

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



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ISLAMIC UNIVERSITY OF TECHNOLOGY  
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Organisation of Islamic Cooperation

**PRODUCTION OF ACTIVATED CARBON AND EXTRACTION OF  
SILICON CARBIDE FROM RICE HUSK**

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**October, 2013**



Organisation of Islamic Cooperation

## PRODUCTION OF ACTIVATED CARBON AND EXTRACTION OF SILICON CARBIDE FROM RICE HUSK

A thesis submitted to the department of Mechanical and Chemical Engineering (MCE), Islamic University of Technology (IUT), in the partial fulfillment of the requirement for the degree of Bachelor of Science in Mechanical Engineering.

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## **DECLARATION**

This is to certify that the work presented in this thesis is an outcome of experiment and research carried out by the authors under the close supervision of Prof. Dr. A. K. M. Sadrul Islam and hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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## ACKNOWLEDGEMENT

All praises to Almighty ALLAH (Sbw) who blessed us with potential and patience to complete this project successfully overcoming the obstacles in the way.

It is not sufficient to only give thanks to some people who helped and guided us when needed and without them the thesis could never come into being successfully in time.

Our gratitude and respect to our supervisors **Prof. Dr. A. K. M. Sadrul Islam**, MCE Department, Islamic University of Technology(IUT) for his encouragement, erudite advices and extreme patience throughout the course for establishing such a creative project. His care, concern and continuous moral support for the students are appreciated.

We would also like to express our sincere appreciation to Dr. Md. Ahiduzzaman for his generous guidance, advice and encouragement in supervising us.

We are also grateful to the Head of Mechanical and Chemical Engineering Department, Dr. Md. Abdur Razzaq Akhanda for providing us with necessary funding and supports. Special thanks to Md Abu Hossain (Thermodynamics and Thermo fluid Lab) for his useful suggestions and availability whenever needed.

We would also like to give thanks to all faculty members of the department for their advice and support throughout the project. All of us are indebted to our family members for their moral supports and prayers.

Although we tried our best to complete this thesis flawlessly, we seek apology if there is any mistake found in this report.

## **ABSTRACT**

The abundance and availability of rice husk, an agricultural waste, make them as a good source for precursor of activated carbon and silicon carbide. The present work entitle “Production of Activated Carbon and Extraction of Silicon Carbide from Rice Husk” was taken up to study the optimum operating conditions at laboratory scale. Rice husk-based activated carbons were prepared via base treated chemical activation process with  $H_3PO_4$  as activating agent. The activated carbon was evaluated with methylene blue dye adsorption test by using visible ultra violet (Vis. UV) Spectrophotometer. Extraction of Silicon Carbide was carried out using various parameters such as pre-treatment or acid leaching, treatment with ammonia solution, pyrolysis of rice husk. The samples were characterized by XRD analysis.

**Keywords:** Activated carbon, Rice husk, Adsorption, Silicon Carbide, XRD analysis.

# **TABLE OF CONTENTS**

	<b><u>Page Number</u></b>
<b>CHAPTER 1: INTRODUCTION</b>	<b>1-6</b>
<b>1.1 : Rice Husk</b>	<b>1-2</b>
<b>1.1 : Activated Carbon</b>	<b>2-4</b>
<b>1.2.1 : Source of Activated carbon</b>	<b>2</b>
<b>1.2.2 : Activation process</b>	<b>3</b>
<b>1.2.2 : Properties of activated carbon</b>	<b>3</b>
<b>1.2.2 : Application of activated carbon</b>	<b>4</b>
<b>1.2 : Silicon Carbide (SIC)</b>	<b>4-6</b>
<b>1.2.1 : Natural Occurrences</b>	<b>5</b>
<b>1.2.2 : Production of SIC</b>	<b>5</b>
<b>1.2.2 : Properties of SIC</b>	<b>6</b>
<b>1.2.2 : Uses of SIC</b>	<b>6</b>
<b>CHAPTER 2: LITERATURE REVIEW</b>	<b>7-8</b>

