermediate to make other chemicals. Its most widely produce derivative is ethylbenzene, precursor to styrene, which is used to make polymers and plastics. Cumene is converted phenol for resins and adhesices. Cyclohexane is used in the manufacture of nylon. Smaller amounts of benzene are used to make some types of rubbers, lubricants, dyes, detergents, drugs, explosives and pesticides. (Mallat R.C., 1974)

Benzene was used as an after-shave lotion but prior to 1920s, benzene was frequently used as an industrial solvent, especially for degreasing metal. As its toxicity became obvious, benzene was supplanted by other solvents such as toluene also known as methyl benzene which has similar properties but is not as carcinogenic. (Adachi et al., 2001)

2.6 Overview of Toluene

Toluene formerly known as toluol is a clear, water-insoluble liquid with the typical smell of paint thinners. It is a derivative of benzene where a single hydrogen atom from six groups of atoms from the benzene molecule has been replaced by a univalent group. It is an aromatic hydrocarbon that is widely used as an industrial solvent and feedstock. It is also sometimes used as an inhalant drug for its intoxicating properties. However, inhaling toluene has a potential to cause severe nerve damage. (Enright A.M. et al, 2007) EQA 1974 has stated that the typical concentration allowed for toluene in wastewater is at 1ppm.

Toluene is a common solvent which is able to dissolve paints, paint thinners, silicone, sealants, chemical reactants, rubber, printing ink, adhesives, lacquers, leather tanners and disinfectants. It can also be used as a fullerene indicator and is a raw material for trinitrotoluene (TNT). (Mallat R.C., 1974)

Toluene occurs naturally at low levels in crude oil and is usually produced in the process of making gasoline from a catalytic reformer, in an ethylene cracker or making coke from coal. Final separation through either distillation or solvent extraction will take place in

one of the many available processes for extraction of the benzene, toluene and xylene isomers (BTX) aromatics. (Chuang K. T. et al., 1992)

2.7 Existing Studies

Rice husk has been treated with many methods in order to convert it into an adsorbent either by physical, chemical or activation treatment. Khan et. Al has reported that rice husk which is an agricultural waste can be utilized as adsorbents for elimination of heavy metals from wastewater.

Wang and Yong found by introducing rice husk silica for synthesis of a new adsorbent improve its surface properties. While Kardivelu et al states that activated carbon prepared from agricultural wastes can be used effectively in the removal of dyes and metal-ions form aqueous solution.

By treating with physical and chemical treatment, the porosity and surface area of the rice husk has improved. Heating the rice husk at temperature of 300°C, 400°C, 600°C resulted in loss of unwanted organic compounds. (Daffala S.B. et al, 2009)

In conclusion, there is no research being done using rice husk for the removal of benzene and toluene from industrial effluent or artificial wastewater.

CHAPTER 3

Methodology

3.1 Materials

The materials and chemicals involved are:

Raw rice husk, distilled water, sieve shaker, oven, furnace, benzene solution (99% purity), toluene solution (99% purity), methanol (95% purity).

3.2 Methodology

Below is the methodology of the project:

1. **Adsorbent Preparation**

   Raw rice husk were washed with distilled water to ensure all dirt are separated from the rice husk. It was then dried in an oven at 100°c for 24 hours to ensure it is dried thoroughly. It was then grinded using a grinder before being sieved to obtain a size of 250 to 500 micrometer particles of the grinded rice husk. The obtained particles were stored in a container before going to the next stage.

2. **Preparing a calibration curve for Benzene and Toluene Solution for Artificial Wastewater**

   Benzene and toluene solution were diluted with methanol to obtain a calibration curve. Five solutions were prepared to obtain 100ppm, 200ppm, 300ppm, 400ppm and 500ppm solution. These solutions were then taken to UV VIS to be analyzed to obtain a standard calibration curve.

3. **Treatment**

   Physical Treatment: Burning in a furnace

   Rice husk was burned in a furnace at five different set of temperatures of 200°C, 300°C, 400°C, 500°C and 600°C for 3 hours. The objective of burning the rice husk is

to increase the amount of carbon and silica composition. As the temperature get higher, we are expecting the amount of carbon and silica to increase but we want to find at to what temperature the increase on carbon composition will stops.

