Amine Solution Removal Using Adsorbent Developed

From Sugarcane Bagasse

by

Mohd Zaem Bin Rosli

Dissertation submitted in partial fulfillment

The requirement for the

Bachelor of Engineering (Hons)

(Chemical Engineering)

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Universiti Teknologi PETRONAS

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF APPROVAL

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Approved by,

(AP.Dr.Hilmi B Mukhtar)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is 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.

MOHD ZAEM BIN ROSLI

Abstract

In gas sweetening plant, natural gas will undergo a pre-treatment process before it can be utilized in further processes. One of the processes involve during the pre-treatment is acid gas removal. In this section, amine solution is widely to remove acid gas like carbon dioxide and hydrogen sulfide. There are several types of amine solutions that commonly used in this industry but only one type of amine was chosen for this study, which was Diethanolamine, DEA.

Therefore, sugarcane bagasse was chosen as a raw material in developing an adsorbent to remove amine solution in wastewater. Sugarcane bagasse is a commonly available agriculture waste in Malaysia and definitely this project will change the waste to wealth. This project focused on the study of capacity and capability of the sugarcane bagasse as a low cost adsorbent to remove amine solution in waste water. In this piece of work, the preparations of adsorbents from sugarcane bagasse were modified via thermal treatment at temperature 500°C and 250°C for 1 hour. Once the adsorbent was prepared, extraction study was carried to study the adsorption capacity.

The physical and surface properties of the developed adsorbent were analyzed using Scanning Electron Microscope (SEM) and Fourier Transform Infrared (FTIR) spectrometer. Meanwhile, right after adsorption experiment, High Performance Liquid Chromatography (HPLC) was used in determining the final concentration of artificial wastewater. The batch process was chosen as a method in the extraction of amine solution from artificial waste water.

For adsorption study, batch method was chosen in conducting the experiment. The artificial wastewater was prepared at two concentrations, i.e 500 ppm and 1000ppm in order to study the effect of concentration on adsorption behavior The results obtained from extraction study shows how an adsorbent can be developed from sugarcane for amine solution removal. At initial concentration 1000ppm, using adsorbent treated at 250°C, the time needed for the adsorbent to reach equilibrium was 2.5 hours while for 500ppm of initial concentration, time needed was 3hours.

For adsorbent burned at 500 °C, with initial artificial concentration was 1000ppm, the time needed for the adsorbent to reach equilibrium was 3 hours while for 500ppm of initial concentration, time needed was 5hours.

In conclusion, sugarcane bagasse have a potential to be developed as an adsorbent in removing sugarcane bagasse and more studies need to be done in order to increase the efficiency of it. From there, we can have a low cost adsorbent and with other words, converting the waste to wealth.

ACKNOWLEDGEMENTS

In the name of Allah the most Beneficent, the Merciful

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Special thanks also to Dr. Nurhayati Mellon and Dr. Asna Mohd Zain as the coordinator for this Final Year Research Project. Without their management and coordination, the flow if this project might not be as expected.

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Abbreaviations and nomenclature

Ct Concentration at t time

Co Concentration at t=0

SCB Sugarcane Bagasse

Chapter 1: Introduction

1.1 Background study

Water is a source of life and energy, although millions of people worldwide are suffering with the shortage of fresh and clean drinking water. Rapid pace of industrialization, population expansion, and unplanned urbanization have largely contributed to the severe water pollution and surrounding soils.

Wastewater is liquid waste discharged by domestic residences, commercial properties, industry, agriculture, which often contains some contaminants that result from the mixing of wastewater from different sources. Pollutants discharged in wastewaters can be toxic to aquatic life and cause natural waters to be unfit as potable water sources. Amine solution is one of pollutant that can harm people if it is released without treatment and do not follow to the requirement that have been established by government. So, for this project, sugarcane is used in developing an adsorbent in removing amine solution from wastewater through the adsorption process.

As we know, sugarcane is one of the agricultural wastes that easily available in Malaysia. Sugarcane also is known as one of agricultural waste that has potential to be an adsorbent that will be employed for the removal of wastewater contaminant. For this project, amine solution is the contaminant that will be removed.

1.2 Problem statement

Most of gas processing plants usually will encounter problem which is so called as wastewater containing amine. Normally the amine processes are cycles of absorption and desorption in order to permit the use of the absorbent. Due to the closed loop nature of these processes, non-regenerable contaminants tend to accumulate and can cause major reduction in efficiencies and operational problems. When carbon capacity is exhausted, or the carbon has become spent, it will no longer clean the amine. Hence, the amine stream becomes contaminated and the effects of dirty amine reoccur.

When amine solutions become dirty, thus, several operational results can occur which adversely affect the performance of the amine system. A dirty amine can cause foaming in the absorber and stripper, reduce scrubbing efficiency, and promote corrosion. As the amine solutions become contaminated, they lose their effectiveness and cause operational problems, which can lead to plant shutdown. Therefore, one of the solution to overcome this problem is, the company need to replace the fresh amine into the process so that, the efficiency of the process can be increased back.

Therefore, one of the sources of amine is during washing equipment processes, there are quantities of amine solution were discharged into waste water stream. Besides that, amine also can come from stripper, whereby, it condensed along with water during the stripping process in order to circulate amine into absorber. Due to that, the water containing amine will be flow into wastewater treatment section before it is discharge into environment. The typical concentration of amine in wastewater treatment plant in industry was about 15000 mg/L and it was over the allowable limit which at least 100mg/L. Prior to that; adsorption process is one of the best solution in removing the amine and it is very important since it is one of the hazardous waste that cannot be easily discharged into environment.

1.3 Objective

The objectives of this project are listed as follows:

1) To develop an adsorbent from sugarcane baggase in order to remove amine solution from artificial wastewater.
2) To study the effect of treatment to the surface, functional group of the sugarcane baggase before and after treatment.
3) To investigate the capability and adsorption performance of the sugarcane baggase before and after treatment.

1.4 Scope of study

The sugarcane bagasses are easily available for this project since it can be obtained from industry of sugar refining or drink. Adsorbents will be developed in thermal treatment after going through the pre -treatment process like drying, grinding and sieving. After the pre-treatment, it will be treated so that we can see the different on surface of adsorbent, functional group and etc. After that, the adsorbent will be tested on the efficiency of removing amine solution in a batch process in order to know the capability of sugarcane bagasse in as an adsorbent.

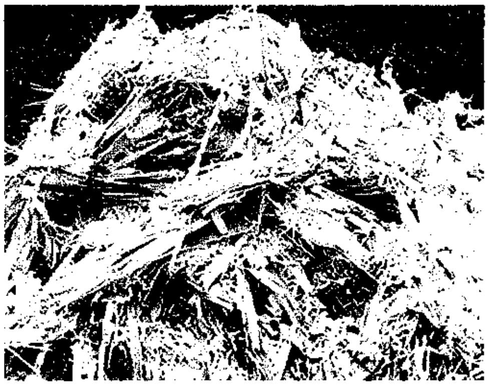

Figure 1: Sugarcane bagasse

1.4.1 The relevancy of the project

Adsorption is recognized to be an efficient and economically feasible method to remove amine from wastewater. Adsorbent that will be used which is from cheap and readily available sources like sugarcane bagasse is believed to be employed for the removal of amine solution from wastewater. Besides, sugarcane bagasse is one of the agricultural wastes which is abundant in Malaysia. Thus, a study is proposed to develop economically feasible adsorbent from sugarcane bagasse, which is considered as low-cost adsorbent

1.4.2 Feasibility of the project

Sugarcane bagasse is a waste byproduct from sugar industry. The sugarcane bagasse used in this work was supplied by drink seller around Seri Iskandar. Several adsorption studies will be conducted in a period of one year which should be sufficient to finish the project. All equipments needed in this project are available in the Chemical Engineering Laboratory as well as the chemicals involved. With all the resources provided, this project can be considered as a feasible project within the time frame given.