<b>CHAPTER 3: METHODOLOGY AND EXPERIMENTAL DETAILS</b>	<b>9-15</b>
3.1 : Formation of activated carbon from Rice husk	9
3.2 : Adsorption studies	12-13
3.2.1 : Adsorption Capacity	12
3.2.2 : Langmuir-Hinshelwood isotherm	12
3.2.3 : Specific surface area	13
3.3 : Formation of Silicon Carbide from Rice husk	13
3.4 : XRD Analysis	14-15
<b>CHAPTER 4: SAMPLE TEST AND RESULT ANALYSIS</b>	<b>16-21</b>
4.1: Yield Rate	16
4.2: Adsorption capacity	16
4.3: Langmuir-Hinshelwood plot	16-18
4.4: Specific surface area	19
4.5: Contact time study	19
4.6: XRD Analysis	21
<b>CHAPTER 5: CONCLUSION AND FUTURE WORK</b>	<b>22</b>
5.1: Conclusion	22
5.2: Scope of Future Work	22
<b>REFERENCES</b>	<b>23-25</b>

## **LIST OF TABLES**

	<b><u>Page Number</u></b>
<b>Table 1.1 : Chemical analysis of Rice Husk</b>	<b>1</b>
<b>Table 1.2 : Compositional analysis of Rice Husk</b>	<b>2</b>
<b>Table 3.1 : Parameters regarding XRD Analysis</b>	<b>14</b>
<b>Table 4.1 : Yield rate of Rice Husk based activated carbon</b>	<b>16</b>
<b>Table 4.2 : Adsorption capacity of activated carbon</b>	<b>16</b>
<b>Table 4.3 : Maximum adsorption capacity using Langmuir-hinshelwood plot</b>	<b>18</b>
<b>Table 4.4 : Specific surface area of Rice Husk based activated carbon</b>	<b>19</b>



## LIST OF FIGURES

	<u>Page Number</u>
<b>Figure 3.1 : Flow diagram of production of activated carbon</b>	<b>9</b>
<b>Figure 3.2 : UV/Vis. Spectrophotometer</b>	<b>10</b>
<b>Figure 3.3 : Calibration of methylene blue solution with vis. UV</b>	<b>11</b>
<b>Figure 3.4 : Flow Diagram of production of silicon carbide</b>	<b>14</b>
<b>Figure 4.1 : Langmuir-Hinshelwood plot for AC Activated at 700°C</b>	<b>17</b>
<b>Figure 4.2 : Langmuir-Hinshelwood plot for AC Activated at 750°C</b>	<b>17</b>
<b>Figure 4.3 : Langmuir-Hinshelwood plot for AC Activated at 800°C</b>	<b>18</b>
<b>Figure 4.4 : Methylene blue adsorption profile at room temperature On 700°C activation temperature activated carbon</b>	<b>19</b>
<b>Figure 4.5 : XRD test of RHA pyrolysis at 1200°C</b>	<b>20</b>
<b>Figure 4.6 : XRD test of RHA pyrolysis at 1500°C</b>	<b>21</b>

# CHAPTER 1

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## INTRODUCTION

### 1.1.RICE HUSK

Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world. Globally, approximately 600 million tons of rice paddy is produced each year. On average 20% of the rice paddy is husk, giving an annual total production of 120 million tones [1]. In majority of rice producing countries much of the husk produced from processing of rice is either burnt or dumped as waste [2]. Burning of RH in ambient atmosphere leaves a residue, called rice husk ash. For every 1000 kgs of paddy milled , about 220 kgs ( 22 %) of husk is produced, and when this husk is burnt in the boilers , about 55 kgs ( 25 % ) of RHA is generated[3]. Rice husk removal during rice refining, creates disposal problem due to less commercial interest. Also, handling and transportation of RH is problematic due to its low density. RHA is a great environment threat causing damage to land and surrounding area where it is dumped. Therefore, commercial use of rice husk and its ash is the alternative solution to disposal problem. Rice husk contains 75-90 % organic matter such as cellulose, lignin etc. and rest mineral components such as silica, alkalis and trace elements [4]. Rice husk is unusually high in ash compared to other biomass fuels in the range 10-20%. The ash is 87-97% silica [5].The dry analysis of rice husks are as follows:

TABLE 1.1: CHEMICAL ANALYSIS OF RICE HUSK

Element Analysis	Mass Fraction %
Carbon	41.44
Hydrogen	4.94
Oxygen	37.32
Nitrogen	0.57
Silicon	14.66
Potassium	0.59
Sodium	0.035
Sulfur	0.3
Phosphorous	0.07
Calcium	0.06
Iron	0.006
Magnesium	0.003

TABLE 1.2: COMPOSITIONAL ANALYSIS OF RICE HUSK

Compositions	Mass Fraction (%)
Silica (SiO <sub>2</sub> )	80-90
Alumina (Al <sub>2</sub> O <sub>3</sub> )	1 –2.5
Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> )	0.5
Calcium oxide (CaO)	1-2–2.0
Magnesium oxide (MgO)	0.5-2.0
Sodium oxide (Na <sub>2</sub> O)	0.2-0.5
Potash	0.2
Titanium dioxide (TiO <sub>2</sub> )	Nil
Loss on Ignition	10-20

## 1.2. ACTIVATED CARBON

Activated carbon, also widely known as activated charcoal or activated coal is a form of carbon which has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reactions.[6] The word active is sometimes used in place of activated. Due to such high degree of micro porosity , just 1 gram of activated carbon has a surface area in excess of 500 m<sup>2</sup> (about one tenth the size of an American football field), as typically determined by nitrogen gas adsorption. Sufficient activation for useful applications may come solely from the high surface area, though further chemical treatment generally enhances the adsorbing properties of the material. Activated carbon is most commonly derived from charcoal.

### 1.2.1. SOURCE OF ACTIVATED CARBON

Many kinds of materials can be used as the source of activated carbon. Among them, wood, charcoal, agricultural by-products like nut shells, fruit pits, rice husk, corncob wastes and synthetic polymers are commonly used as the starting material [7-11].

### **1.2.2 ACTIVATION PROCESS**

There are basically two methods for preparing activated carbon:

- physical activation. and
- chemical activation.

Physical activation consists of two steps: the carbonization of starting material at 400-500°C to eliminate the bulk of the volatile matter and the activation of char by using carbon dioxide and water steam at 800-1000 °C or with air at low temperature. In chemical activation both the carbonization and the activation steps proceed simultaneously [8,9,12]

As for chemical activation, pyrolysis char would be impregnated with some chemical reagents such as H<sub>3</sub>PO<sub>4</sub>, ZnCl<sub>2</sub>, KOH, CaCl<sub>2</sub> and H<sub>2</sub>SO<sub>4</sub> [7,9,12,13,14]. Major advantages of chemical activation compared to physical activation are lower treatment temperatures and shorter treatment times. In addition, activated carbon obtained by chemical activation exhibits a larger surface area and better developed mesoporosity than physical activation [11,14,15]. However, there are some disadvantages of the chemical activation process, such as corrosiveness of the process and the washing steps after carbonization [15].

### **1.2.3. PROPERTIES OF ACTIVATED CARBON**

Most significant properties of activated carbons are

- High porosity
- Large surface area
- High adsorption capacity

The high porosity and the large surface area, achieved after the activation process, ensures very high adsorption capacity to activated carbons, which is difficult to obtain with other sorbents [13].