Table 3.1: Expected Result at End of Experiment

Adsorbents	Artificial Wastewater Concentration			
	Benzene		Toluene	
	Initial	Final	Initial	Final
Rice Husk at 200°C for 1hr				
Rice Husk at 300°C for 1hr				
Rice Husk at 400°C for 1hr				
Rice Husk at 500°C for 1hr				
Rice Husk at 600°C for 1hr				
Rice Husk at 200°C for 3hr				
Rice Husk at 300°C for 3hr				
Rice Husk at 400°C for 3hr				
Rice Husk at 500°C for 3hr				
Rice Husk at 600°C for 3hr				

4. Characterization

Several equipments were used to characterize the adsorbents. These equipments will tell the functional groups inside the adsorbent, the morphological surface area, specific surface area and also the chemical composition of the adsorbent before and after treatment. Below are the list of equipments:

i.   Fourier Transform Infrared (FTIR)

- To determined and analyse the chemical composition of each RH samples

ii.   Scanning Electron Microscope (SEM) and Field Emission Scanning Microscope (FSEM)

- To determined and analysed the porosity and surface area of the raw and treated RH

5. Performance Analysis

The test performance of the prepared adsorbents was done in batch mode. A benzene or toluene solution with a concentration of 100ppm was filled in a flask. Then, 0.05g of treated rice husk was weighed and put into the flask containing the benzene solution. The flask was put into a water shaker bath with room temperature at 27°c. Reading was taken for the first 5, 10, 15 and 20 minutes with a pipette getting only 0.25mL of the solution. The pipette solution went through a filter paper before entering a test tube to be brought to be analyzing for the concentration. Only 4 readings were taken from each flask. After 4 readings have been taken, a new 100ppm solution of benzene and 0.05g of treated rice husk will be put into the water bath. This was continued until sample has been taken for 24 hours. Sample will be taken at 5, 10, 15, 20, 25, 30 minutes. Then continued for 30 minutes for 6 hours then 1 hour each for the remaining time. The samples collected will be brought to the UV-VIS to be analyzed accordingly. This is the control steps to find the suitable time to conduct the experiment.

After the control experiment, the next experiment was conducted for only one hour. Readings were taken every 3 minutes. This was continued for the rest of the project.

CHAPTER 4

Results & Discussions

4.1 Characterization

4.1.1 FTIR results

A FTIR graph showing RH before treatment and another for RH after treatment are shown below. This is to differentiate the difference in chemical composition between raw and treated RH.
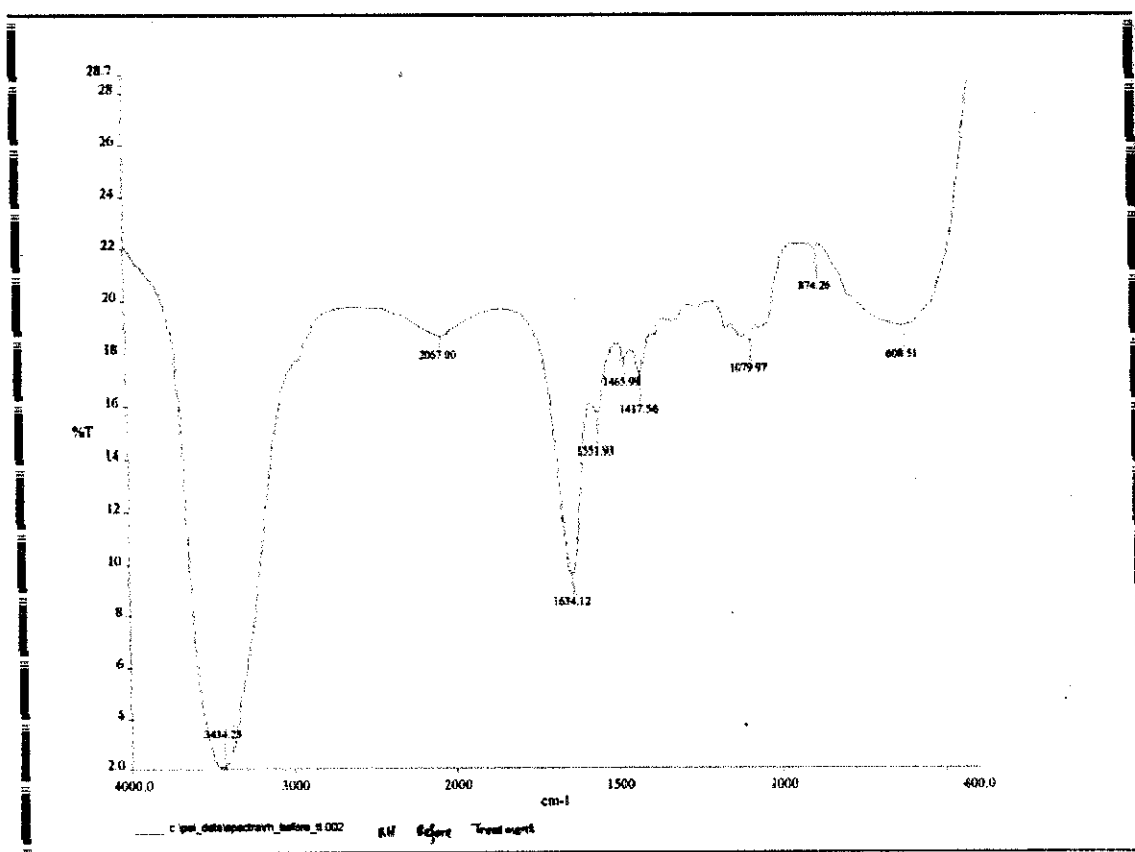
Graph obtained:

Figure 4.1: Rice Husk before treatment

As we can see from figure 11, rice husk before treatment contain many functional groups. The functional groups that were found are 8 types. They are $C=C(3434.28$ cm$^{-1})$, silicate or

Aryl-H(2067 cm^{-1}), CH$_3$(1634.12 cm^{-1}) , CH$_2$(1551.93 cm^{-1}), Aliphatic C=C (1465.99 cm^{-1}), C=O(1417.54 cm-1) and O-H(1079 cm^{-1}) bonds.
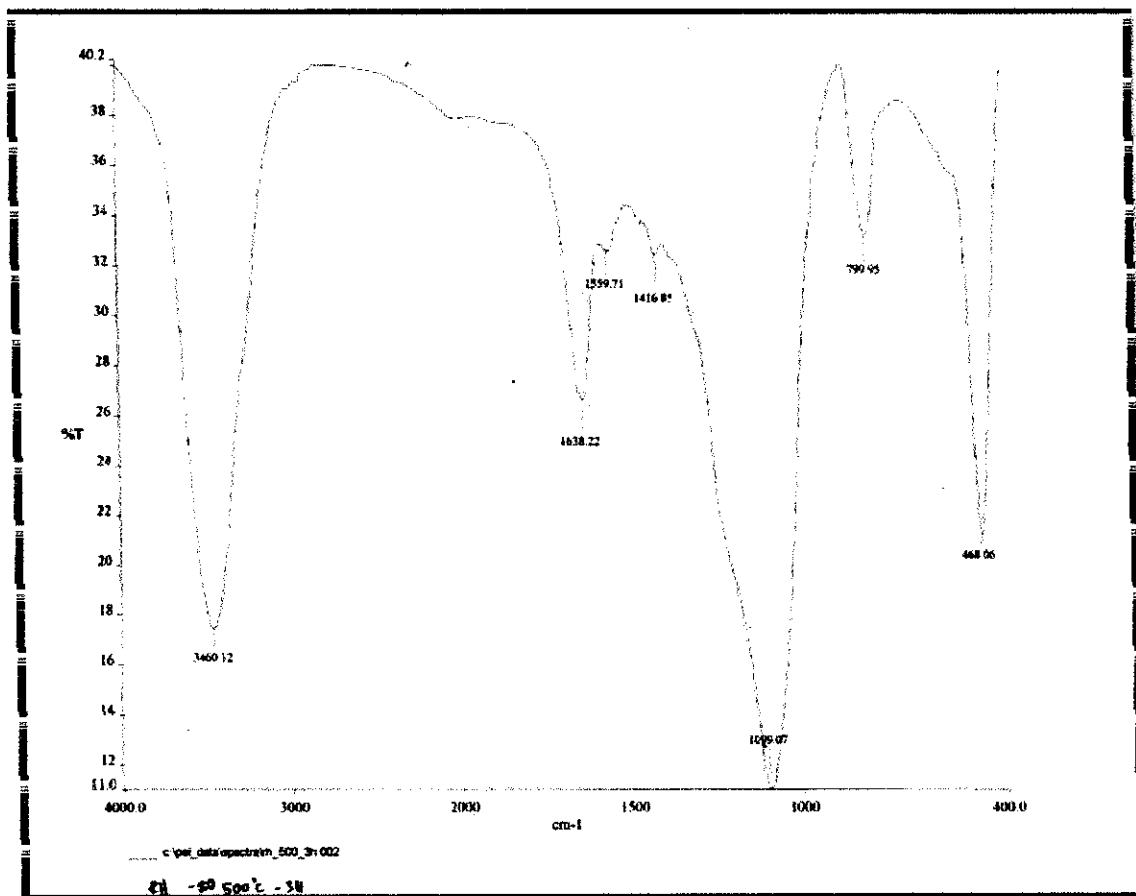

Figure 4.2: Rice Husk after treatment at 500°c for 3 hours

From figure 12, we can see significant change in the amount of functional group still intact in rice husk after treatment. RH was burned in a furnace at a temperature of 500°C for 3 hours. Here we can see that the functional group is much less that the untreated rice husk. There were only seven functional groups analyzed. They are C=C(3460.12 cm-1), C-H(1638.22 cm-1), Silicates(1559.71 cm-1), CH$_3$(1416.85 cm-1) and C=O(1099.07 cm-1).

As we can see, there are significant changes in the composition of the functional groups between untreated and treated rice husk. What these changes means will be analyze during the performance analysis of the project.