Chapter 2: Literature review

2.1 Wastewater

Wastewater can be classed as sanitary, commercial, industrial, agricultural or surface runoff. Term wastewater need to be separated from the term sewage, sewage is subset of wastewater that is contaminated with feces or urine though many people use term sewage referring to any waste water. Wastewater mostly consists of pure water (more than 95%), and there are numerous processes that can be used to clean up waste waters depending on the type and extent of contamination. Treated wastewater can then be reused as the drinking water after it has been cleared of contaminants.

Water treatment process selection is a complex task involving the consideration of many factors which include, available space for the construction of treatment facilities, reliability of process equipment, waste disposal constraints, desired finished water quality and capital and operating costs. The treatment of wastewaters to make them suitable for subsequent use requires physical, chemical and biological processes. A number of technologies are available with varying degree of success to control water pollution. Some of them are coagulation, foam flotation, filtration, ion exchange, aerobic and anaerobic treatment, advanced oxidation processes, solvent extraction, adsorption, electrolysis, microbial reduction, and activated sludge. However, most of them require substantial financial input and their use is restricted because of cost factors overriding the importance of pollution control

Based on Environment Quality Act 1974, under Environment Quality (Sewage and Industrial Effluent) Regulation 1979, stated that the wastewater discharged to river should not beyond the two standards, Standard A and Standard B. For amine solution, it will be tested under Chemical Oxygen Demand (COD) requirement because it is indirectly measure the amount of organic compounds in water. Amine itself is an organic compound. Hence, make COD is useful in measuring the quality waster containing amine.

Table 1: Parameter limits according to Regulation No. 11: Discharge standard for industrial effluent for other parameters, Industrial Effluent Regulations, 2009.

Parameter	Unit	Standard A	Standard B
Temperature	° C	40	40
pH value	-	6.0 – 9.0	5.5 – 9.0
COD	mg/L	50	100
BOD_5 at 20°C	mg/L	20	50
Suspended solids	mg/L	50	100
Mercury	mg/L	0.005	0.05
Cadmium	mg/L	0.01	0.02
Chromium, Hexavalent	mg/L	0.05	0.05
Chromium, Trivalent	mg/L	0.20	1.0
Arsenic	mg/L	0.05	0.10
Cyanide	mg/L	0.05	0.10
Lead	mg/L	0.10	0.5
Copper	mg/L	0.20	1.0

The different between Standard A and Standard B is, whenever the wastewater is discharged before the water intake point (for people usage), the standard that must be followed is Standard A which is higher in requirement compared to the standard B.

Among various available water treatment technologies, adsorption process is considered better because of convenience, ease of operation and simplicity of design (Amit Bhatnagara, 2010). Further, this process can remove and minimize different type of pollutants and thus it has a wider applicability in water pollution control.

2.2 Adsorption

The term adsorption refers to the accumulation of a substance at the interface between two phases such as solid and liquid or solid and gas. The substance that accumulates at the interface is called 'adsorbate' and the solid on which adsorption occurs is 'adsorbent'. Larvitz in 1792 and Kehl in 1793 observed similar phenomenon with vegetable and animal charcoals, respectively. However, the term 'adsorption' was proposed by Bois-Reymond but introduced into the literature by Kayser at 1978. Ever since then, the adsorption process has been widely used for the removal of solutes from solutions and gases from air atmosphere.

At the surface of the solids, there are unbalanced forces of attraction which are responsible for adsorption. In cases where the adsorption is due to weak van der Waals forces, it is called physical adsorption (Amit Bhatnagara, 2010).

Adsorption process has been proven one of the best water treatment technologies around the world and activated carbon is undoubtedly considered as universal adsorbent for the removal of diverse types of pollutants from water. However, widespread use of commercial activated carbon is sometimes restricted due to its higher costs (Amit Bhatnagara, 2010) . At the surface of the solids, there are unbalanced forces of attraction which are responsible for adsorption. In cases where the adsorption is due to weak van der Waals forces, it is called physical adsorption. On the other hand, there may be a chemical bonding between adsorbent and adsorbate molecule and such type of adsorption is referred as chemisorption.

Usually the amount adsorbed is only a fraction of a monolayer. Thus to adsorb a substantial amount of material, the adsorbent must have a large specific surface area. According to Walter Jr, adsorption is a fundamental process in the physicochemical treatment of municipal wastewaters, a treatment which can economically meet today's higher effluent standards and water reuse requirements (Walter, 2007). Major types of adsorbents in use are like activated alumina, silica gel, activated carbon, molecular sieve carbon, molecular sieve zeolites and polymeric adsorbents. Adsorption of an impurity from water on to activated carbon may result from solute hydrophobicity, or it may be caused by a high affinity of the solute for the carbon The solubility of a substance in water is significant whereby solubility in the sense of the chemical compatibility between the water and the solute. The more hydrophilic a substance the less likely it is to be adsorbed. Conversely, a hydrophobic substance will more likely be adsorbed. In the context of solute affinity for the solid, it is common to distinguish between three types of adsorption. The affinity may be predominantly due to:

(I) Electrical attraction of the solute to the adsorbent (exchange adsorption)

(2) Van der Waals attraction (physical or ideal adsorption)

(3) Chemical reaction (chemisorption or chemical adsorption).

Many adsorptions of organic substances by activated carbon result from specific interactions between functional groups on the adsorbate and on the surface of the adsorbent. It is possible for specific adsorptions to exhibit a large range of binding energies, from values commonly associated with 'physical' adsorption to higher energies associated with chemisorptions.

2.3 Factor affecting adsorption

2.3.1 Effect of particle

The adsorption capacity of SCB very much depends on the surface activities, i.e., specific surface area available for solute interaction, which is accessible to solute. It is expected that adsorption capacity will be increased with a larger surface area. In the other words, smaller particles size increases the adsorption capacity.

2.3.2 Contact time if adsorption activities.

The contact time effect of SCB adsorbent to the adsorption of the contaminant indicates that as the contact time increases, the contaminant adsorbed will also be increased (Ajmal et al, 2003: Guo et al, 2000). About three hours of adsorption, the rate of adsorption will constant which means the adsorption process has achieved an equilibrium condition (S. F . Montanher et.al, 2005). However, the fast kinetics between SCB and contaminant depends on analytical speed and the removal efficiency condition (S. F . Montanher et.al, 2005). Therefore, this factor need to be considered and must be made constant as the effect of contact time is tested.

2.4 Sugarcane

From the sources of the Department of Agricultural, Negeri Sembilan is identified as the biggest producer of sugarcane in Malaysia with annual production for 2010 is around 6000 metric ton which are planted in total area about 165.1 hectares. In 2010, Malaysia had produced sugarcane with a production of 44, 780 metric ton per year and was planted in a total area of 2 216 hectares lands all around Malaysia. The other states that also contribute huge amount of sugarcane production in Malaysia are Selangor, Johor and Melaka. In 2010, Food and Agriculture Organization of the United Nations (FAO) estimates it was cultivated on about 23.8 million hectares, in more than 90 countries, with a worldwide harvest of 1.69 billion tones. Brazil was the largest producer of sugar cane in the world. The next five major producers, in decreasing amounts of production, were India, China, Thailand, Pakistan and Mexico. The table below shows the composition of sugarcane:

Table 2: Chemical Composition of Sugarcane (Lijun Wang et al., 2009)

Composition	Percent (%)
Glucan	56
Xylan	18
Acetil groups	2
Total lignin	23
Ashes	2

Agricultural materials particularly those containing cellulose shows potential sorption capacity for various pollutants. The basic components of the agricultural waste materials include hemicellulose, lignin, lipids, proteins, simple sugars, water, hydrocarbons, and starch, containing variety of functional groups (Amit Bhatnagara, 2010). Agricultural waste materials being economic and eco-friendly due to their unique chemical composition, availability in abundance, renewable nature and low cost are viable option for water and wastewater remediation. Agricultural waste is a rich source for activated carbon production due to its low ash content and reasonable hardness (M.Ahmeda et.al 2000). Sugarcane bagasse was converted into a carbonaceous adsorbent and used for the removal of cadmium and zinc from wastewater (D. Mohan et al., 2002). Bagasse pith, a waste product from sugarcane industry has been studied by McKay et al. (1287) without any pretreatment, for the removal of two basic dyes and two acidic dyes from aqueous solutions.