#### **1.2.4. APPLICATION OF ACTIVATED CARBON**

Activated carbon is used in

- gas purification,
- gold purification,
- metal extraction,
- water
- purification,
- medicine,
- sewage treatment and many other application[16,17]

One major industrial application involves use of activated carbon in the metal finishing field. Recently Activated Carbon filters have gained popularity among recreational users of Cannabis, and other smoking herbs for their use in effectively filtering out "Tar" from the smoke. They are becoming quick competition for Vaporizers as they are only a fraction of the cost and achieve nearly the same thing.[15]

#### **1.3 SILICON CARBIDE**

Silicon carbide (SiC), also known as carborundum, is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics which are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Silicon carbide with high surface area can be produced from SiO<sub>2</sub> contained in plant material [18]. Silicon Carbide is potentially useful such as high temperature structure material, because of its high hardness, high oxidation resistance, good thermal shocking resistance etc. However, the production of high density ceramics by solid state sintering is difficult due to the strong covalent nature of Si-C bond. The solid state sintering of SiC can be performed at high temperature up to 2200°C.

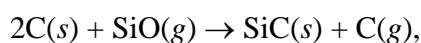
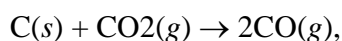
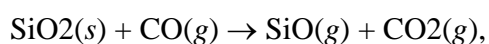
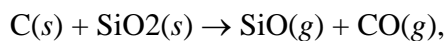
### 1.3.1 NATURAL OCCURRENCES

Moissanite is natural form of Silicon carbide. When the first artificial moissanite reached the jewelry market, it has been regarded as an excellent diamond substitute, with optical properties exceeding those of diamond. Because it has its own unique appearance, it cannot be truly called a diamond stimulant [19] [20]. Its ethical production, however, does make it a popular alternative to diamonds. Because of its hardness, it is useful for high-pressure experiments (e.g., using diamond anvil cell) competing there with diamond. Large diamonds, used for anvils, are prohibitively expensive. Therefore for large-volume experiments, much cheaper synthetic moissanite is a more realistic choice. Synthetic moissanite is also interesting for electronic and thermal applications because its thermal conductivity is similar to that of diamonds. High power SiC electronic devices are expected to play an enabling and vital role in the design of protection circuits used for motors, actuators, and energy storage or pulse power systems [21] [22] [23].

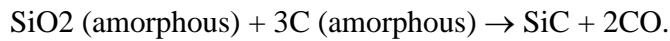
### 1.3.2 PRODUCTION OF SiC

Due to the rarity of natural moissanite, silicon carbide is typically man-made. Most often it is used as an abrasive, and more recently as a semiconductor and diamond simulant of gem quality. The simplest manufacturing process is to combine silica sand and carbon in an Acheson graphite electric resistance furnace at a high temperature, between 1600 and 2500 °C [24] [25]. Fine SiO<sub>2</sub> particles in plant material (e.g. rice husks) can be converted to SiC by heating in the excess carbon from the organic material.

Rice husk contains silica in hydrated amorphous form and cellulose which yields carbon when thermally decomposed. When such a product is further heated at high temperature (> 1400°C) a reaction occurs between silica and carbon resulting in the formation of SiC. The possible reactions of such a process can be written as



Resulting in the overall reaction



### 1.3.3 PROPERTIES OF SiC

Pure SiC is colorless. The brown to black color of industrial product results from iron impurities. The high sublimation temperature of SiC (approximately 2700°C) makes it useful for bearings and furnace parts. SiC does not melt at any known pressure [26]. It is also highly inert chemically. There is currently much interest in its use as a semiconductor material in electronics, where its high thermal conductivity, high electric field breakdown strength and high maximum current density make it more promising than silicon for high-powered devices [27] [28]. SiC also has a very low coefficient of thermal expansion ( $4.0 \times 10^{-6} / \text{K}$ ) and experiences no phase transitions that would cause discontinuities in thermal expansion.