4.1.2 Scanning Electron Microscope

Figure 33: Raw Rice Husk (SEM)

Figure 4.4: Treated or Burned Rice Husk at 300°C (SEM)

Above are the images from SEM which shows the detailed morphology of the samples. Figure 11 shows the morphology of the raw RH which has not been treated in any kind of way. The raw RH has a more compact and dense surface area. Pores are detected in the image.

Figure 12 shows the morphology for the treated or burned RH. The difference can be seen on the surface are of the RH. The surface area has increased dramatically compare to before it was treated. There are more pores detected compare to in figure 11.

This proves that burning of RH has changed the morphology of raw RH. The surface area has increased dramatically as seen in the images. The increases in porosity are also detected.

4.2 Performance Analysis

After the samples have been run in UV-VIS, the adsorbency are taken. Then, a graph of Removal Efficiency (RE) VS Time (minutes) are plot to show the removal efficiency of each adsorbent.
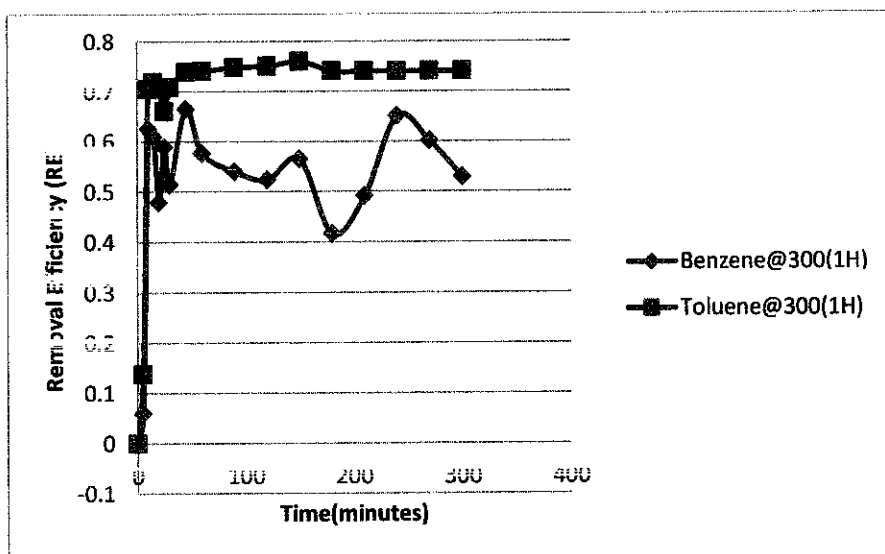
4.2.1 Removal Efficiency

Figure 4.5: Removal Efficiency for adsorbent@300°C

The control experiment indicates the breakthrough time of the adsorbent that has been burned for 1hour at 300°C. The breakthrough time was found by analyzing the graph of figure 13. According to the graph, the breakthrough time found was about 10minutes. This indicates that after 10minutes, the adsorbent will not be able to adsorb anymore adsorbate as it is saturated. As such, all the experiment will only be conducted for 1 hour to find the removal efficiency for the other adsorbents.
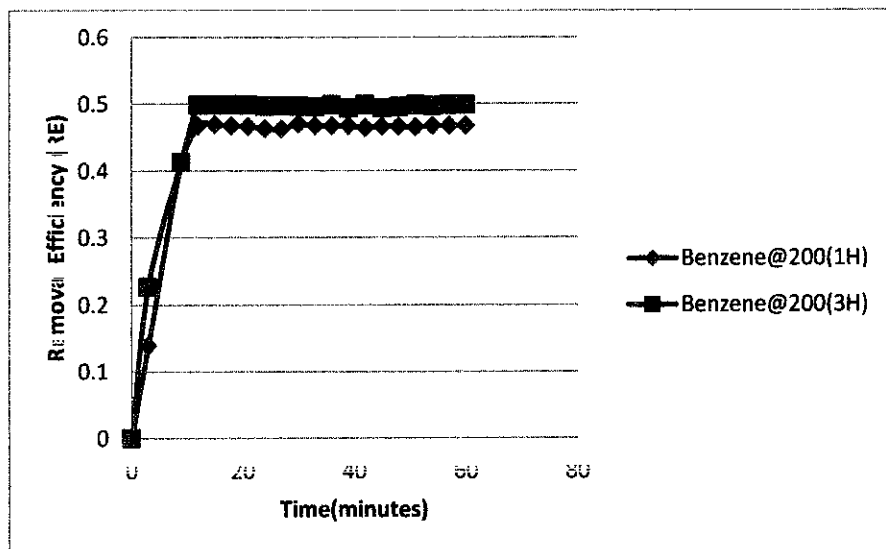
31