In the last several decades, various agricultural wastes have been explored as low-cost adsorbent. Some of them include the shells and/or stones of fruits like nuts, peanuts, olive wastes, almonds, apricots stones and cherries and wastes resulting from the production of cereals such as rice, maize and corn.

2.5 Adsorbent preparation and type of treatment

A good adsorbent must have some characterizations like comes with simple technique which means requires little processing, good adsorption capacity, selective adsorption of adsorbate, low cost, free availability and easy regeneration. Adsorbent can be considered as cheap or low-cost if it is abundant in nature or a byproduct of waste material from a certain industry (M. Ahmaruzzaman et al., 2011).

In general, most sour gas processing facilities use chemical absorption using alkanolamines (or amines in short) to separate hydrogen sulfide and carbon dioxide from the raw gas. The alkanolamines of prime significance include monoethanolamine (MEA), diethanolamine (DEA), methyldiethanolamine (MDEA), diisopropanolamine (DIPA), and diglycolamine (DGA). For this study, monoethanolamine (MEA) will be used because of its characteristic which is coloured amine

The adsorbents will be prepared through different type of treatments which are through thermal treatment at different temperature and time of burning. From there, we can investigate which adsorbent will give the highest removal capacity so that we know the best treatment should be applied.

Before being treated thermally, sugarcane bagasse will firstly undergo pre-treatment process like washing, grinding and sieving to remove impurities that will affect results at the end of the project. Some portion of sieved bagasse is taken for characterization analysis. Characterization of biosorbent surface and structure hold keys to understanding the metal binding mechanism onto biomass (M.A. Martin et al, 2006). The Infrared spectrum revealed biosorbent heterogeneity, evidenced by different characteristic peaks with the possible presence of carboxylic, hydroxyl and carbonyl groups. Some information about the surface chemistry characterization of the sugarcane bagasse, for example the alteration of functional groups, can be used as evidences in proposing the biosorption mechanism.

For the thermal treatment, the adsorbent will be burned at different temperature in producing more carbon in the adsorbent. But, the amount of carbon will decrease in increased of temperature of burning (Samah et el., 2010) . Savova et al. (2001) applied a one-step pyrolysis process to almond shells, nut shells, peach stones, cherry stones and grape seeds. The process involved direct heating of the precursors with steam at a rate of 15 ◦C/min and 1 h retention time at 800 ◦C. The best results were obtained for apricot stones with a surface area of 1190m2/g, followed by almond shells at 998m2/g, cherry stones at 875m2/g, nut shells at 743m2/g and grape seeds at 497m2/g. As what have been done by Dimitrios Kalderis et al. (2008, January), the sugarcane bagasse was heated at 500–800 ◦C and the result was, produced carbons had surface areas up to 3000m2/g.

Chapter 3: Materials and methods

3.1 Material

Chemical that involved in this study were:

- Dithanolamine (DEA) with purity of 99%. It is is an organic compound with the formula $HN(CH_2CH_2OH)_2$. The density of DEA is 1.097 g mL^{-1}.
- Distilled water. It is used to clean the sugarcane bagasse in order to remove any contaminant existed in it.

Equipments that involved in this project were:

- Furnace
- Water bath shaker
- High Performance Liquid Chromatography (HPLC)
- Fourier Transform Infrared Spectrocopy (FTIR)
- Scanning Electron Microscope (SEM)

3.2 Methods

The overall methodology of this study could be divided into four major parts. The first part was the treatment of the sugarcane bagasse until it was transformed into adsorbent and the last part is performing adsorption experiment.

3.2.1 Pretreatment

Sugar cane bagasse was cleaned with distilled water to remove all the contaminants such as dust and small insect. It was repeated until the conductivity and the color of flow out water was equal to flow in water. Sugar cane bagasse was dried at 105 ◦C for 24 hours to ensure low moisture content prior to pretreatment. Then the sugarcane bagasse was grinded using the laboratory blender. After that, it was sieved using sieved tray sized and the particle size of 500 μm was selected to be the adsorbent size for this study.

3.2.2 Thermal treatment

The sieved sugarcane bagasse was burned at temperature 500 °C for 1 hour in furnace. It was believed that temperature and time of burning can affect the amount of carbon produced in the adsorbent. The sieved sugarcane bagasse was filled into crucibles before being placed into furnace. After 1 hour of burning, the furnace was switched off. The sugarcane bagasse could be taken once the temperature of the furnace was already cooled down for the safety. Some portion of sugarcane bagasse was taken as a sample for characterization analysis. The procedures were repeated by changing the temperature of burning to 250 °C for 1 hour.

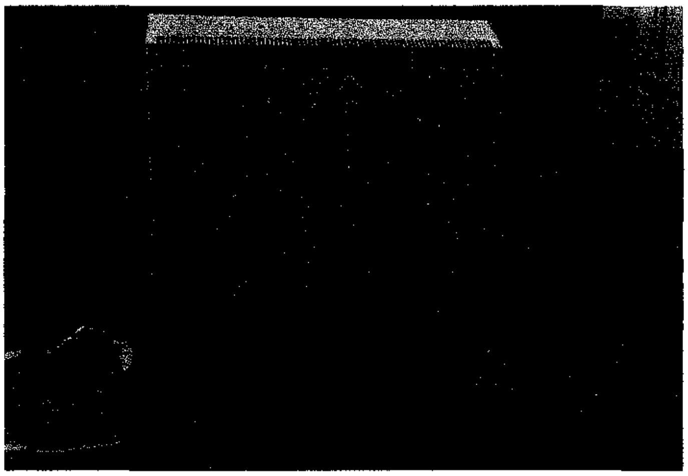

Figure 2: Furnace

3.2.3 Characterization analysis

Samples of before and after sugarcane bagasse treatment were sent for analysis the characteristic using Fourier Transform Infrared Spectrocopy (FTIR) and Scanning Electron Microscope (SEM).

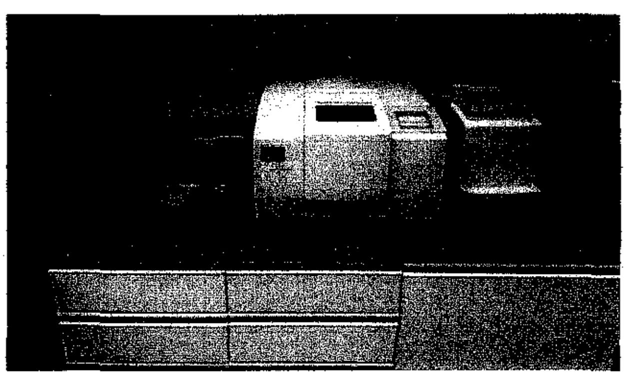

Figure 3: Fourier Transform Infrared Spectrocopy (FTIR)

3.2.4 Adsorption experiment

The artificial wastewater was prepared by dissolving appropriate amount of amine solution in distilled water. Batch mode experiment was chosen as the method for this experiment using water bath shaker. Artificial wastewater solutions at were prepared at various concentrations i.e. 500ppm, 1000ppm with constant volume, 100mL. For the first batch of experiment, 1L of Diethanolamine (DEA) solution was prepared at concentration of 1000ppm. 4 conical flasks were used for this batch. Each flask was filled up by 0.005g of adsorbent. Then, the flasks were filled up by 100ml of artificial wastewater with Diethanolamine (DEA) solution at concentration of 1000ppm. Time was started. Then, all the flasks were put into water bath shaker.

