UNIVERSITI
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Enhanced Toluene Adsorption in aqueous solution by employing modified

Coconut based Activated Carbon

By

Amr Magdeldin Abdelwahid Mohamed

A project dissertation submitted in partial fulfillment of the requirement for the

BACHELOR OF ENGINEERING (HONS)

(CHEMICAL ENGINEERING)

September 2011

Universiti Teknologi PETRONAS

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Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____
(Dr. Usama Mohamed Nour El Demerdash)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
SEPTEMBER 2011

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.

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(AMR MAGDELDIN ABDELWAHID MOHAMED)

ABSTRACT

The aim of this research is to produce high quality coconut shell based activated carbon, and testing the adsorption capabilities of Toluene in aqueous solution on modified coconut based activated carbon.

One of the most proven effective way for organic solvent removal is adsorption by using activated carbon, using coconut shell as a raw material for the activated carbon due to its availability in Malaysia, and its high recommendation as a raw material worldwide, After sometime during adsorption, the activated carbon will be saturated and need to be regenerated, which is expensive. By increasing the adsorption capacity of the activated carbon, the frequency of regeneration can be reduced, therefor reducing the operating cost. The adsorption capacity can be increased by modifying the surface of the activated carbon. Method of modification will be decided depending on the targeted impurities. Based on the characterization analysis, the morphologies of the activated carbon has changed.

The experiment would be conducted on a packed bed of activated carbon, and tested at certain values of mass flow rate, pressure and temperature. One of the most common methods used for VOC (Volatile Organic compounds) removal is by using activated carbon. This Experiment would be firstly producing activated carbon and testing it activity level, and then experimenting of the effect and the efficiency of using that activated carbon in toluene purification.

The Main aim of this study is to prove the efficiency and the effectiveness of using coconut shell based activated carbon in the purification of VOCs (Toluene).

ACKNOWLEDGEMENT

First and foremost, I would like to express my praises to God for His blessing.

My deepest appreciation and gratitude is extended to my Supervisor, Dr Usama Mohamed Nour El Demerdash for being very encouraging, supportive and responsive throughout the whole process of completing this final year project to fulfil the university requirement. Without his constant supervision and guidance, I may not be able to complete this project successfully.

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Last but not least, I would like to acknowledge, my family members for keeping me motivated throughout the year.

Thank you.

(Amr Magdeldin Abdelwahid)

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ABREVIATIONS

AC	:	Activated Carbon
BET	:	Brunauer-Emmett-Teller
FTIR	:	Fourier Transform Infrared
KOH	:	Potassium Hydroxide
VOC	:	Volatile Organic Compounds
FAC	:	Formed Activated Carbon
GAC	:	Granular Activated Carbon
NAC	:	Nitrogen Treated Activated Carbon
CO2AC	:	Carbon Dioxide Treated Activated Carbon
SEM	:	Scanning Electron Microscope
XRD	:	X-Ray Diffraction

CHAPTER 1

INTRODUCTION

Background of study

Toluene is one of the most important materials in the chemical industry, it's a starting material for many compounds, is also widely used as a chemical solvent in various industries. Due to the high toxicity and the negative effect that toluene has on the environment, added to that the new rules & regulation implemented worldwide on the emission of the toluene in the effluent of chemical & petrochemical plants has become more strict, therefor there is a high demand on research in this area the treatment and adsorption of toluene from aqueous solution.

Of all methods of solvent treatment, adsorption using activated carbon is the most recommended in all fields; also it offers the best option for overall treatment, especially for low concentration effluents or streams. Because activated carbon has been proved before to have impressive capacity of adsorption of organic compounds, it's the most widely used adsorbent in this process.

Although activated carbon has been widely used in this matter, but the handling of activated carbon has to be monitored intensively, regeneration of activated carbon is by no means an easy procedure. The adsorption capacity of the activated carbon can be enhanced and increased through surface modification & the type of modification is depending on the targeted impurities in this case Toluene.

Therefore, the present work aims to produce coconut based activated carbon and using Nitrogen (N_2) and Carbon Dioxide (CO_2) atmosphere during the carbonization step, Adding to that modifying the surface of Nitrogen (N_2) Treated coconut based activated carbon & Carbon Dioxide (CO_2) treated coconut based activated carbon by employing the chemical treatment method using Potassium Hydroxide (KOH). Subsequently, an adsorption study is conducted to compare the performance of the Nitrogen (N_2) & the Carbon dioxide (CO_2) treated activated carbon in Toluene adsorption.

Problem Statement

Toluene, is toxic and is emitted from industrial structures and sources, such as chemical processing plants and Petrochemical treatment plants, therefor this compounds is very hazardous to the environment and also to human health.

Carbon adsorption is commonly used as a major part in chemical plants, this process is highly necessary to remove the organic compounds contaminants in the streams, after undergoing the adsorption process for a certain amount of time, the activated carbon needs to be regenerated and reused for cost optimization, however the regeneration of activated carbon could be very costly, therefore the less frequency of regeneration is mostly desired by the managers of the chemical plants, it can be achieved by surface modification of the activated carbon in order to increase its adsorption capacity.

Objectives

The objectives of this research are:

1. Production of Activated Carbon from Raw Coconut shell by using Nitrogen (N_2) & Carbon Dioxide (CO_2).
2. Surface Modification of the produced Activated Carbon by chemical treatment using potassium Hydroxide (KOH)
3. Study the adsorption efficiency on both nitrogen (N_2) & carbon dioxide (CO_2) treated activated carbon in adsorbing Toluene.

Scope of study

This research is about enhancing the efficiency of adsorption of toluene in chemical processing plants & Natural Gas processing plants; therefor it's necessary to understand the various stages of the solvent adsorption process.

It's important in this study to know the applications of Toluene in Real life and its industrial applications, Toluene is a vital chemical used in the adhesive, laboratory, paint, pesticide, pharmaceuticals, and rubber industries. It is usually used as a solvent for dilution, extraction, and electroplating. The largest use for toluene, however, is in benzene production.

Toluene is usually used a solvent due to its ability to dissolve paints, silicone sealants, lacquers, adhesives, rubber, printing ink, leather tanners, and disinfectants.

This substance is also used as an enhancer and octane booster in gasoline, as a coolant in nuclear reactor systems because of its natural heat transfer properties, as well as in biochemistry experiments where toluene is used to rupture red blood cells for hemoglobin extraction.

Toluene along with other hydrocarbons are present in the aqueous amine solvent in LNG treatment plants, due to the new rules & regulations implemented worldwide the percentage of toluene has to be decreased in all aspects of the Petrochemical industries.

The production of the adsorb ant from raw material is vital for this research, choice of the raw material isn't an easy task, but due to the availability of the coconut in Malaysia, Hardness of the shell, Various pore structure and high porosity which made the selection method easier.

This research is also focused on the properties of the produced activated carbon, its application and implementation in different industries, Methods of treatment were identified and studied and the Method chosen was based on the targeted impurity. Toluene was used as the pollutant in this study further description of the activated carbon will be discussed in Chapter 2.

After the production of the coconut based activated carbon & modification of the surface, the adsorption study was conducted to evaluate the efficiency of the adsorbing of the toluene. Therefor deep understanding of the adsorption process is essential. The mechanism of the adsorption process is further discussed and expansively explained in Chapter 2, the optimum conditions for the adsorption process where taken initially from former studies in the field of adsorption using activated carbon, and then manipulated with the initial values in order to reach the optimum operating conditions.

The surface Analysis was then done by comparing the Nitrogen (N_2) and Carbon Dioxide (CO_2) treated Activated carbon on toluene adsorption.

CHAPTER 2

LITERATURE REVIEW

Many has been written in the literature of Solvent purification using activated carbon, Different methods of VOC emissions control have been proposed, different types of activated Carbon has been produced. For the Purpose of this study the literature review has been divided into 2 parts,

1) Literature Review of Activated Carbon

2) Literature Review of Toluene Purification

Activated Carbon

Activated carbon is a porous structure and large internal surface area of the material. Because of its large surface area, pore structure, high adsorption capacity and high surface activity and a unique multi-functional adsorbent, and it's cheap, can be part of daily life, and it can effectively remove wastewater, waste gas in the most organic and some inorganic substances, it is widely used in countries of the world's sewage and waste treatment, air purification, solvent recovery of rare metals and other areas of environmental protection and resource recycling.

Activated carbon is a carbon material mostly derived from charcoal. The unique structure of activated carbon produces a very large surface area: 1 lb of granular activated carbon typically provides a surface area of 125 acres (1 Kg =1,000,000 sq. m.). The activated carbon surface is non-polar which results in an affinity for non-polar adsorbents such as organics. Activated carbon is very effective in applications requiring air or water purification as well as precious metal recovery or removal.