4.2.1.1 Removal Efficiency for Benzene

Figure 4.6: Removal Efficiency for adsorbent@200°C

Figure 14 indicates the removal efficiency VS time graph for removal of benzene with RH burned at a temperature of 200°C for 1 hour and 3 hours respectively. From the graph, the removal efficiency increases until around 13 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is benzene.
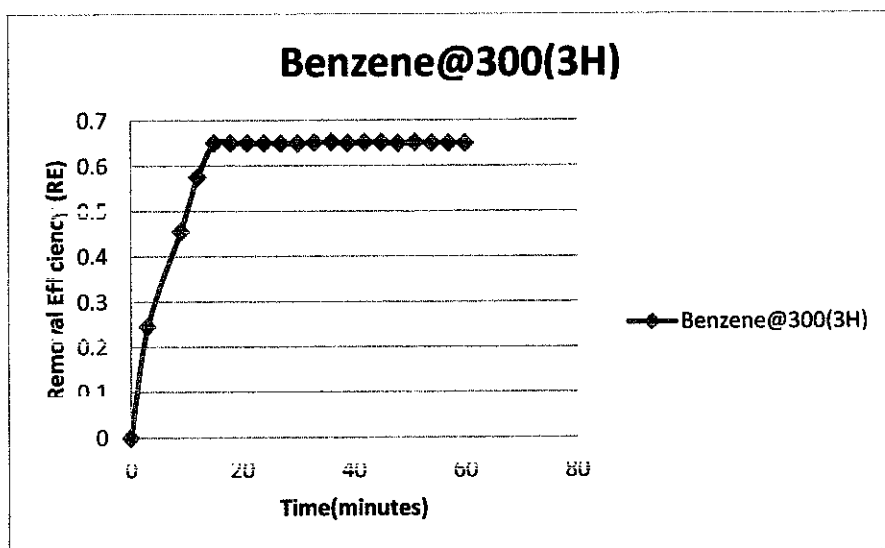

Figure 4.7: Removal Efficiency for adsorbent@300°C

Figure 15 indicates the removal efficiency VS time graph for removal of benzene with RH burned at a temperature of 300°C for 3 hours. From the graph, the removal efficiency increases until around 16 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is benzene.
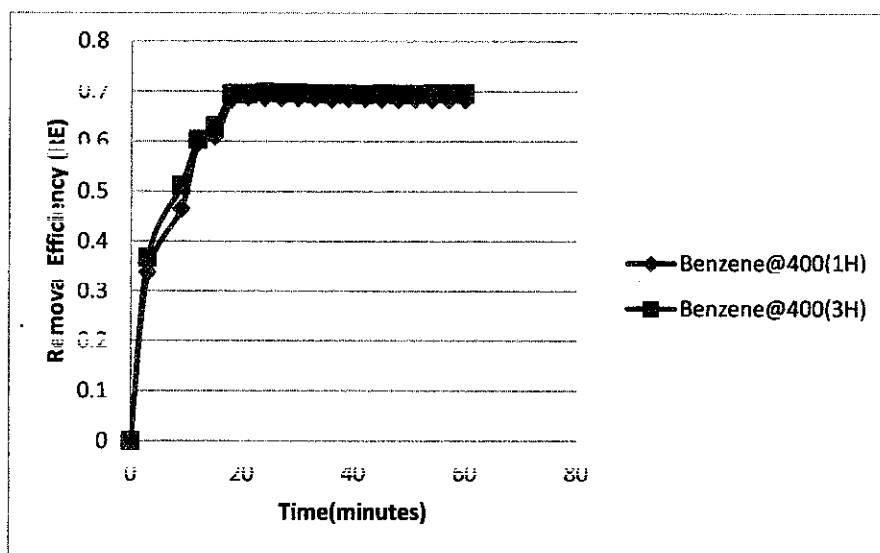

Figure 4.8: Removal Efficiency for adsorbent@400°C

Figure 16 indicates the removal efficiency VS time graph for removal of benzene with RH burned at a temperature of 400°C for 1 hour and 3 hours respectively. From the graph, the removal efficiency increases until around 18 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is benzene.

Figure 4.9: Removal Efficiency for adsorbent@500°C

Figure 17 indicates the removal efficiency VS time graph for removal of benzene with RH burned at a temperature of 500°C for 1 hour and 3 hours respectively. From the graph, the removal efficiency increases until around 20 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is benzene.
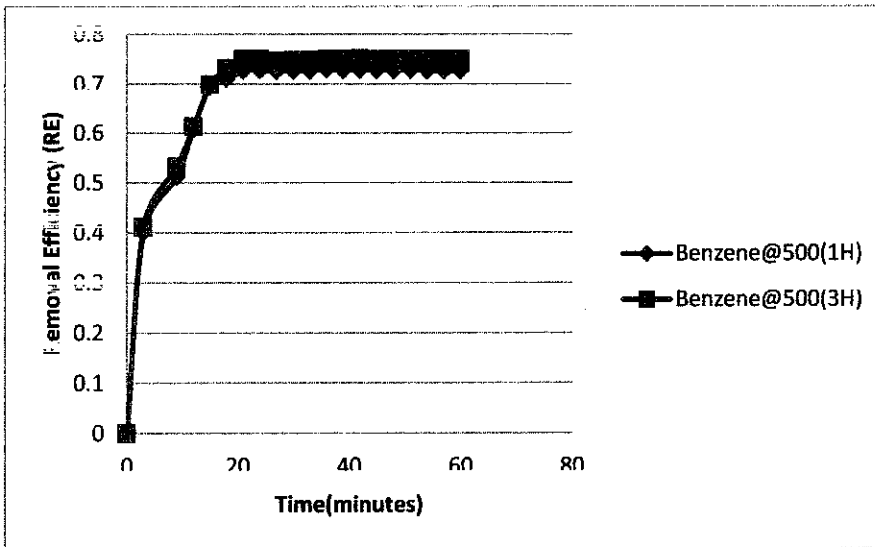