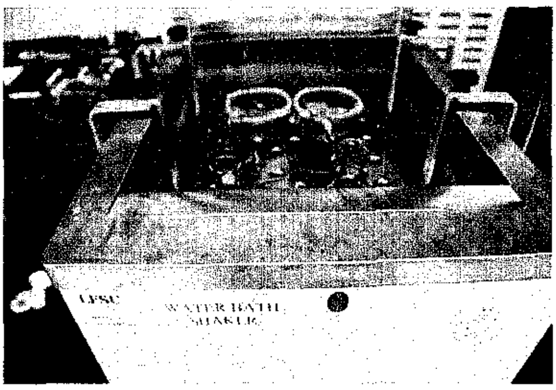

Figure 5: Conical flasks were put into water batch shaker

At condition:

Concentration: 1000 ppm

Mass of adsorbent: 0.05gram

Rpm: 160 rpm

Temperature set: 25 ^{0}C

After a certain time, 10 mL of solution inside conical flask was taken out and filtered to get sample for artificial wastewater.

Figure 6: The sample was filtered to remove spent adsorbent

After the extraction process is done, the sample was analyzed using High Performance Liquid Chromatography (HPLC) to get the final concentration of amine solution.

Chapter 4: Result and Discussion

This chapter presents the findings and discussion from the results obtained during lab work of preparation of adsorbent and the adsorption of amine solution using sugarcane bagasse.

4.1 Pre-treatment of sugarcane bagasse

During sugarcane bagasse cleaning process, it has been observed that a lot of paddy and other contaminant and impurities were floating on the surface of water. Cleaning process was needed in order to get rid of impurities of sugarcane bagasse composition. It was crucial in order to avoid unstable result at the end of the study. After grinding and sieving, amount of sugarcane bagasse collected was 600g. the color of 500 μm sugarcane bagasse was white.

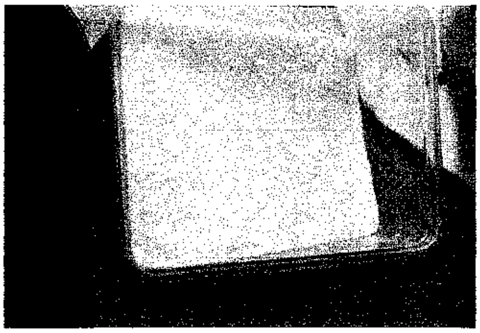

Figure 7: 500 μm sieved sugarcane bagasse before treatment

4.2 Treatment of sugarcane bagasse via thermal treatment

The 500 μm of sugarcane bagasse was burn at two different temperatures i.e 500°C and 250°C for 1 hour. The mass of sugarcane bagasse had reduced after the burning process and the color turned to be black for both temperatures.

Table 3: Percent of mass reduced after burning

Temperature	Percent of mass reduced (%)
250 °C	40%
500 °C	55%

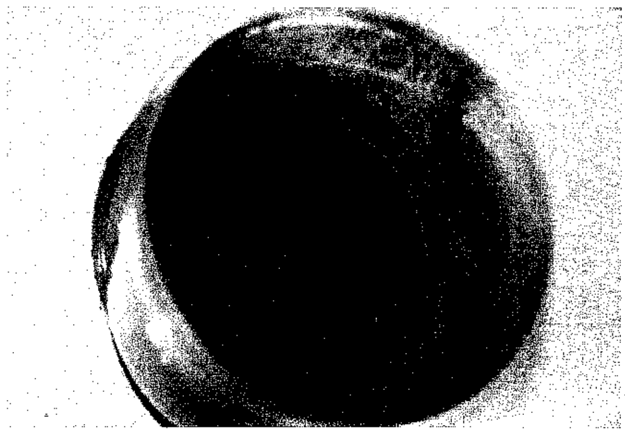

Figure 8: 500 μm sieved sugarcane bagasse after treatment

4.3 Characterization Analysis

4.3.1 Scanning Electron Microscope (SEM)

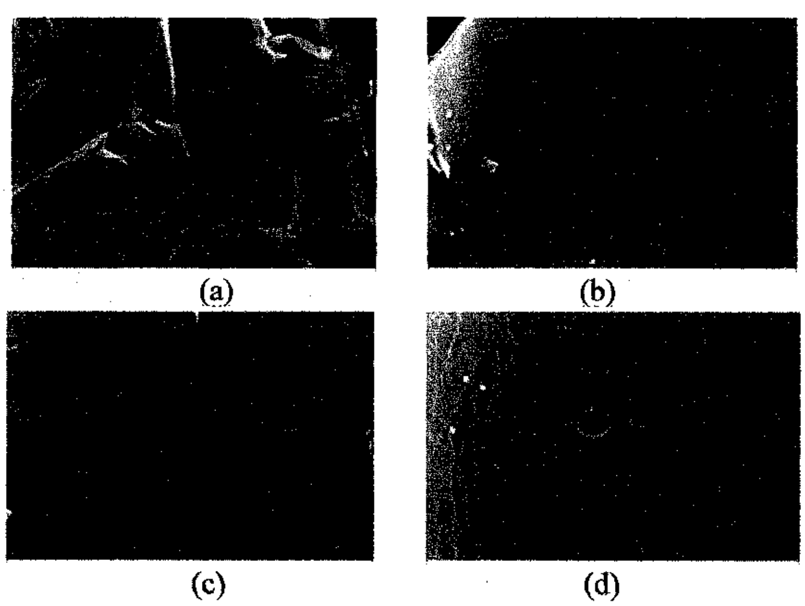

Figure 9: Morphology of raw SCB.

(a) 300X magnification, (b) 1500X, (c) 2000X, and (d) 5000X.

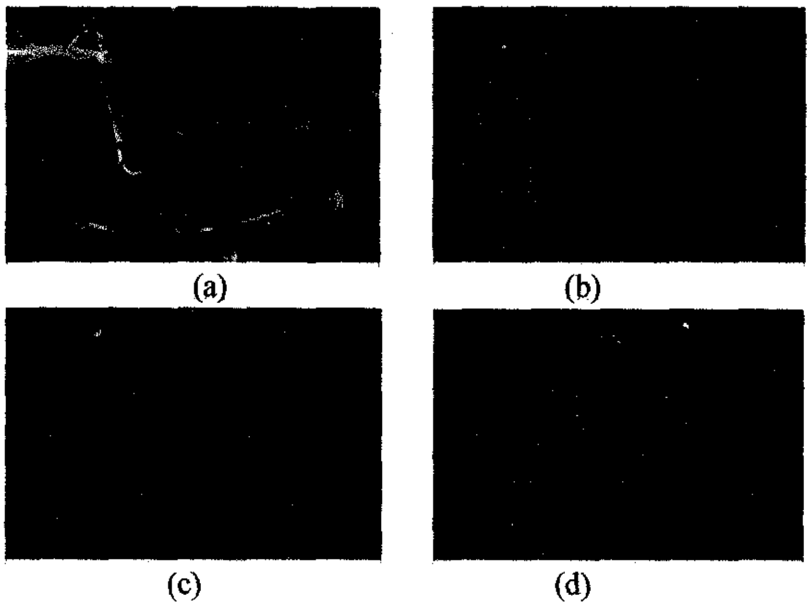

Figure 10: Morphology of SCB after burning

(a) 300X magnification, (b) 1500X, (c) 2000X, and (d) 5000X.

SEM images for raw SCB and SCB after burning were obtained for both before adsorption process. Many magnifications have been used for the images in order to get a clearer picture of the biomass wall. The objective is to see the differences between before and after the treatment.

From images, it shows that the samples do have pores at it surface wall and it is also rough. This suggests that SCB has the potential to bind solute through adsorption process. These solutes will fill the SCB pores and attached there, thus reducing the amount of contaminants from its solution.

Besides that, we can see the different where the pores were seen more on the after burning images. It shows that, via burning process, the numbers of pores will increases. Thus, more amine ion can be adsorp and removed from the artificial wastewater.