Activated carbon is manufactured from several of carbonaceous material such as coal, bone, palm oil shell and coconut shell. These raw materials undergo carbonization process, where they are heated at very high temperature (400 °C – 700 °C), to force out the volatile impurities in the raw materials, for activation of the carbon produced, the carbon undergoes heating to even higher temperature (700 °C – 900 °C) with Nitrogen (N_2) or Carbon dioxide (CO_2) atmosphere for a specific amount of time, to produce carbon product that has high porosity and specific surface area.

Types of Activated carbon

Basically there are two commonly used types of activated Carbon:

1. Formed Activated Carbon (FAC)
2. Granular Activated Carbon (GAC)

Granular Activated Carbon is widely common in the field of adsorption and very effective for micro pollutant extraction, in this research we will be using GAC in the form of coconut shell for the adsorption of toluene.

According to Wikipedia, Granular Activated Carbon have larger particle size compared to other carbons, which present a smaller external surface, these carbons are preferable for all the adsorption processes of gases or vapors for the high diffusion rate.

Characteristics & properties of the activated carbon

- Moisture Content
- Carbon content
- Surface Area
- Surface functional groups of AC
- Pore Structure
- Micro structure of AC

Coconut shell based activated carbon

Like its name, coconut shell activated carbon comes from the coconut shell. To create its activated carbon form, the coconut undergoes a steam activation process. During activation, it creates millions of pores at the surface of the carbon thus increasing the total surface area. Activated carbon pores can be divided into three general sizes Micro-pores (diameter in the range of less than 2 nm), Miso-pores (diameter in the range of 2 – 25 nm), and Macro-pores (diameter in the range of above 25 nm). Coconut shell carbon has mainly micro-pores to miso-pores and due to its unique distribution of pores diameter, coconut shell activated carbon are very popular in the gas phase purification and potable water purification industries.

Surface Modification

Although activated carbon has already been proven as an adsorbent for a wide range of pollutants, more research has been going in the direction of surface modification due to the wide need for development in the field of purification of specific contaminants and removing them from industrial applications, the characteristics of the activated carbon mentioned above give significant impact towards the performance of the activated carbon in adsorption. These characteristics can be further enhanced using surface modification.

The surface chemistry of activated carbon is determined by the acidic & basic character of their surface, can be modified or changed by treatment in either gas or liquid phase, Wenzhong and colleagues stated that the employment of oxidizing agent in wet or dry methods will generate three types of characteristics & properties that could be applied to a different type of pollutant.

The presence of acidic functions on AC enhances its adsorption capacities to their metal adsorptive capacities, but it is not recommended for the adsorption of organics like toluene, phenol or benzene.

Therefor it's very important to identify the target impurity prior to surface modification.

Basic Treatment is highly favorable for adsorption of organic pollutants, a research conducted by Yamin shows that the activated carbon treated with Potassium hydroxide (KOH) shows better performance in adsorbing organic compounds (dye). Basic modification is commonly done by treating activated carbon of aqueous ammonia and sodium hydroxide, this is commonly known (amination process), but due to the unavailability of the equipment to handle this type of process inside Universiti Teknologi PETRONAS (UTP), another option had to be utilized.

Chiang and his friends reported that activated carbon treated with sodium hydroxide (KOH) would result in great adsorption efficiency, and that is the method used in this research.

Characterization of Activated Carbon

1. Fourier Transform Infrared Spectrum (FTIR)

FTIR analysis was used to investigate variations in the functional groups of the sample, the rapid changes in the spectrum peaks shows how the experimental conditions affect the structure of material, FTIR is used to identify chemical that are either organic or inorganic.

2. X-ray Diffraction (XRD)

XRD is for the identification of crystalline compounds by their diffraction pattern.

3. Scanning electron Microscope (SEM)

Conventional light microscopes use a series of glass lenses to bend light waves and create a magnified image. SEM creates magnified images by using elections instead of light waves. The SEM shows 3-dimensional images created without light waves rendered black & white. It can be used to estimate the pore size of the activated carbon. Pore entrances, clearly visible as dark irregular shapes on lighter membrane background.

Adsorption

The process of adsorption involves separation of a substance, called an adsorb ate from the liquid phase, and the concentration at the surface named an adsorbent, the adsorption process takes place in 4 or more steps which are as follows:

1. Bulk solution transport
2. Film diffusion transport
3. Pore transport
4. Adsorption

Adsorption isotherm

Under regular operating conditions, the activated carbon adsorptive capacity is directly proportional with the concentration until it reaches maximum saturation capacity, at the maximum saturation capacity stage, activated carbon needs to be replaced or regenerated, Isotherms are empirical calculations and relations that are used to predict how much solvent can be adsorbed by the activated carbon.

There are a number of types of isotherm, but the most commonly used to describe adsorption characteristics of organic solvent is Freundlich Isotherm:

$$x/m = Kc^{1/n}$$

Where x/m	=	mass of adsorbate adsorbed per unit mass of adsorbent
K	=	Freundlich capacity factor
C	=	equilibrium concentration if adsorbate in solution after adsorbtion
1/n	=	Freundlich intensity parameter

The constants in the Freundlich isotherm can be determined by plotting log(x/m) versus log C and the equation is rewritten as:

$$log(x/m) = logk + (1/n)logc$$

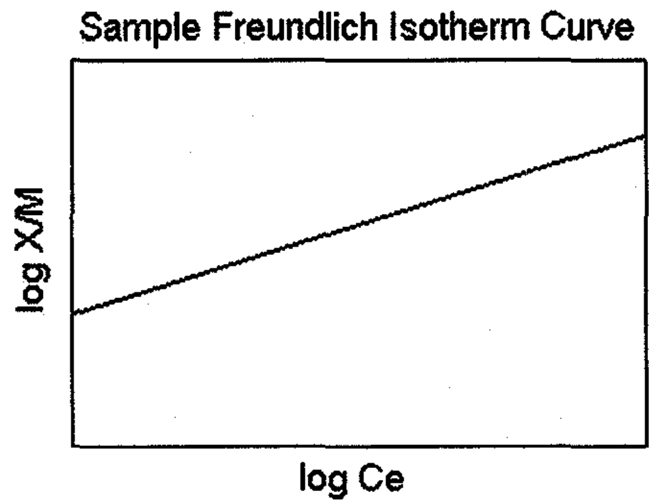


Figure 1- Freundlich Isotherm graph

Another Isotherm is called Langmuir isotherm:

$$x/m = abC/(1 + bC)$$

Where x/m = mass of adsorbate adsorbed per unit mass adsorbent

a , b = empirical constant

C = equilibrium concentration of adsorbate in solution after adsorption

The constants in the Langmuir equation can be obtained by plotting (C/(x/m)) versus C would be rewritten as :

$$q_e = \frac{C_m b C_e}{1 + C_m C_e}$$

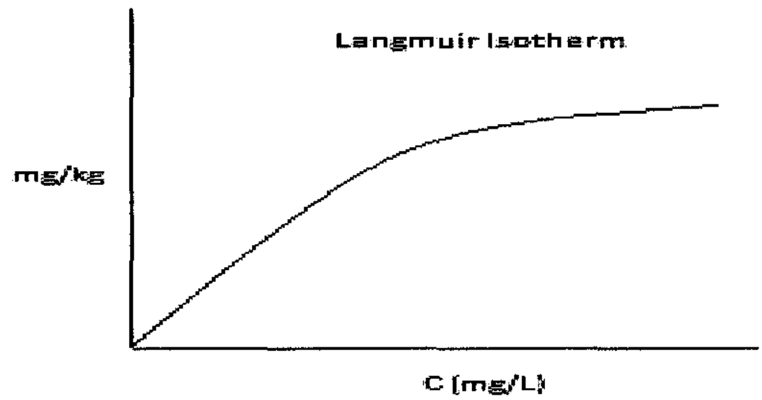


Figure 2- Langmuir Isotherm Graph

Adsorption of Toluene

Toluene is considered harmful to people and also the environment, for that reason specifically the removal of toluene from streams and effluent of chemical & petrochemical plants is vital. There are many methods that could be used for removal of toluene, the most effective is adsorption on activated carbon, based on the experiment done by Herman Hindarso more than 90 % of toluene was absorbed to the activated carbon.