Figure 4.10: Removal Efficiency for adsorbent@600°C

Figure 18 indicates the removal efficiency VS time graph for removal of benzene with RH burned at a temperature of 600°C for 1 hour and 3 hours respectively. From the graph, the removal efficiency increases until around 22 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is benzene.
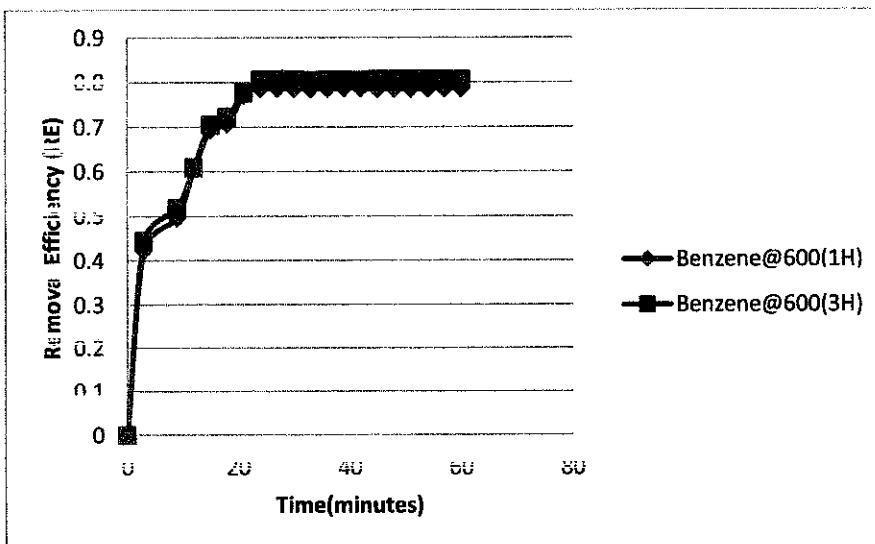
From the results obtained, it is found a steady increase of breakthrough time for RH adsorbents increases with the temperature it was burned. Breakthrough occurs when an adsorbent is not able to adsorb anymore adsorbate which is benzene in this case. Comparing the graph from figure 13 to 18, we can see the removal efficiencies of the RH adsorbent increases as the time for treatment or burning increases. The removal efficiencies for RH burned at 200°C, 300°C, 400°C, 500°C, and 600°C are 50%, 65%, 70%, 75% and 80% respectively. This proves that the surface area of the RH has increased during the treatment process where it was burned in a furnace. The increase in surface area has increase the ability of the RH adsorbent as it is able to adsorb more of the benzene from the artificial wastewater. This results in effective removal of benzene from artificial wastewater.
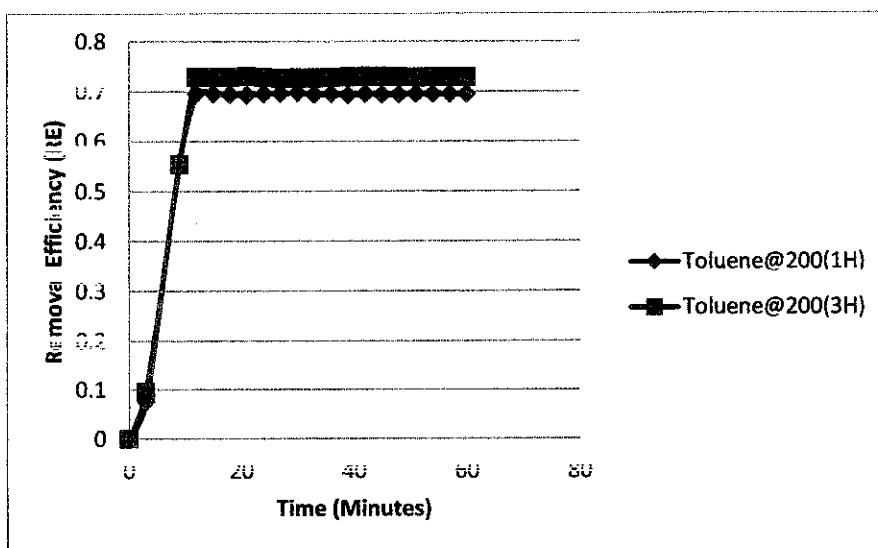
4.2.1.2 Removal Efficiency for Toluene

Figure 4.11: Removal Efficiency for adsorbent@200°C

Figure 19 indicates the removal efficiency VS time graph for removal of toluene with RH burned at a temperature of 200°C for 1 hour and 3 hours respectively. From the graph,

the removal efficiency increases until around 15 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is toluene.