4.3.2 Fourier Transform Infrared Spectroscopy (FTIR)

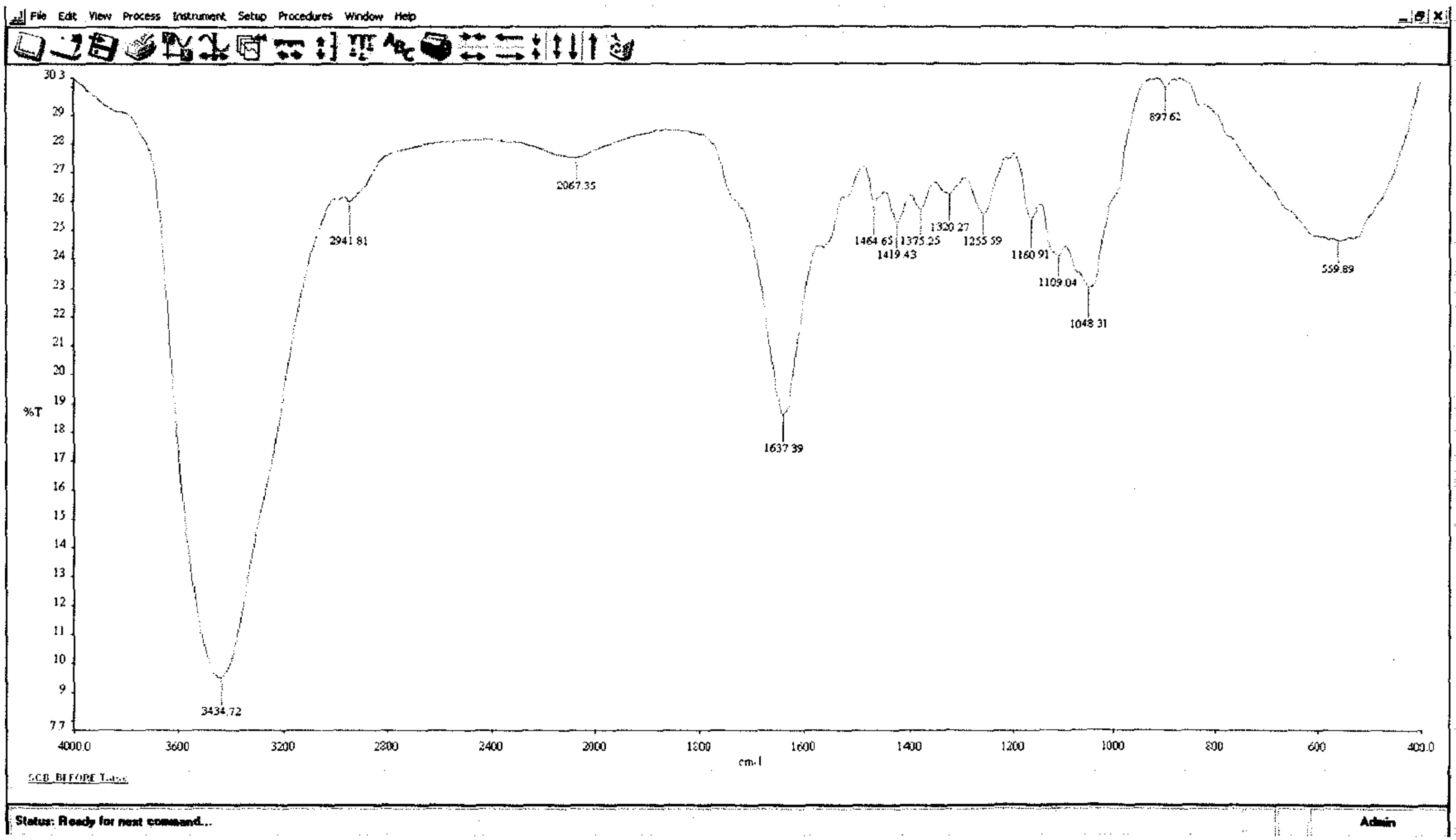

Figure 11(a): FTIR for SCB before treatment

Typical Infrared Absorption Frequencies						
	Stretching Vibrations			Bending Vibrations		
Functional Class	**Range (cm^{-1})**	**Intensity**	**Assignment**	**Range (cm^{-1})**	**Intensity**	**Assignment**
Alkanes	2850-3000	str	CH_3, CH_2 & CH	1350-1470	med	CH_2 & CH_3 deformation
			2 or 3 bands	1370-1390	med	CH_3 deformation
				720-725	wk	CH_2 rocking
Alkenes	3020-3100	med	=C-H & =CH_2 (usually sharp)	880-995	str	=C-H & =CH_2
	1630-1680	var	C=C (symmetry reduces intensity)	780-850	med	(out-of-plane bending)
				675-730	med	cis-RCH=CHR
	1900-2000	str	C=C asymmetric stretch			
Alkynes	3300	str	C-H (usually sharp)	600-700	str	C-H deformation
	2100-2250	var	C≡C (symmetry reduces intensity)			
Arenes	3030	var	C-H (may be several bands)	690-900	str-med	C-H bending &
	1600 & 1500	med-wk	C=C (in ring) (2 bands)			ring puckering
			(3 if conjugated)			
Alcohols & Phenols	3580-3650	var	O-H (free), usually sharp	1330-1430	med	O-H bending (in-plane)
	3200-3550	str	O-H (H-bonded), usually broad	650-770	var-wk	O-H bend (out-of-plane)
	970-1250	str	C-O			
Amines	3400-3500 (dil. soln.)	wk	N-H (1°-amines), 2 bands	1550-1650	med-str	NH_2 scissoring (1°-amines)
	3300-3400 (dil. soln.)	wk	N-H (2°-amines)	660-900	var	NH_2 & N-H wagging
	1000-1250	med	C-N			(shifts on H-bonding)
Aldehydes & Ketones	2690-2840(2 bands)	med	C-H (aldehyde C-H)			
	1720-1740	str	C=O (saturated aldehyde)	1350-1360	str	α-CH_3 bending
	1710-1720	str	C=O (saturated ketone)	1400-1450	str	α-CH_2 bending
				1100	med	C-C-C bending
	1690	str	aryl ketone			
	1675	str	α, β-unsaturation			
	1745	str	cyclopentanone			
	1780	str	cyclobutanone			
arboxylic Acids & Derivatives	2500-3300 (acids) overlap C-H	str	O-H (very broad)	1395-1440	med	C-O-H bending
	1705-1720 (acids)	str	C=O (H-bonded)			
	1210-1320 (acids)	med-str	O-C (sometimes 2-peaks)			
	1785-1815 (acyl halides)	str	C=O			
	1750 & 1820 (anhydrides)	str	C=O (2-bands)			
	1040-1100	str	O-C			
	1735-1750 (esters)	str	C=O			
	1000-1300	str	O-C (2-bands)	1590-1650	med	N-H (1°-amide) II band
	1630-1695(amides)	str	C=O (amide I band)	1500-1560	med	N-H (2°-amide) II band
Nitriles	2240-2260	med	C≡N (sharp)			
socyanates,Isothiocyanates, Diimides, Azides & Ketenes	2100-2270	med	-N=C=O, -N=C=S -N=C=N-, -N_3, C=C=O			

Figure 12: Typical Infrared Absorption Frequencies

Fourier Transform Infrared Spectrocopy (FTIR) is the most preferable method of infrared spectroscopy. An FTIR spectrometer simultaneously collects spectral data in a wide spectral range. The size of the peaks in the spectrum is a direct indication of the amount of material present. The main purpose of performing FTIR analysis in this study was to identify the functional groups that exist in the biomass sample thus know the composition of the adsorbent.

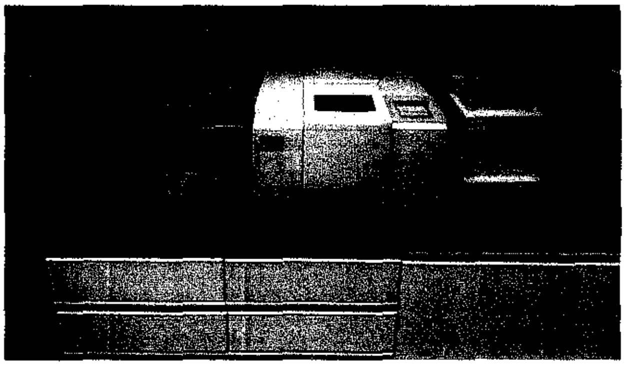

Figure 13: Fourier Transform Infrared Spectroscopy (FTIR)

The all the peaks in figure 11 (a) and (b) will be analyzed by referring to figure 12 in order to know the functional group that exists in the sugarcane bagasse. Each functional group has its own wavelengths that will differentiate the type of it.