There are a few factors that affect, influence and can actually fluctuate the results and the efficiency of adsorption such as:

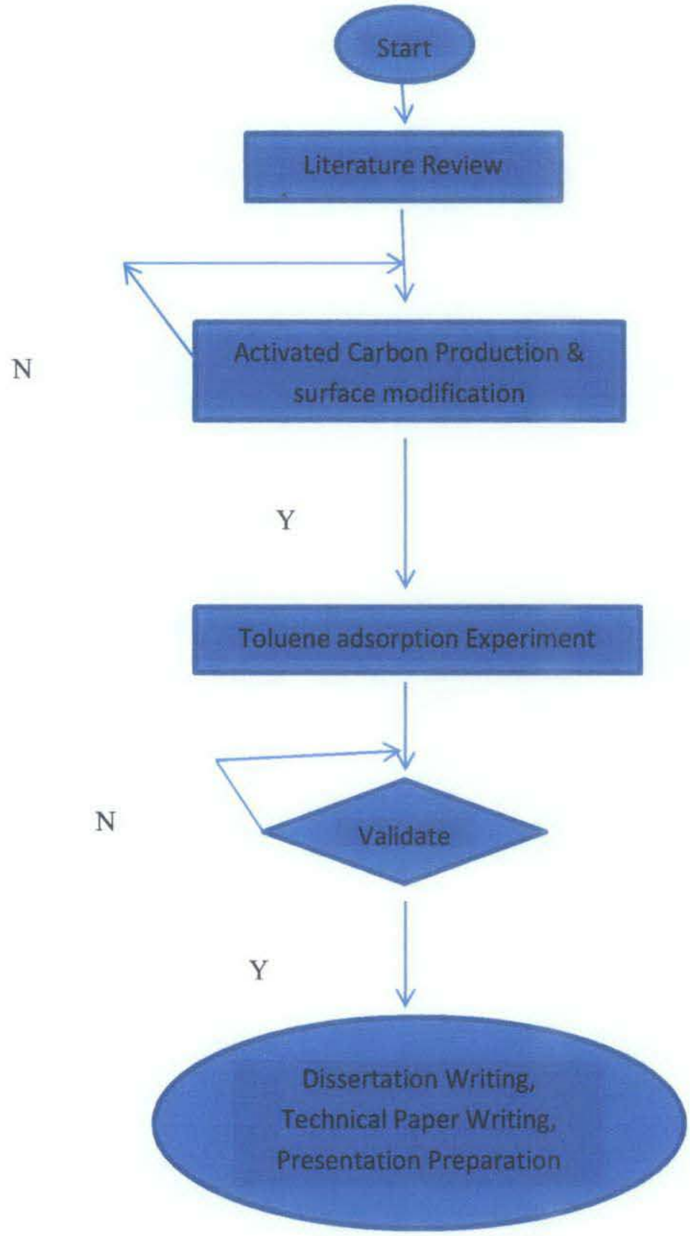
1. PH value
2. Dosage of adsorbent
3. Adsorbate concentration

CHAPTER 3

METHODOLOGY

This chapter discusses the methods or ways of achieving the desired objectives. It describes the different project works involved, the milestones and how are they going to be achieved step by step.

Research Methodology



Equipment & Chemicals

This experiment consists of three parts, where the first part is the manufacturing and preparation of coconut shell based carbon, and the second part is to prepare the surface modified activated carbon both Nitrogen (N_2) treated along with the carbon dioxide treated (CO_2), the last part of the experiment is to conduct the adsorption experiment using Nitrogen (N_2) treated and carbon dioxide (CO_2) activated carbon.

Table below shows summarizes the equipment and chemicals used in this project.

Equipment	**Description**
Tube Furnace	Used in the Carbonization of the raw coconut shell, with constant flow of Nitrogen (N_2) or Carbon Dioxide (CO_2)
Oven	Used for Drying stage of various steps in the experiment
Water Bath Shaker	Used in the adsorption process
UV Vis spectrophotometer	Used to determine the initial and final concentration of Toluene
Fixed Bed Activation Unit	Used to activate the carbon after being treated with Potassium Hydroxide (KOH)
Granulator	Used for granulation of the crushed coconut shell
Chemicals	**Description**
Raw Coconut Shell	Used to produce the activated carbon (Adsorbent)
Potassium Hydroxide (KOH)	Used for surface modification of activated carbon
Toluene	Pollutant (Adsorb ate)

Figure 3- Table of Equipments & Chemicals

Experimental procedures

1. Raw Materials

This is step is the first and the first milestone of this research where we collect coconut shells to prepare our activated carbon. After intensive research and travelling to farms in the nearby areas, we have discovered that the produced coconut by these farms are contracted to be sold to companies to benefit from.

Then we went to different markets to try and purchase coconut fruits and then extract the coconut shell from it after cracking the shell, and due to inexperience in this field we bought 20 fruits of young coconut with the green colored skin as shown in the figure below.

Figure 4- Raw young coconut fruit

After consulting and more research we have reached a conclusion that this is not the type of coconut desired to produce the activated carbon, it has to be an old coconut fruit because its high hardness of the shell, similar to the ones shown In the figures shown below:

Figure 5- Raw Old coconut fruit

2. Drying, Crushing & Granulation

Firstly removing all the hair particles from the shells, and cleaning it using distilled water. We placed the coconut to sundry right outside of block 5 in UTP campus. But due to the raining season we couldn't leave it long. As shown in the figure below

Figure 6- Sun Drying Coconut shell

Then we moved to the drying process to remove some of the impurities and prepare the coconut shells for crushing, we placed the coconut shells in an oven in block 4, at an optimum temperature for this procedure 105 degree Celsius for 24 hours, as shown in the figure below.

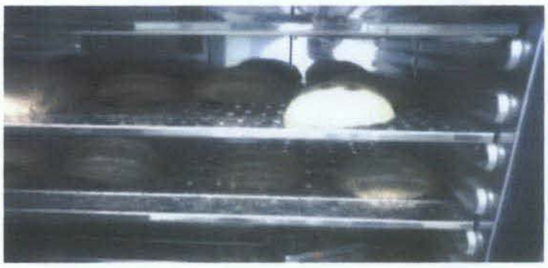


Figure 7- Coconut Shell Drying in Oven

After the cleaning and drying of the coconut the next step would be crushing it to a size that can be used in any of UTP facilities for sizing materials.

We used for crushing a regular hammer that you can obtain from any outlet or from any lab/facility inside UTP. The size of the coconut shell after crushing varied from (5 cm – 15 cm) due to in accurate crushing with hammer. As shown in the figure below.

Figure 8- Coconut Shell crushing (5 cm -- 15 cm)

This Step is important for the production of activated carbon, because size of particles is very important for the accuracy & the efficiency of the results.

There were different methods to follow in this part in particular, but we chose to use the granulator available in UTP in Block 17.

Granulator machines are designed with high speed, medium inertia, open rotor body, with 2, 3 or 5 hardened steel knives. Granulators can grind material down to 80 meshes or up to 2" in size. Interchangeable qualifying screens with various diameter holes determine the final reduction size. With decibel ratings of less than 65 Db, these units are ideal for placement at individual work stations.

The granulator in Block 17 is shown in the figure below.

Figure 10- Granulator (1)

Figure 9- Granulator (2)

Shown in the figure below is the coconut shell after sizing using granulator.

Figure 11- Coconut Shell Granulated (3mm to 10 mm)

3. Carbonization

Coconut shell after granulation is then moved on to the carbonization method, using the Tube Furnace equipment, prior to be used it is washed by distilled water to remove the ash and then dried using oven at 100 for 24 hours.

The first conditions of the tube furnace is 600 °C, Nitrogen flow 0.4 l/min and time is for 3 hours.

The second conditions of the tube furnace is 600 °C, Carbon Dioxide 0.4 l/min and time is for 3 hours.

Figure 12- Tube Furnace

4. Surface modification of activated carbon

The produced activated carbon then immersed in concentrated KOH solution (12M) for 24 hours, with stirring. As shown in the figure below

Figure 13- Carbon treated with KOH solution

The resulting sample was repeatedly washed to neutralize the pH and removing any excess KOH, subsequently, the sample was dried in oven for 24 hours at 110 °C, then the sample was placed in the fixed bed activation unit and heated from room temperature until 800 °C, under nitrogen flow of 0.2 l/min. The sample was then held for 3 hours before cooling to room temperature under Nitrogen flow; once it reached room temperature air is introduced it is called NAC. And then repeat the same step under carbon dioxide flow once it reaches room temperature it is called CO2AC

5. Characterization of Activated Carbon

All samples, The Raw activated carbon, Nitrogen (N_2) treated carbon and Carbon Dioxide (CO_2) treated carbon, are weighed, sent to Fourier Transform Infrared Spectrum (FTIR), Scanning Electron Microscope (SEM) and X-ray Diffraction (XRD).

6. Adsorption Studies

The adsorption of Toluene on activated carbon was carried out using batch technique, The effect of contact time, drying weight, adsorbent dosage and initial adsorb ate concentration were investigated.

a. The effect of contact time

50 ml of 150 ppm toluene was added into two different conical flasks containing 0.2 g NAC and CO2AC, then it was shaken for 60 minutes in a water bath shaker at 25 °C with shaking grade of 200 rpm, the samples were withdrawn every 5 to 10 minutes time interval and initial and final concentration determined using UV-Vis spectrophotometer. The effect of contact time was used to determine the equilibrium time for the adsorption.

Figure 14- Water Bath shaker

b. The effect of adsorbent dosage on toluene adsorption

Various amounts of adsorbent in the range of (0.1g-2.0g) were added to 250 ppm Toluene(M&B Chemicals) and were shaken until equilibrium. After shaking for 1 hour the samples were taken and its final concentration was determined using UV-Vis spectrophotometer. The experiment was done for both NAC & CO2AC.