### 1.3.4 USES OF SILICON CARBIDE

Silicon carbide is used as

- Abrasive and cutting tools
- Structural material
- Automobile parts
- Jewelry
- Electric and electronic systems
- Thin film pyrometry and heating elements
- Carborundum printmaking
- Graphene production

## CHAPTER 2

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### LITERATURE REVIEW

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Rice husk contains the necessary carbon and silica, intimately dispersed, to provide an early ideal source material for production of SiC, an industrially important ceramic material. Rice husk was first used by Cutler (1973) as a starting material for the production of silicon carbide. Since the rice husk route appears to be promising, much attention has been paid to it (Mansour and Hanna 1979; Nutt 1988; Patel 1991; Ray et al 1991; Singh et al 1993, 1995; Romera and Reinso 1996; Moustafa et al 1997; Krishnarao et al 1998; Padmaja and Mukunda 1999; Janghorban and Tazesh 1999; Panigrahi et al 2001). Almost all the processes investigated so far involve two process steps i.e. (i) cooking at lower temperature (400–800°C) in a controlled manner to remove volatiles and (ii) reacting the cooked rice husk at high temperature (> 1300°C) to form SiC.

Special emphasis on the preparation of active carbons from agricultural by-products has been given, due to the growing interest in low-cost active carbons from renewable safe copious supplies, especially for applications concerning environmental monitoring. Increased use of agricultural residues is an attractive addition to the utilization of wood and other carbonaceous materials for the production of active carbons. Chemical activation is one of the possible methods for the production of active carbons otherwise known as activated carbon (Guo et al., 2000; Hayashi et al., 2002; Baquero et al., 2003; Suarez-Garcia et al., 2004). The carbon precursors are hydrolyzed in presence of the chemical activating agent such as phosphoric acid (H<sub>3</sub>PO<sub>4</sub>), zinc chloride (ZnCl<sub>2</sub>), potassium hydroxide (KOH) etc. Phosphoric acid functions as a dehydrating agent and inhibits the formation of tar (Su et al., 2003). The use of phosphoric acid is considered to be an environmentally benign technology, because of the ease of its recovery by washing with water (Baquero et al., 2003). Previously, wood bark (Barkauskas et al., 2004); bagasse (Jaguaribe et al., 2005); maize cobs (Ekanem 1996); rice straws (Oh and Park 2002); rice husk (Imagawa et al., 2000); coconut shells (Gimba et al., 2001); oil palm shells, walnut shells (Hayashi et al., 2002) and coffee bean husks (Baquero *et al.*, 2003) have been pyrolyzed to produce active carbon, but activation by ortho phosphoric acid impregnation of bagasse, millet and sorghum straws have not been studied to evaluate its possible



influence on the quality and yield of carbon, as this method of producing active carbons may lower the energy cost. A number of precursors of vegetable origin have been activated with acid at 450 °C (Suarez-Garcia *et al.*, 2002; Baquero *et al.*, 2003), but the effects of lower pyrolysis temperatures with phosphoric acid activation were investigated in this study. The main objectives of this study therefore, were to prepare active carbons from bagasse, sorghum and millet straws by ortho phosphoric acid activation, examine the influence of preparation conditions (temperature, residence time and acid impregnation ratio) on the yields of the active carbons and investigate the potential of the active carbons for removal of benzene and toluene, which are known carcinogens present in the wastewater from petroleum refineries (Koh and Dixon 2001).

## CHAPTER 3

### METHODOLOGY AND EXPERIMENTAL DETAILS

#### 3.1 FORMATION OF ACTIVATED CARBON FROM RICE HUSK

Dry raw rice husks were washed thoroughly with water to remove the adhering soil and other contaminations present in them and then dried in the sunlight for 24 hrs. These were designated as raw rice husk (RRH). Base treatment was performed by treating the RRH with concentrated NaOH solution (1:1) in distilled water for 24 hours. It was then washed thoroughly with distilled water followed by reaction with dilute HCl (1:1) for 10 minutes to remove the traces of base. The treated husk was taken out and washed thoroughly in distilled water followed by drying in oven at 105°C for 24 hrs. About 25g base-treated rice husk (BRH) was carbonized at 400°C, and then activated using phosphoric acid at a ratio of 0.5:1.0 by volume per weight (phosphoric acid: BRH) (Mopoung & Thongcharoen, 2009). Afterwards, the pyrolysis of the Rice husk carbon was performed at 700°C, 750°C and 800°C. The carbon powder was washed and then dried in oven at 105°C for 24 hours. Then the activated carbon powder was crunched in a ball mill grinder. The very fine powder was sieved through a 400-mesh screen to get 45µm size.