From the figure 11 (a) which is sugarcane bagasse before treatment,we can see the functional groups that exist are like O-H (alcohol)(3434.72 cm^{-1}), C=C (alkene)(1637.39 cm^{-1}), silicate (2067.35 cm^{-1}), akyl halide (C-Br,C-Cl) (1048.76 cm^{-1}).Meanwhile, in figure 11 (b) shows the functional groups that exist in sugarcane bagasse after treatment in burning for 1 hour at temperature 500 ^{o}C. Among the functional groups that exists in the adsorbent are O-H (alcohol) (3434.72 $cm^{-1)}$, C-N(nitrite)(2245.5672 cm^{-1}), C=C (alkene)(1620.36 cm^{-1}), akyl halide (C-Br,C-Cl) (1048.76 cm^{-1}..

4.4 Adsorption Study

4.4.1 Effect of wastewater concentration

This section presents the results that obtained from High Performance Liquid Chromatography (HPLC) in order to get the final concentration of artificial wastewater after adsorption process.

Table 4: Adsorption result using adsorbent treated at 250°C for 1 hour with initial concentration of 500ppm

Contact Time (min)	Concentration	Ct/Co	% Rejection
5	440	0.88	12
10	434	0.868	13.2
20	426	0.852	14.8
30	410	0.82	18
45	395	0.79	21
60	387	0.774	22.6
120	364	0.728	27.2
150	357	0.714	28.6
180	348	0.696	30.4
240	348	0.696	30.4
300	346	0.692	30.8
360	347	0.694	30.6
420	348	0.696	30.4

Table 5: Adsorption result using adsorbent treated at 250°C for 1 hour with initial concentration of 1000ppm

Contact Time (min)	concentration	Ct/Co	% Removal
5	940	0.94	6
10	928	0.928	7.2
20	910	0.91	9
30	868	0.868	13.2
45	842	0.842	15.8
60	812	0.812	18.8
120	748	0.748	25.2
150	730	0.73	27
180	728	0.728	27.2
240	729	0.729	27.1
300	728	0.728	27.2
360	729	0.729	27.1
420	726	0.726	27.4

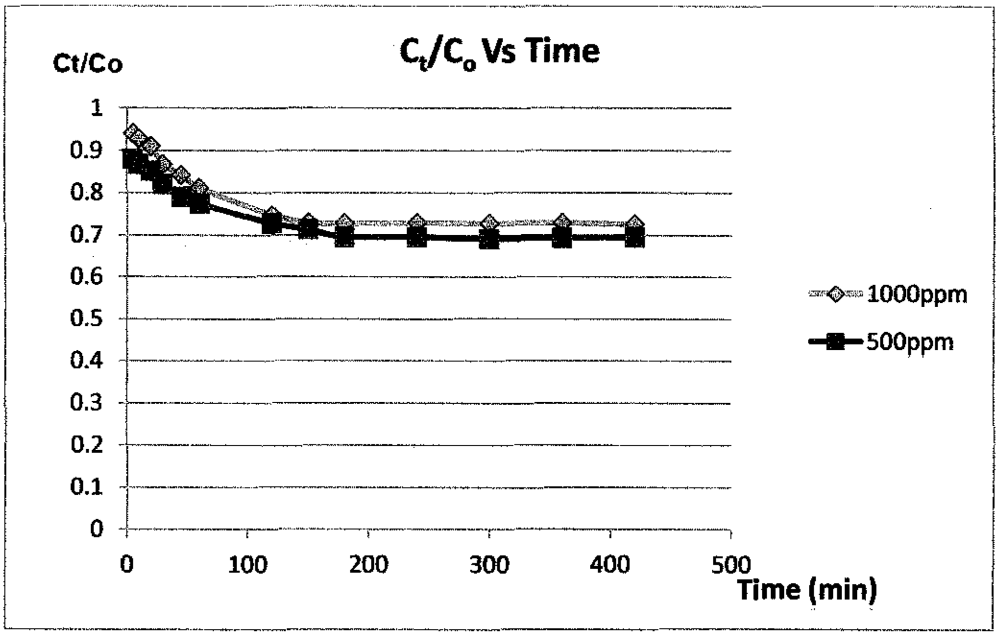

Figure 14: Removal efficiency adsorbent burned at 250°C, Ct/Co vs Contact time

Ct was concentration at t time while Co was initial concentration. For this graph, initial concentrations 500ppm and 1000ppm

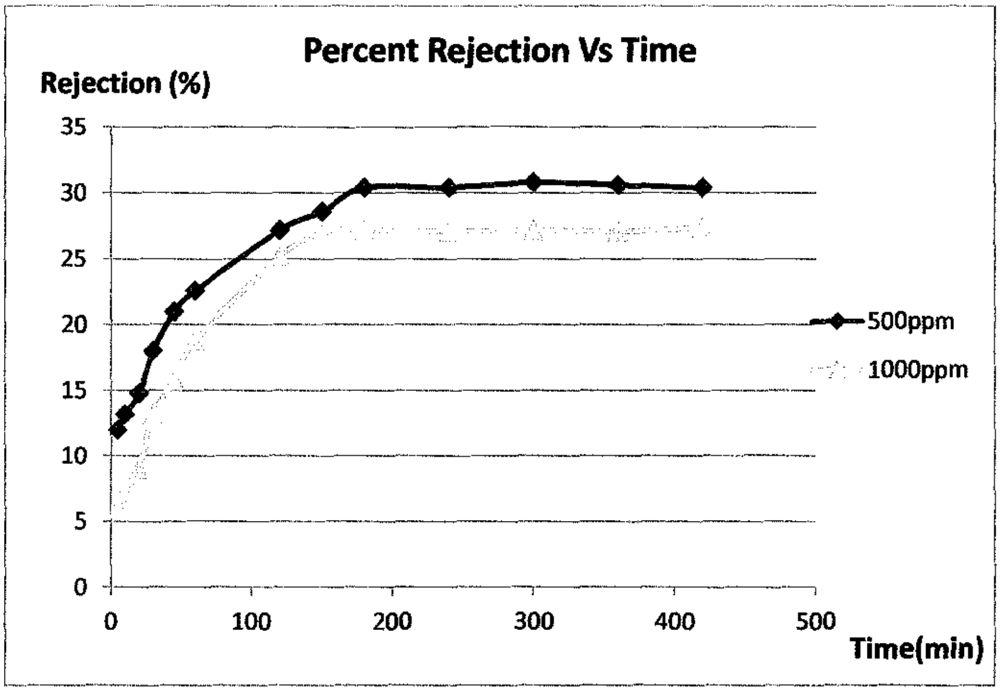

Figure 15: Removal efficiency adsorbent burned at 250°C, Percent of rejection vs Contact time

Figure 15 shows the percent of rejection vs contact time graph for amine removal from artificial wastewater using sugarcane bagasse burned at 250°C with two different initial concentrations, 500ppm and 1000ppm. For 500ppm as initial concentration, the line turns into planar after 3 hours. It means, the time taken for the adsorbent to reach its equilibrium and became saturated was after 3 hours. Meanwhile, for 1000ppm initial concentration, it needed for 2.5 hours to reach the equilibrium and became saturated. Saturated means, there was no more pores or vacancy for solute (amine) to take place since all the pores were already filled by the other amine. Thus, from the result, we can see that for higher initial concentration will need a shorter time to become saturated and vice versa.