Figure 15- Toluene(M&B Chemicals)

c. The effect of adsorbate concentration

The adsorption as carried out using different toluene concentration ranging from 100 ppm to 350 ppm and same amount of adsorbent, which was 0.5 gm. This experiment is conducted for both NAC &

CO2AC.

Figure 16- adsorbate concentration sampling

Figure 17- Solution Sample for adsorbate concentration experiment

Figure 18- Stirring

CHAPTER 4

Results & Discussion

Characterization of Activated Carbon

Scanning Electron Microscope (SEM)

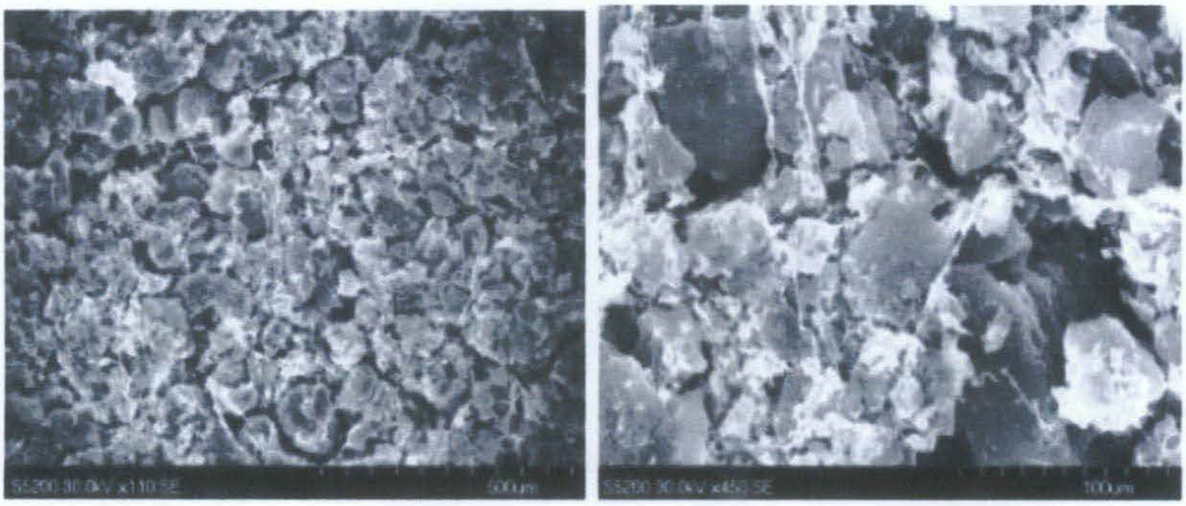


Figure 19- SEM example for coconut based activated carbon in reference to (C. Brasquet, Research on. Observation of activated carbon fibres with SEM and AFM correlation with adsorption data in aqueous solution.)

For adsorbent the pore size distribution & surface area are the most important factors that will affect its performance in adsorbing pollutant, the activation process is basically to produce a distribution of both internally and externally pores and enhancement of the adsorptive capacity.

The pores of activated Carbon are classified as macro pores having an average diameter of more than 50 nm, meso pores with a diameter of 2-50 nm, and micro pores with a diameter less than 2 nm. The figure above shows an example of SEM images for activated carbon; our results are aiming to be similar to the above ones.

X-Ray Diffractometer (XRD)

The crystal structure of the results Samples are analyzed by x-ray diffractometer (XRD) as a radiation source, the measurement will be carried out in a scale 2 θ and a long duration of scan 15 seconds.

Fourier Transform-Infrared Spectroscopy (FTIR)

A quantitate analysis of activated carbon will be conducted by obtaining FTIR transmission spectra of NAC, CO2AC. The adsorption capacity of carbon depends on porosity as well as the chemical reactivity of functional groups at the surface.

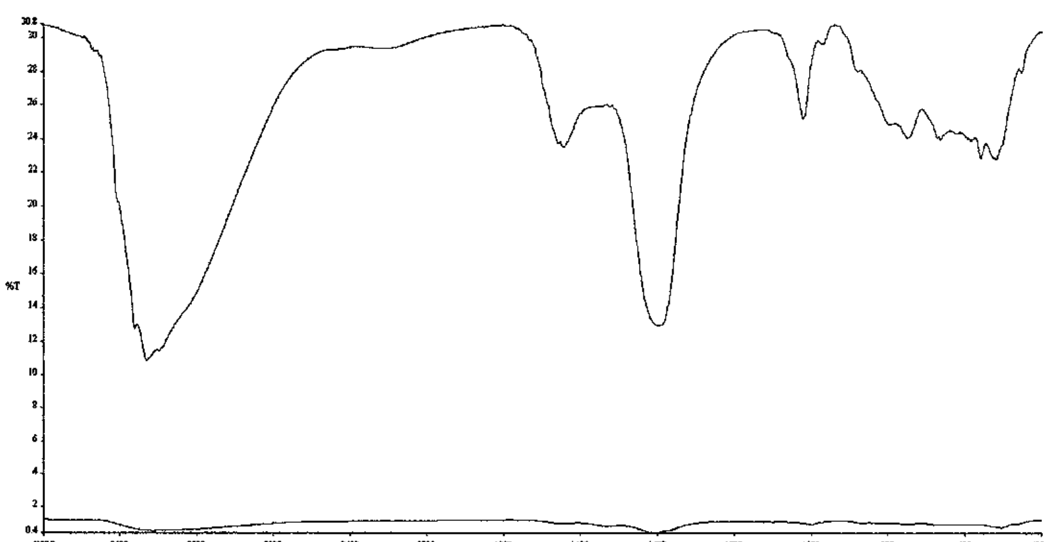


Figure 20- CO2AC sample

Based on figure 20- the FTIR sample is a lot different than the FTIR sample for N2AC in Figure 21, in Figure 20 it shows the formation of the pore structure and different pore sizes due to the thermal treatment under carbon dioxide flow at 800 °C, the activated carbon becomes more basic and more favorable for adsorption of organic compounds.

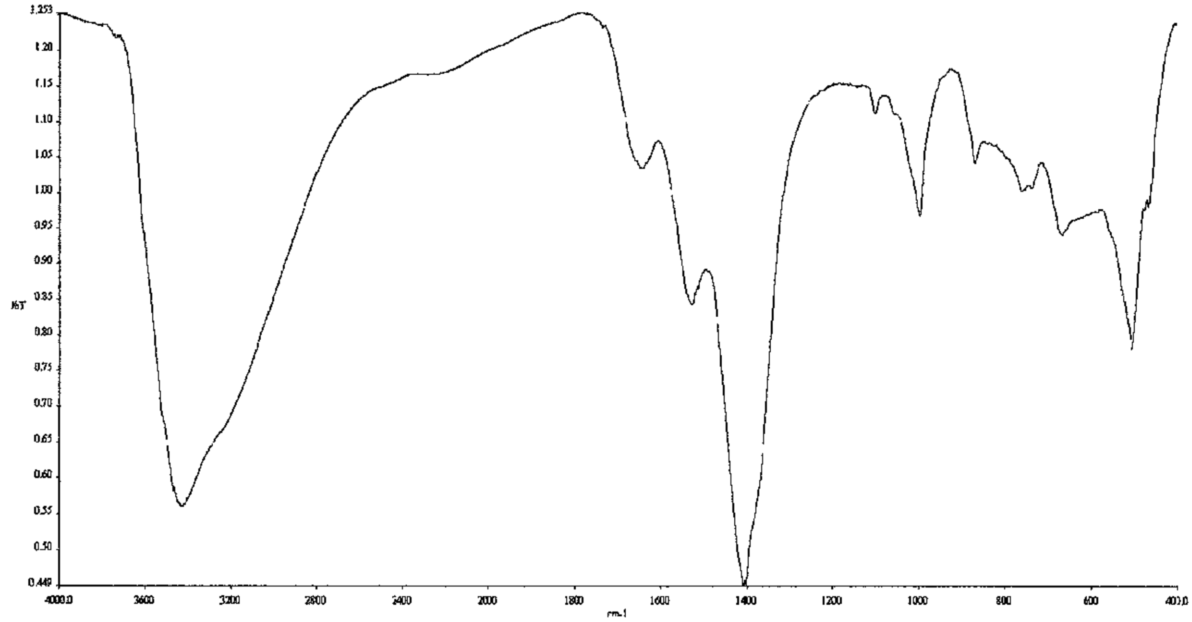


Figure 21- N2AC sample

Based on Figure 21- after undergoing treatment under nitrogen flow, there are formations of new nitrogen-containing groups on the surface, which also would lead to increment of the adsorption efficiency of organic groups, similar results have been obtained by Zahrini in her research.

The difference between the two graphs is obvious and shows the effect of Nitrogen Treatment in the Peaks in Figure 21 at 1400 cm and 3420 cm, on the other hand in Figure 20- the peaks are obvious at the same points at Figure 21- but the difference is clear on the surface modification part.

Drying Weight

This is a study to analyze the weight of the NAC & CO2AC before and after drying, the initial weight is 100 g. and the time for the experiment is 6 hours.