#### Flow Diagram of production of activated carbon

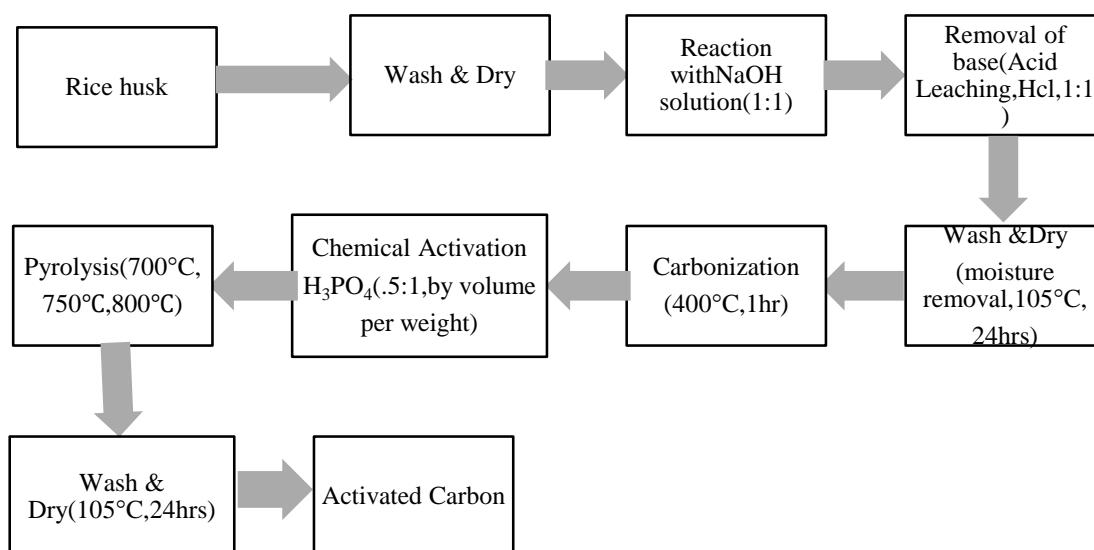


Figure 3.1: Flow diagram of production of activated carbon

### 3.2 ADSORPTION STUDIES

The activated carbon is firstly evaluated with methylene blue dye adsorption test. Solution of 32 mg/L (i.e  $1.00 \times 10^{-4}$  mole /L) Methylene blue was prepared by mixing appropriate amount of Methylene blue with distilled water. The adsorption studies were conducted by mixing a fixed amount of rice husk-based activated carbon with 100 ml of Methylene blue solution in Erlenmeyer flasks. The flasks were then shaken by hand at room temperature and kept it for a fixed period.

Methylene blue adsorption was measured by using visible ultra violet (Vis. UV) equipment (model 6715 UV/Vis. Spectrophotometer, JENWAY) in the Environmental Engineering Lab of Civil and Environmental Engineering Dept. of IUT.



Figure.3.2: UV/Vis. Spectrophotometer

A calibration chart of methylene blue with respect to absorbance of UV was determined. Coefficient of extinction was found to be 65280 liter per gram mole per cm ( $\text{LM}^{-1}\text{cm}^{-1}$ ) shown in Fig. 3.2