Figure 4.12: Removal Efficiency for adsorbent@300°C

Figure 20 indicates the removal efficiency VS time graph for removal of toluene with RH burned at a temperature of 300°C 3 hours. From the graph, the removal efficiency increases until around 18 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is toluene.
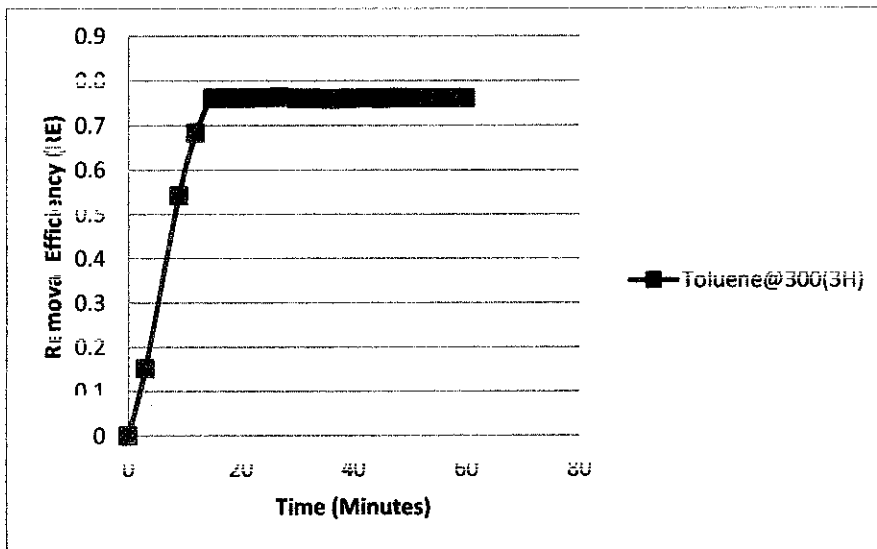
Figure 4.13: Removal Efficiency for adsorbent@400°C

Figure 21 indicates the removal efficiency VS time graph for removal of toluene with RH burned at a temperature of 400°C for 1 hour and 3 hours respectively. From the graph, the removal efficiency increases until around 20 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is toluene.
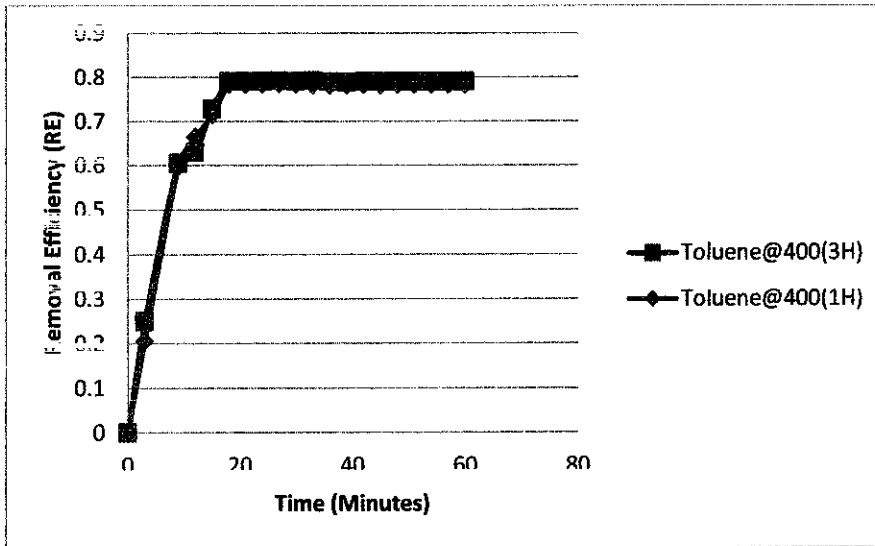