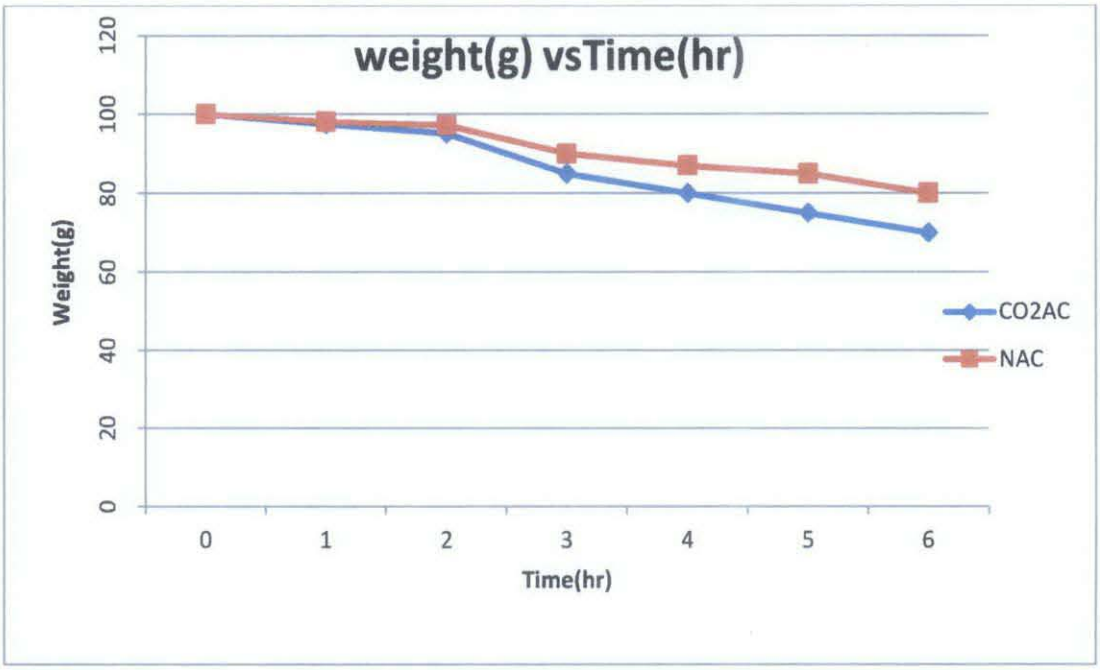


Figure 22- Chart to show the difference in drying weight effect on CO2AC vs NAC

The weight of the Activated Carbon is inversely proportional with time at constant temperature 110 °C. As observed in the table above, the decay of the weight of the activated carbon increases as the time spent in the oven increases, it is believed that the weight of carbon could reach to 0 g, if left un supervised in the oven or forgotten. And will turn completely to ashes.

It is also shown and observed in the graph above, that the NAC withstands heat more than CO2AC as the rate of decay of CO2AC is higher.