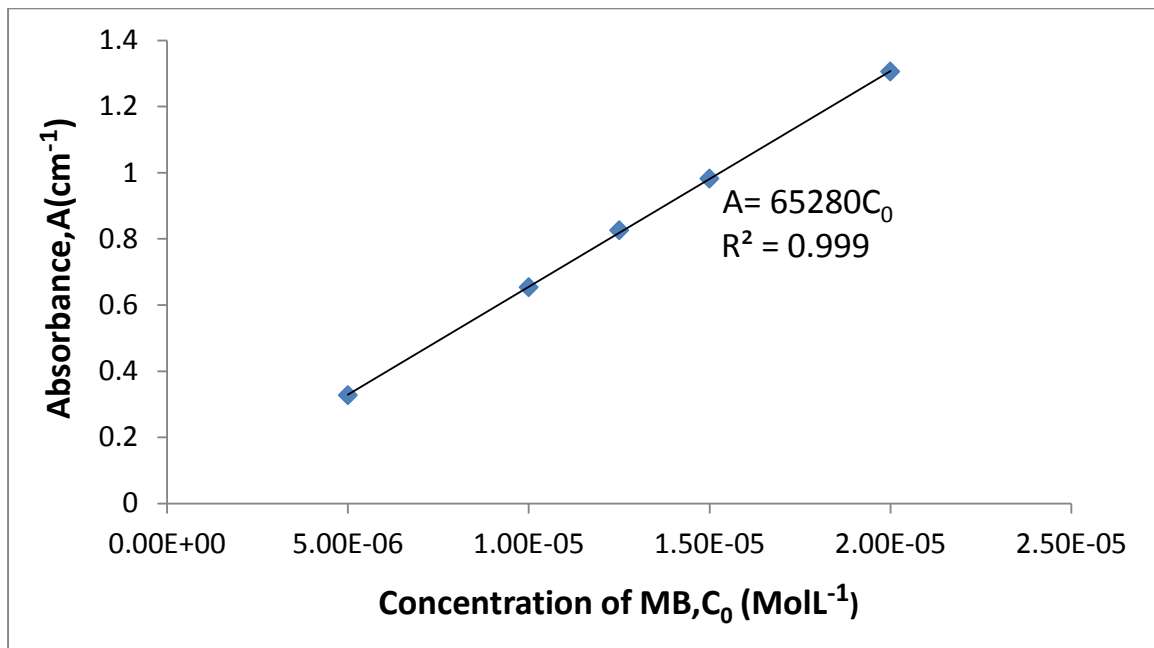


Figure 3.3. Calibration of methylene blue solution with vis. UV

The concentration of methylene blue after adsorption was determined using the following equation:

$$C_e = \frac{A}{E} \dots\dots\dots(3.1)$$

Where,

$C_e$  = concentration of methylene blue solution after adsorption

$A$  = absorbance of vis. UV,  $\text{cm}^{-1}$

$E$  = coefficient of extinction, 65280

### 3.2.1 Adsorption Capacity

The amount methylene blue adsorbed is calculated by using the following equation:

$$q_e = \frac{(C_0 - C_e)V}{m} \dots\dots\dots(3.2)$$

---

Where,

- $q_e$  = amount of dye adsorbed, mg/gm
- $C_0$  = initial concentration of dye, mg/L
- $C_e$  = final concentration of dye, mg/L
- $V$  = volume of dye solution, L
- $m$  = weight of activated carbon, gm

### 3.2.2 Langmuir-Hinshelwood isotherm

The Langmuir and Hinshelwood equation can be used to determine the adsorption capacity

$$\frac{C_{eq}}{q_{eq}} = \frac{1}{Q_{max} K_{ads}} + \frac{C_{eq}}{Q_{max}} \dots\dots\dots(3.3)$$

---

Where,

- $Q_{eq}$  = uptake of activated carbon at equilibrium, mg/gm
- $C_{eq}$  = concentration of solution at equilibrium, mg/L
- $Q_{max}$  = the maximum adsorbed quantity, mg/gm
- $K_{ads}$  = Langmuir adsorption constant related to energy of adsorption, L/mg

### 3.2.3 Specific surface area

The surface area of the activated carbon was calculated by using the constant value obtained from Langmuir-Hinshelwood plot. To calculate the surface area the following equation is used.

$$S_s = \frac{q_e \times A_V \times A_{MB}}{W \times 10^{-20}} \dots\dots\dots(3.4)$$

---

Where,

$S_s$  = specific surface area, m<sup>2</sup>/gm

$q_e$  = amount of methylene blue adsorbed, gram mole/gm

$W$  = molar weight methylene blue, mg

$A_V$  = Avogadro's number (6.02 x 10<sup>23</sup> per gram mole)