Table 6: Adsorption result using adsorbent treated at 500°C for 1 hour with initial concentration of 500ppm

Contact Time(min)	Concentration(ppm)	Ct/Co	% Removal
5	445	0.89	11
10	432	0.864	13.6
20	426	0.852	14.8
30	422	0.844	15.6
45	414	0.828	17.2
60	405	0.81	19
120	377	0.754	24.6
150	345	0.69	31
180	334	0.668	33.2
240	324	0.648	35.2
300	317	0.634	36.6
360	315	0.63	37
420	315	0.63	37

Table 7: Adsorption result using adsorbent treated at 500°C for 1 hour with initial concentration of 1000ppm

Contact Time(min)	Concentration(ppm)	Ct/Co	% Removal
5	968	0.968	3.2
10	954	0.954	4.6
20	926	0.926	7.4
30	910	0.91	9
45	874	0.874	12.6
60	850	0.85	15
120	809	0.809	19.1
150	774	0.774	22.6
180	750	0.75	25
240	740	0.74	26
300	738	0.738	26.2
360	738	0.738	26.2
420	737	0.737	26.3

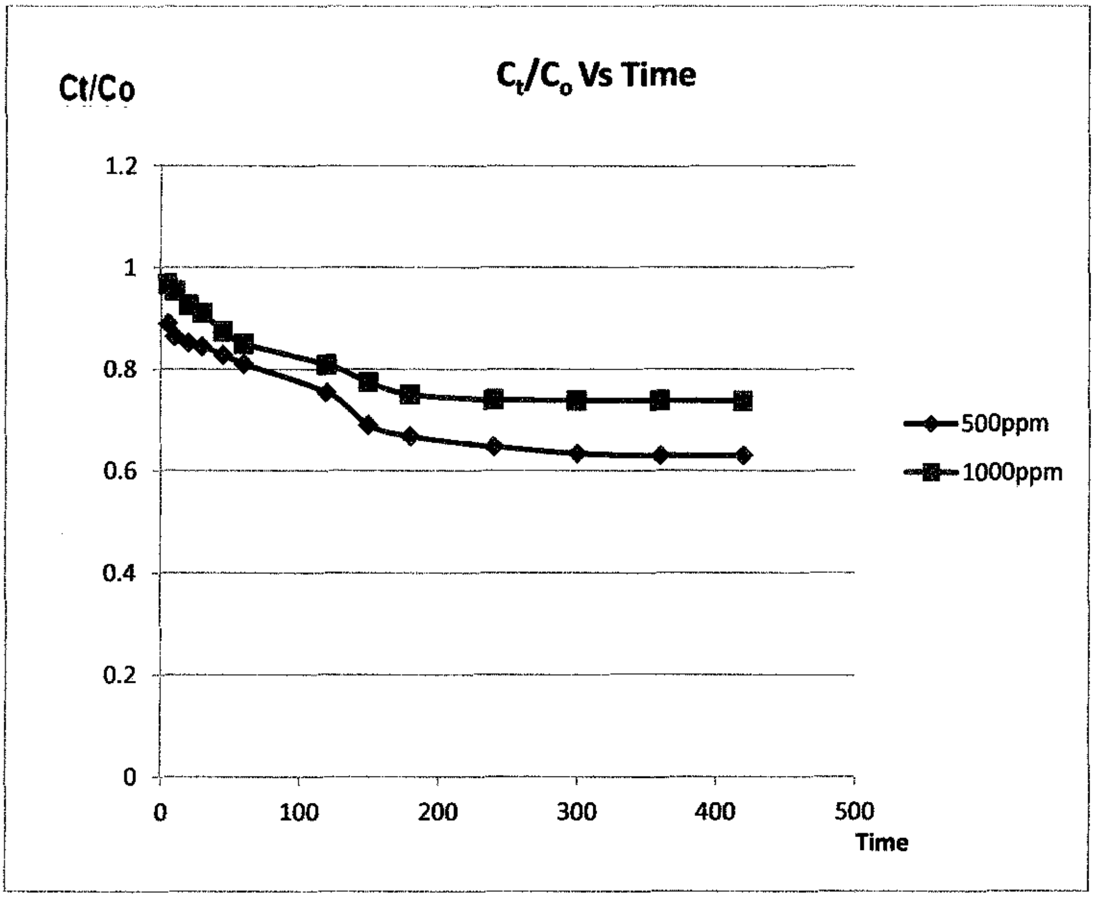

Figure 16: Removal efficiency adsorbent burned at 500°C, Ct/Co vs Contact time

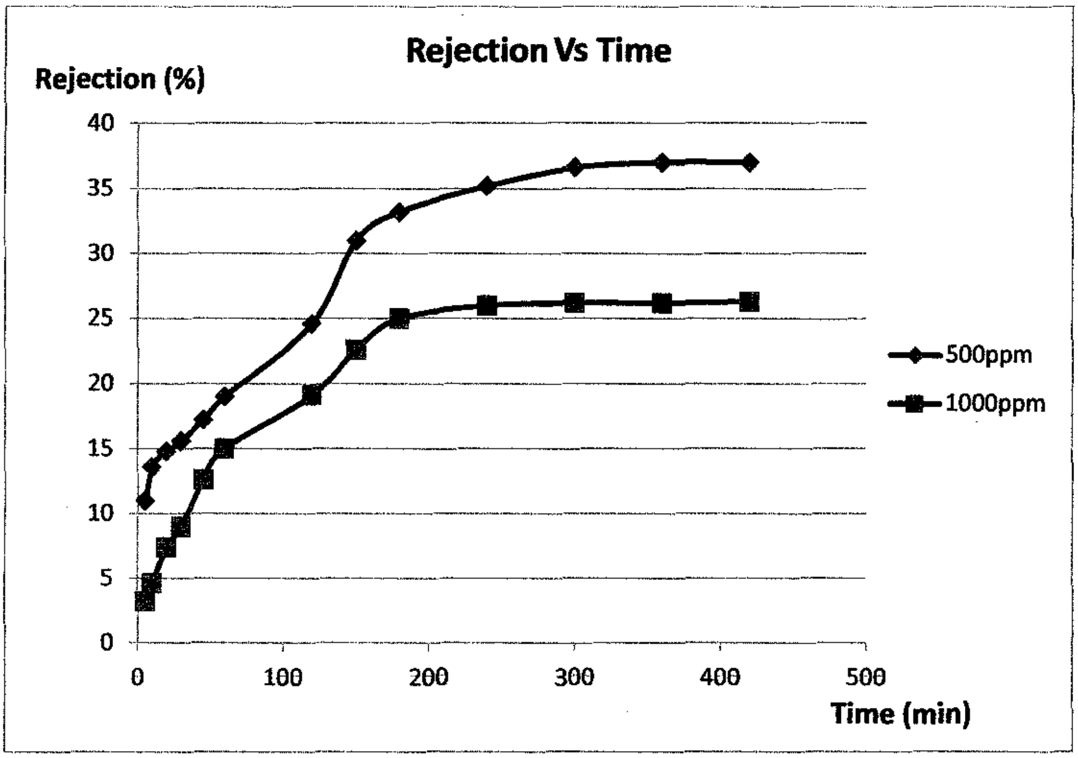

Figure 17: Removal efficiency adsorbent burned at 500°C, Percent of rejection vs Contact time

Figure 17 shows the percent of rejection vs contact time graph for amine removal from artificial wastewater using sugarcane bagasse burned at 500°C with two different initial concentrations, 500ppm and 1000ppm. From the graph, for 500ppm as initial concentration, the line becomes planar after 5 hours. It means, the time taken for the adsorbent to reach its equilibrium and became saturated was after 5 hours. Meanwhile, by 1000ppm as initial concentration, it needed only for 3hours to reach the equilibrium and became saturated. Thus, from the result, for 500°C adsorbent, we can see that for higher initial concentration will need a shorter time to become saturated.