Adsorption Study

a. Effect of Contact Time

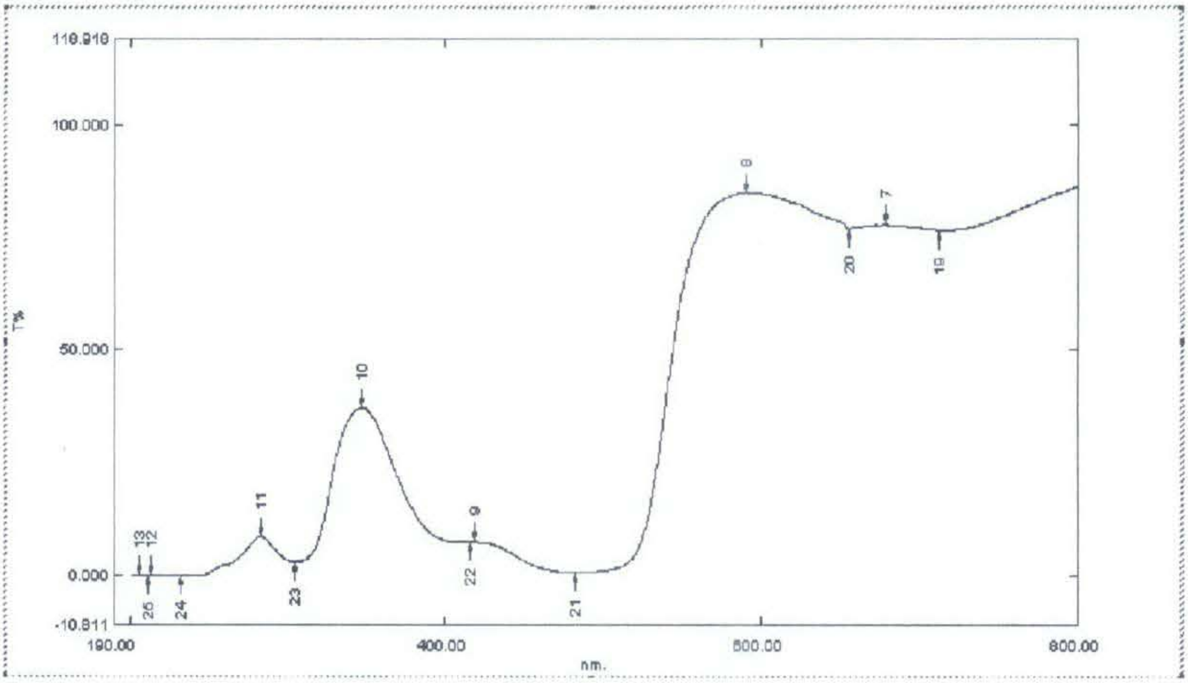


Figure 23- Spectrum of Contact Time experiment CO2AC

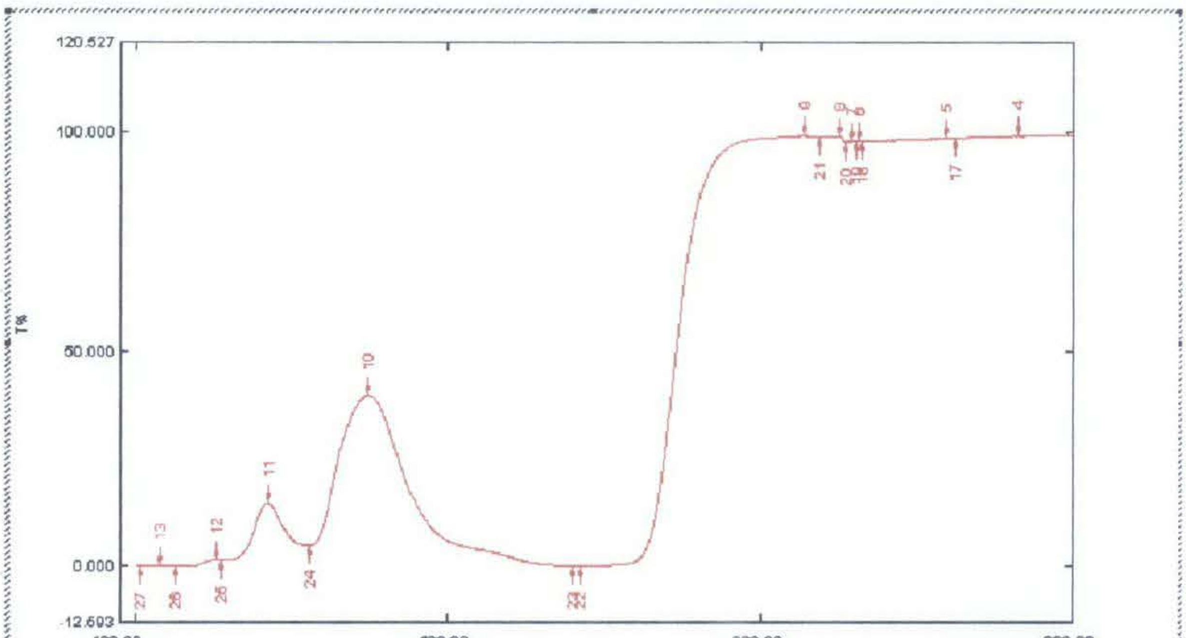


Figure 24- Spectrum of Contact Time experiment NAC

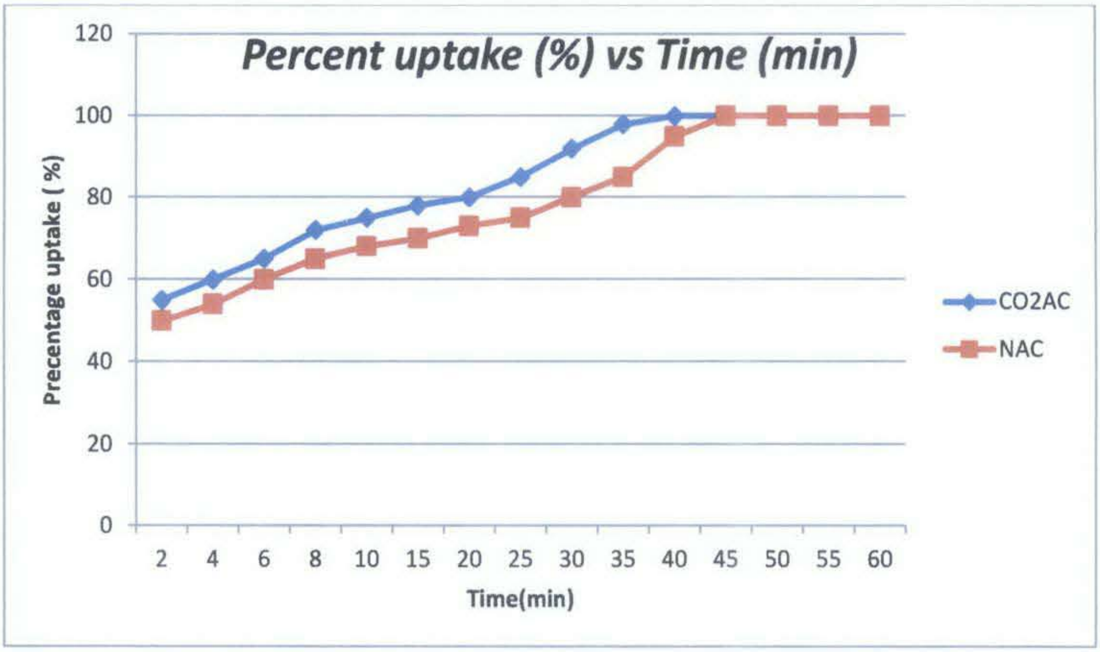


Figure 25- Chart for Effect of Contact Time on (CO2AC vs NAC)

Percentage uptake is calculated using:

$$\% \ Uptake = \frac{Cinitial - Cfinal}{Cinitial} \times 100\%$$

In the figure above shows the percentage uptake of Toluene after 1 hour, from this figure it shows that CO2AC starts to reach equilibrium at 40 min, while NAC at 40 min. This might be because of the greater pore structure of CO2AC after treatment with KOH and presence of Carbon Dioxide (CO_2), Along with that the variety in pore sizes and pore structure leads to better adsorption of Toluene.

b. Effect of adsorbent dosage on toluene adsorption

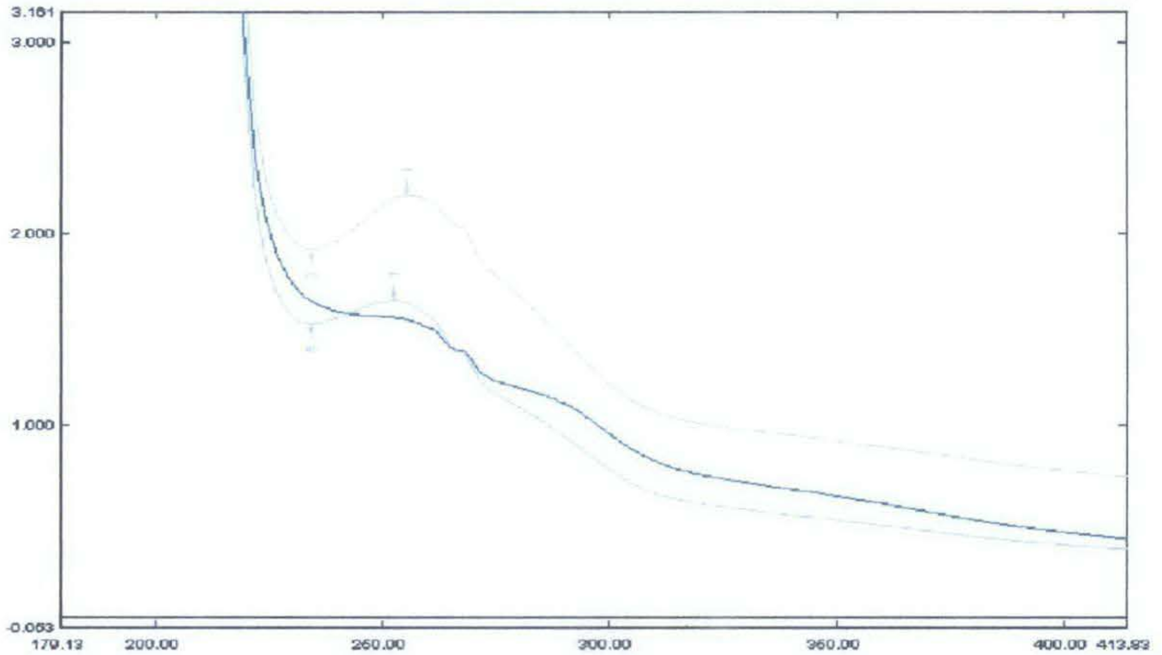


Figure 26-Spectrum of CO2AC in Adsorbant dosage Experiment

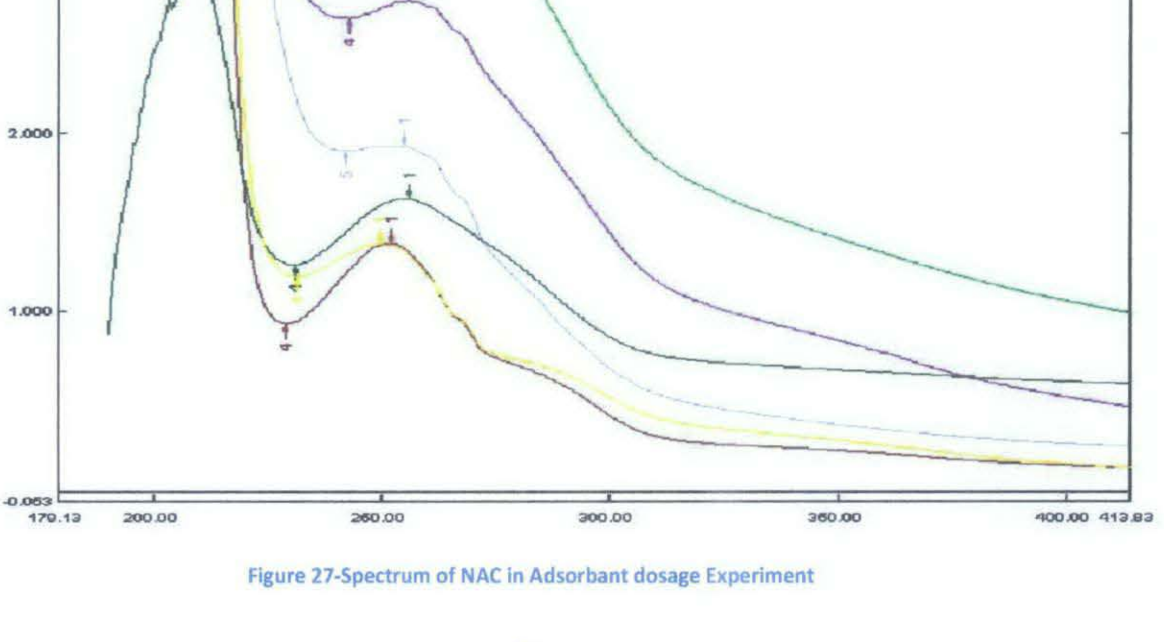


Figure 27-Spectrum of NAC in Adsorbant dosage Experiment

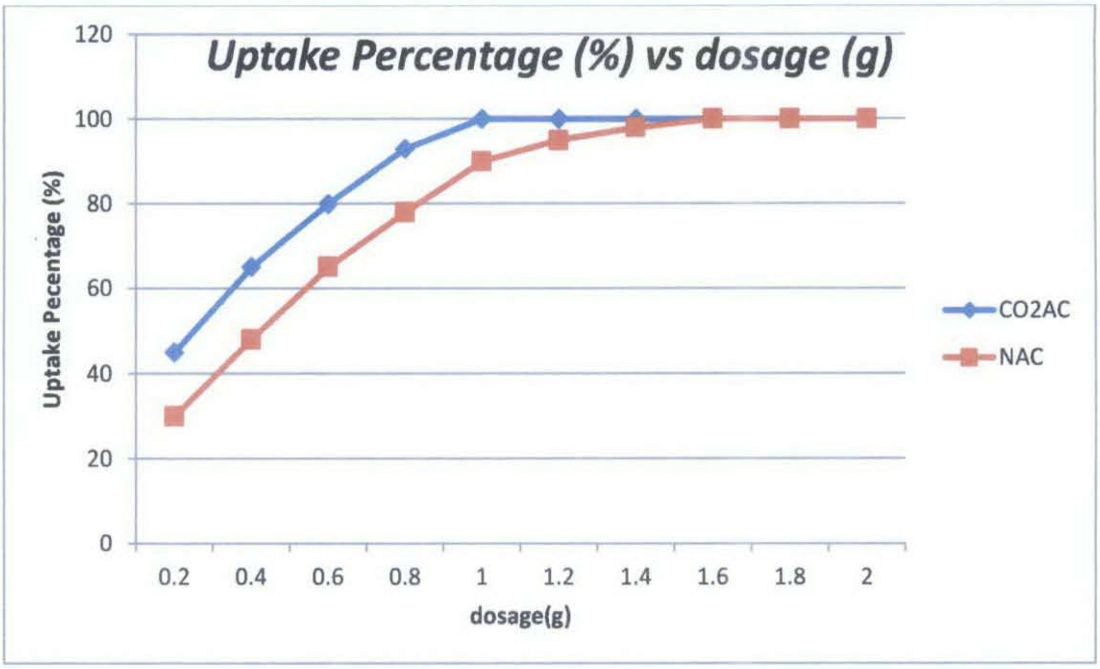


Figure 28- Chart for Effect of adsorbant dosage (CO2AC vs NAC)

The adsorption of toluene is influenced by the adsorbent dosage, it determines the number of active surface area available for adsorption to occur, To study the relationship, the amount of adsorbent was varied from 0.2 g to 2.0 g, the above figure shows that the amount of the adsorbent dosage is directly proportional to the amount of toluene adsorbed onto the activated carbon.