Figure 4.14: Removal Efficiency for adsorbent@500°C

Figure 22 indicates the removal efficiency VS time graph for removal of toluene with RH burned at a temperature of 500°C for 1 hour and 3 hours respectively. From the graph, the removal efficiency increases until around 22 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is toluene.
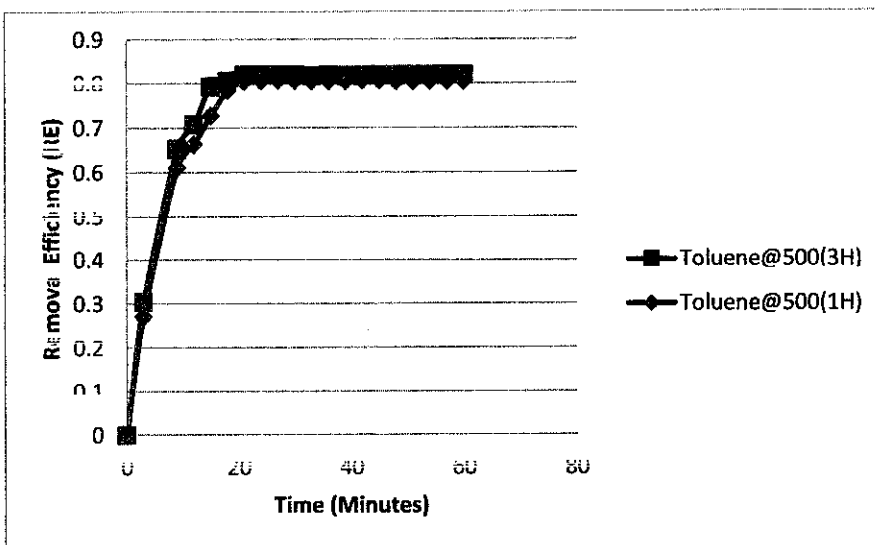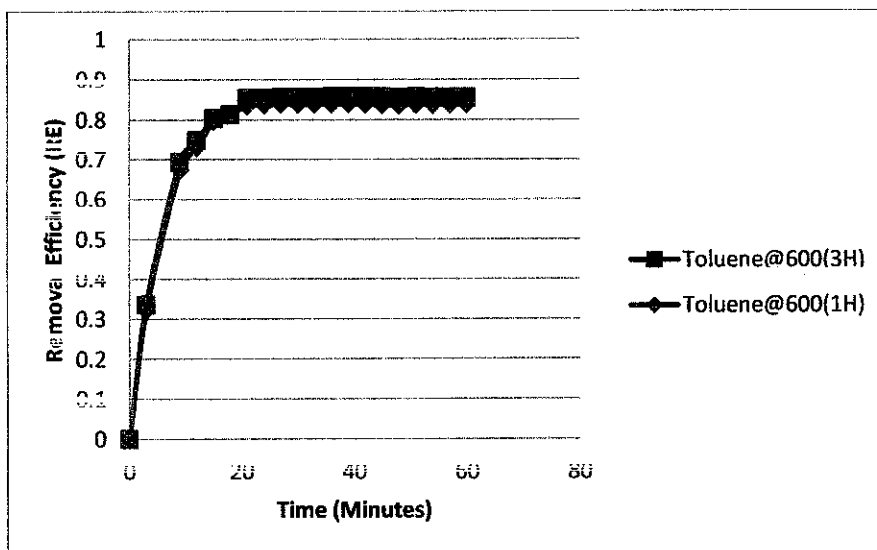

Figure 4.15: Removal Efficiency for adsorbent@600°C

Figure 23 indicates the removal efficiency VS time graph for removal of toluene with RH burned at a temperature of 600°C for 1 hour and 3 hours respectively. From the graph, the removal efficiency increases until around 23 minutes where the removal efficiency does not increase nor decrease. This means that the adsorbent has reached its breakthrough point. The adsorbent has reached its saturation point where it was not able to adsorb anymore adsorbate which is toluene.

From the results obtained, it is found a steady increase of breakthrough time for RH adsorbents increases with the temperature it was burned. Comparing the graph of figure 19 to 23, we can see the removal efficiency for removal of toluene steadily increases. The removal efficiencies for RH burned at 200°C, 300°C, 400°C, 500°C, and 600°C are 70%, 75%, 80%, 83% and 85% respectively. This again proves that the surface area of the RH has increased

during the treatment process where it was burned in a furnace. The increase in surface area has increase the ability of the RH adsorbent to remove toluene from the artificial wastewater.

CHAPTER 5

Conclusion & Recommendations

5.1 Conclusion

The project has been able to produce adsorbents from rice husk. The treatment of rice husk has increased the specific surface area of the developed adsorbents, changed the functional groups of the raw rice husk.

Experiments found that, the treatments of rice husk have increased the adsorbent ability to remove benzene and toluene from artificial wastewater. The increase in temperature in the treatment of the rice husk has increase the removal efficiency of the adsorbents developed.

It is concluded that the experiment has achieved its original objective which are the experiment was able to developed adsorbent from rice husk for the removal of benzene and toluene from artificial wastewater with a removal efficiency of 80% for benzene and 85% for toluene.

5.2 Recommendations

It is recommended that the study to be continued with adsorbents treated chemically and also by activating it. The treatments will increase the adsorption ability of the adsorbents developed. (Adachi et al, 2004)

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