4.4.2 Effect of burning temperature

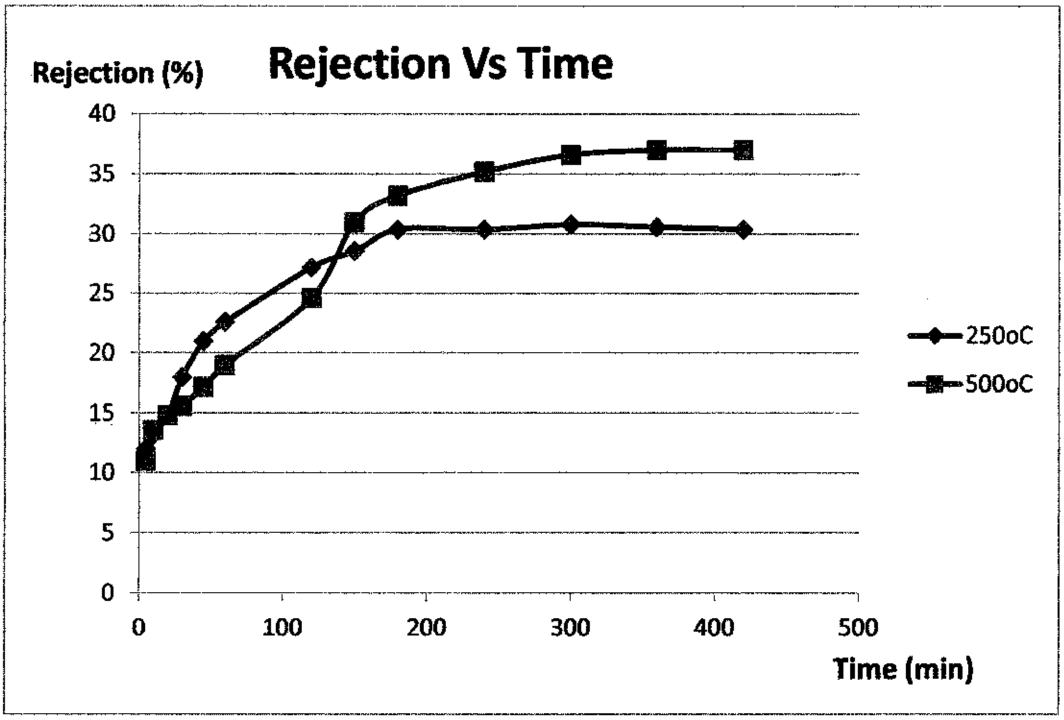

Figure 18: Comparison between two types of adsorbent with initial concentration 500ppm

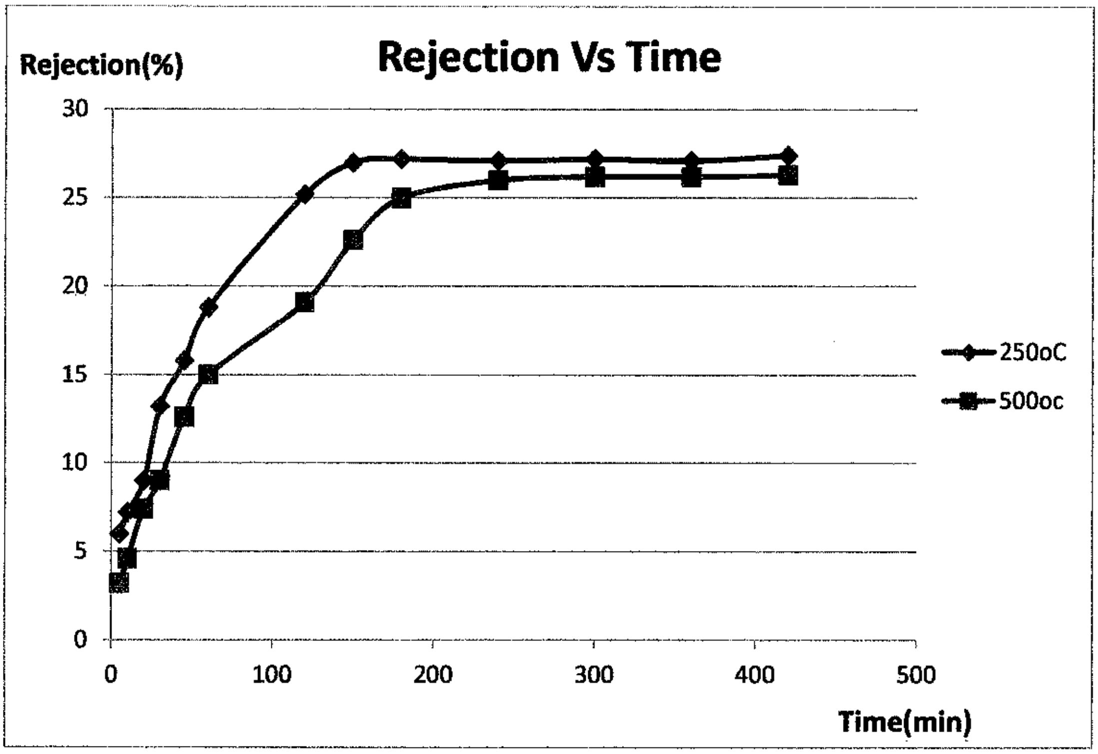

Figure 19: Comparison between two types of adsorbent with initial concentration 1000ppm

Referring to the graphs, we can see the different between the lines before it be constant and stable. Based on the result obtain, it was observed that, adsorbent that treated through burning at 250°C have a shorter time to saturated compared to adsorbent that treated through burning at 500°C. From there, we can say that the number of active sites and pores were more inside adsorbent at 500°C since the line to be planar is longer which means, it could adsorp more solute from wastewater with a same quantity of adsorbent.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

From the study, it can be concluded that, sugarcane bagasse can be developed as an adsorbent in removing amine solution from wastewater. Besides that, from the treatment, which is thermal treatment, the changes can be seen whether from morphology and also the composition of sugarcane bagasse itself.

5.2 Recommendations

It is recommended that, more study can be done regarding the sugarcane bagasse's potential to be developed as an adsorbent. There are some other ways in treating the abundant waste in converting the waste to wealth such as via chemical treatment and activated carbon treatment.

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Appendix I

Figures of project

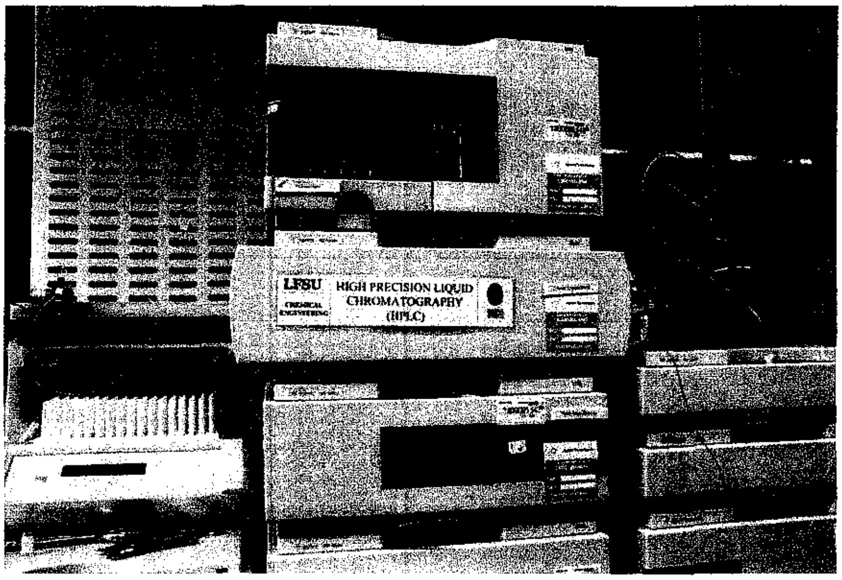

Figure 20: High Performance Liquid Chromatography (HPLC)

Appendix II

Calculation of percent rejection

$$\% \text{ Rejection} = [\, 1 - (C_t/C_o)\,] \times 100\%$$

For example:

At t= 20 min,

concentration, C_t = 780ppm

initial concentration, C_o = 1000ppm

so,

$$\% \text{ Rejection} = [\, 1 - (C_t/C_o)\,] \times 100\%$$
$$= [\, 1 - (780/1000)\,] \times 100\%$$
$$= 22\%$$