The maximum obtained adsorption uptake is at 1.6, according to various studies in this matter, no matter the difference between adsorb ate and adsorbent used the results have the same pattern, the more the adsorbent dosage added the more the increase in the adsorption to occur, the adsorb ate and adsorbent interaction is becoming less hindered or less there is less competition, which contributes to easier adsorption and more adsorption efficiency.

c. **The effect of initial concentration**

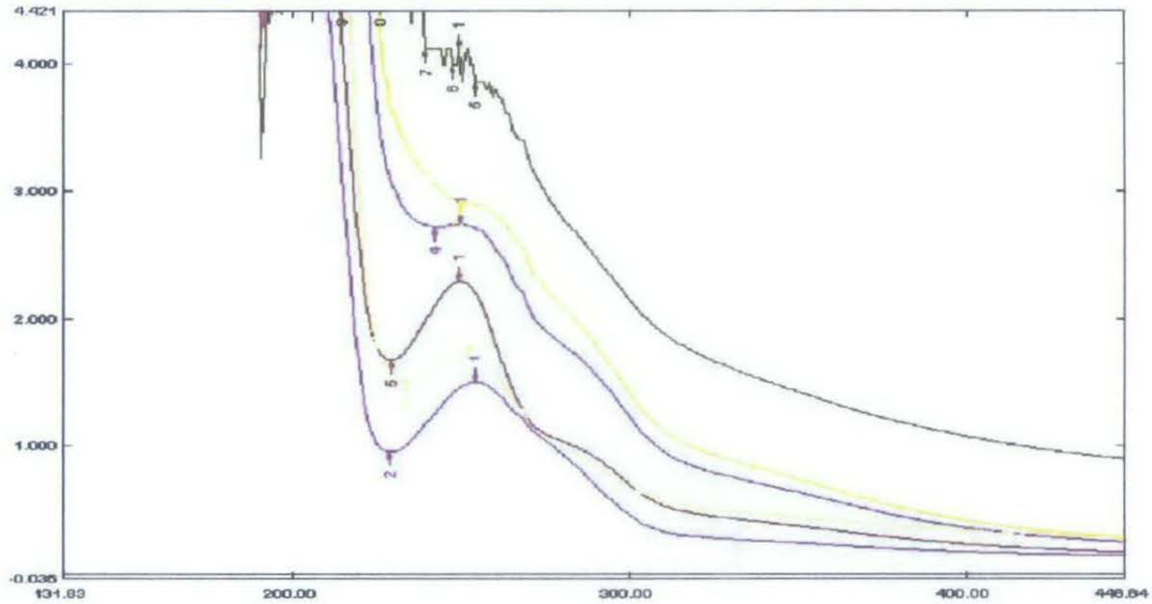


Figure 29-Spectrum of CO2AC in initial Conc Experiment

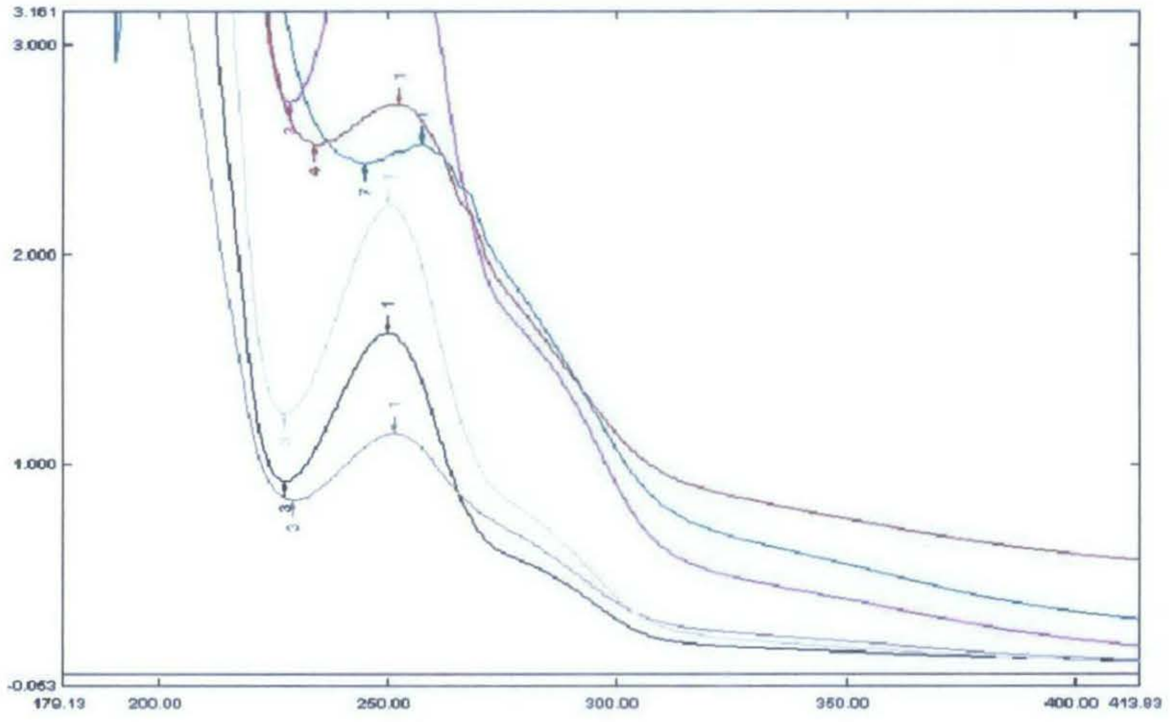


Figure 30-Spectrum of NAC in Initial Conc Experiment

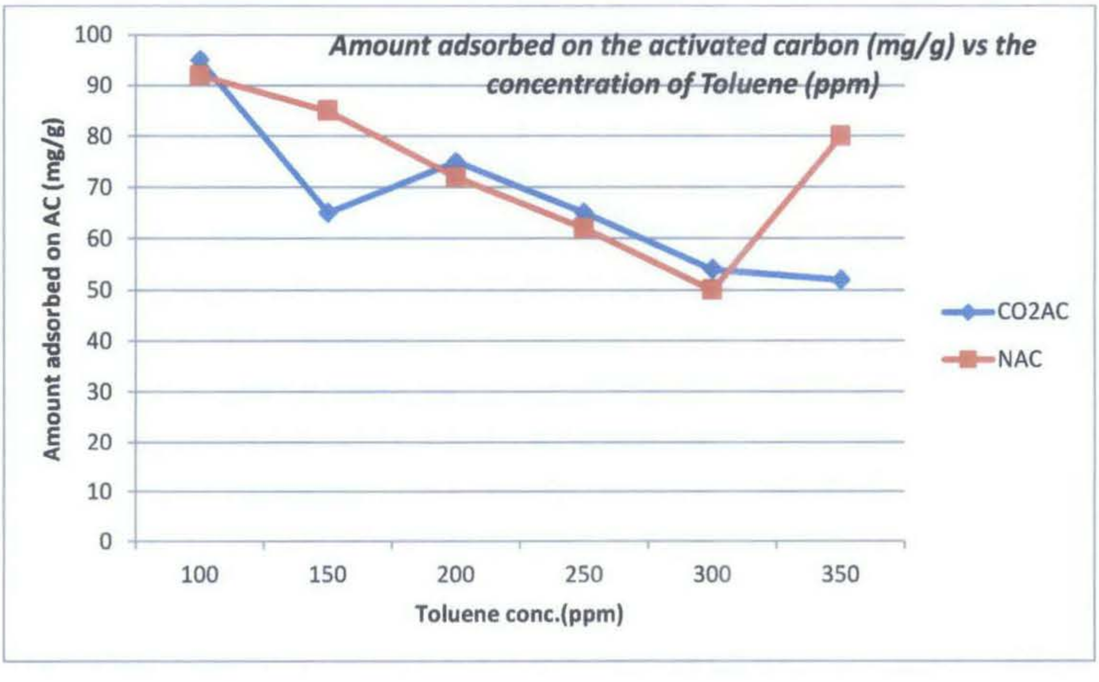


Figure 31-Chart for Initial Concentration (CO2AC vs NAC)

The adsorption isotherm was obtained as shown in the graph above, the amount of adsorbed toluene on the surface of the activated carbon was determined using:

$q_e = (C_0 - C_e)V/m$

Where Co and Ce are the initial and final concentrations of Toluene, V is the volume of the aqueous solution, and m is the mass of the activated carbon, It is clearly obvious that as the initial concentration increases, the adsorptive capacities also increases, the same results have also been obtained by Herman Hindarso and his colleagues, This means the rate of Toluene that passes through the bulk of activated carbon which leads to easier adsorption process to occur.

However on another note the percentage uptake of toluene is decreasing as the increase of the initial percenantages, this might be for the reason of saturation of the activated carbon after 1 hour time of shaking,

The percent uptake is calculated using the following equation:

$$\% \, Uptake = \frac{Cinitial - Cfinal}{Cinitial} \times 100\%$$

Hence the initial concentration increase as the percent uptake decreases, the same results have been obtained by Emanuel et al. adsorption of phenol on mesoporous carbon,

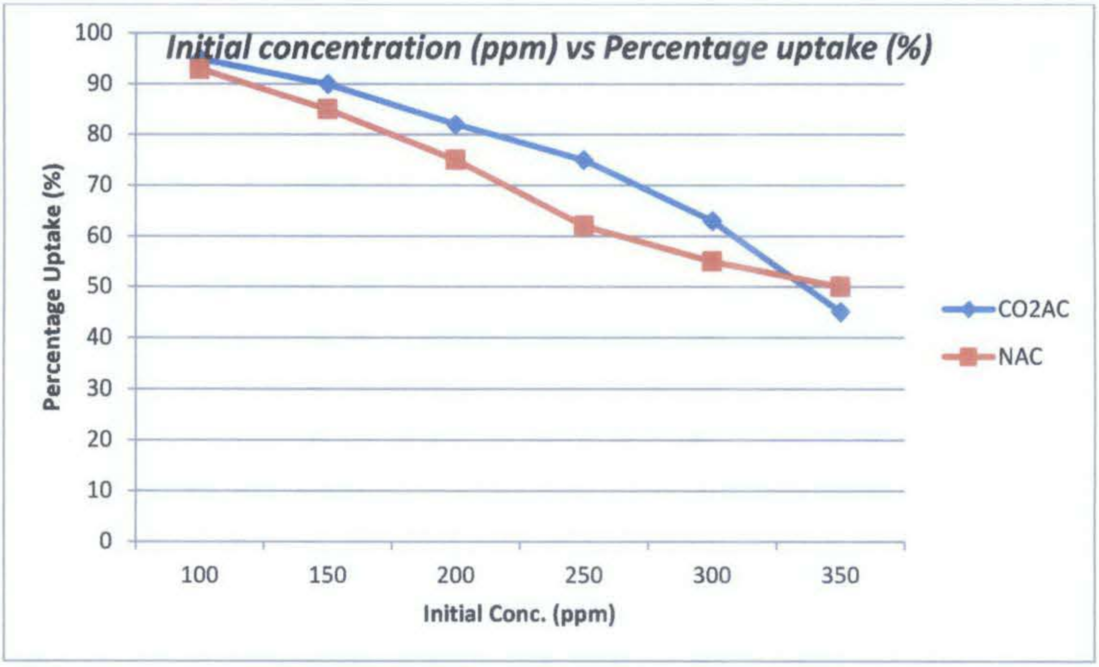


Figure 32-Chart for Initial Concentration vs Percentage uptake (CO2AC vs NAC)

Besides that, Langmuir isotherm is generally and commonly used as a model to describe the adsorption isotherm. The Langmuir equation is given as shown in the research of Bassim on the adsorption of toluene using low cost adsorbent:

$$q_e = \frac{X_m K C_e}{(1 + K C_e)}$$

The Above Equation can be arranged to a linear form of:

$$\frac{C_e}{q_e} = \frac{1}{X_m K} + \frac{C_e}{X_m}$$

Where	Ce:	equilibrium concentration of adsorbate (mg/l)
	qe:	The amount of adsorbate adsorbed (mg/g)
	Qo:	Langmuir Constant (Maximum Adsorption Capacity)
	K:	Langmuir Constant (related rate of adsorption)

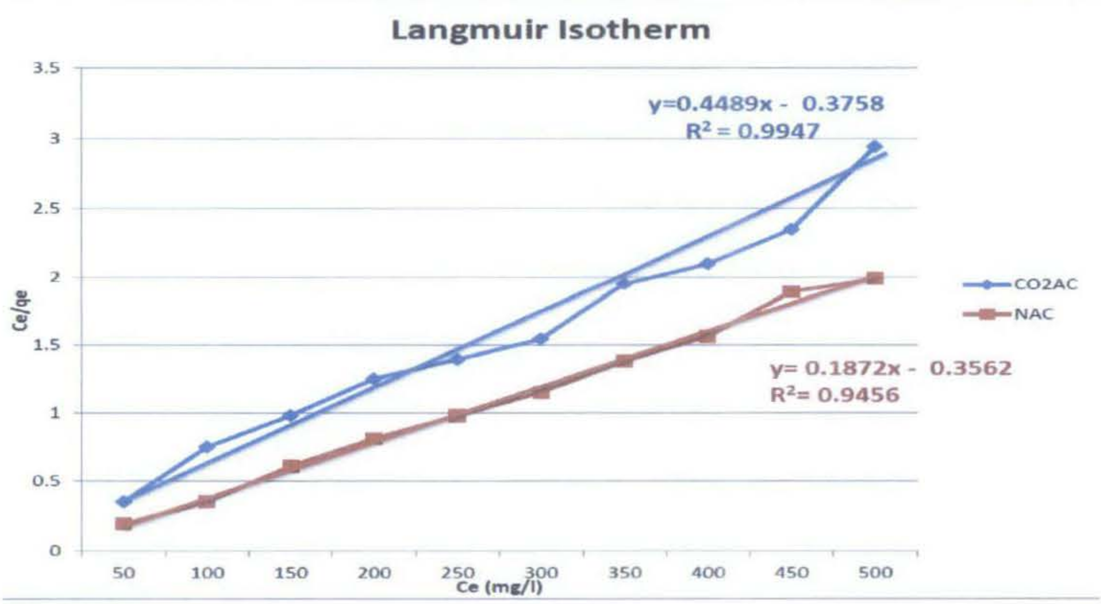


Figure 33- Langmuir Isotherm for adsorption of Toluene

The Plot of **Ce/qe vs. Ce** gives straight line for almost all concentrations of Toluene (50 mg/l to 500 mg/l), which implies that it fits well to Langmuir's isotherm, The Correlation for Both CO2AC and NAC are 0.9947 and 0.9456 respectively, Besides that Qo value which indicates the maximum adsorption capacity, is 5.88 mg/g, while for NAC is 3.89 mg/g.

This value once again proves that the adsorption capacity of CO2AC is higher compared to NAC.

Both Samples NAC and CO2AC have relatively high adsorption capacity because of the surface modification using KOH.

CHAPTER 5

CONCLUSION

The produced activated carbon from coconut shell has to be produced from old coconut fruits not young coconut due to the high level of hardness of the shell, and high porosity. Surface modified activated carbon by Carbon Dioxide (CO_2) shows higher efficiency and better performance in toluene adsorption than Nitrogen (N_2) treated activated carbon, there is a various change between both Nitrogen (N_2) treated activated carbon which is more related to surface modification could be more effective with phenol adsorption, on the other hand Carbon dioxide (CO_2) treated activated Carbon is more related to pore sizes and pore structure which is more effective in toluene adsorption. Also in that field the decay rate of Carbon dioxide treated Activated Carbon is higher than Nitrogen treated Activated Carbon, in both cases weight decay is inversely proportional with Time at constant temperature. Besides that in the adsorption study it has been proven that the adsorbent dosage is directly proportional to the percentage uptake of toluene, on a different note the initial concentration of adsorbent is directly proportional to the percentage uptake of Toluene.

RECOMMENDATION

There are a few recommendations proposed to improve this project, The BET & porosity analysis should be done to have stronger evidence about the increase of the surface area and the porosity of activated carbon after the modification and also to show the difference in clearer terms between Nitrogen treated activated carbon & Carbon Dioxide treated activated carbon. Along with that the effect of parameters as the concentration of KOH, activation temperature & gas flow during activation should be studied further to obtain the optimum conditions of operation. Ammonization is a different method of activation of activated carbon, a future comparison study would be extremely beneficial to all, finally it's recommended to run the adsorption tests using different pollutants, both organic and inorganic and comparing to confirm the adaptability of it to other contaminant

CHAPTER 6

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