$A_{MB}$  = area covered by one molecule of methylene blue (130 Å<sup>2</sup>)

### 3.3: FORMATION OF SILICON CARBIDE FROM RICE HUSK

Dry raw rice husks were washed thoroughly with water to remove the adhering soil and other contaminations present in them and then dried in the sunlight for 24 hrs. These were designated as raw rice husk (RRH). Acid leaching was performed by treating the RRH with dilute HCl (1:1) in distilled water for 1 hour. It was then washed thoroughly with distilled water followed by treatment with dilute ammonia solution (10 vol. %) for 1 hr to remove the traces of acid. The treated husk was taken out and washed thoroughly in distilled water followed by drying in air for 24 hrs. About 15g acid-treated rice husk (ARH) were taken in cylindrical crucibles and introduced into a muffle furnace for pyrolysis at different temperatures varying from 700°C to 1200°C at an interval of 100°C and at 1500°C for 2 hrs. Soaking time in static air, and weight losses were measured after each pyrolysis by an electronic balance. Then Rice Husk Ash were prepared for further study.

### Flow Diagram of production of silicon carbide

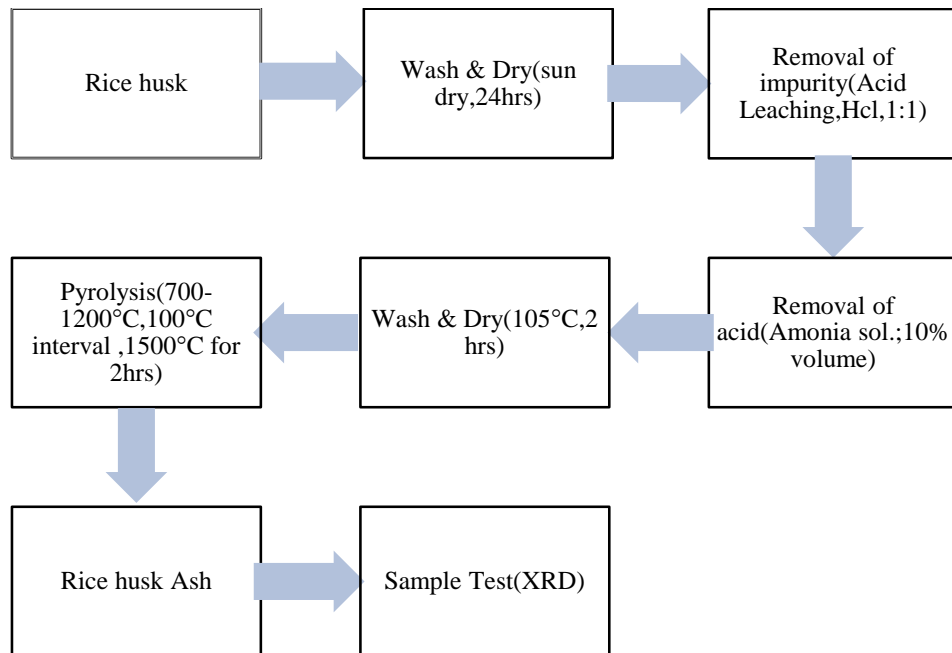


Figure3.4: Flow Diagram of production of silicon carbide

### 3.4: XRD ANALYSIS

The XRD analysis conducted to detect presence of silicon carbide which have been made from rice husk were studied by X-ray diffraction using a high resolution XPERT-PRO Diffractometer system, with Cu - K $\alpha$  radiation ( $\lambda=1.54 \text{ \AA}$ ). The phases formed were identified by insidious comparison of the recorded diffraction peaks with the ICDD database. Instrumental broadening was correlated by using FWHM of Silicon standard. X-ray Diffraction scans were conducted for phase present in the produced material.

TABLE3.1: PARAMETERS REGARDING XRD ANALYSIS

<b>Parameters</b>	<b>Value</b>
Raw Data Origin	XRD measurement (*.XRDML)
Start Position [ $^{\circ}2\theta$ .]:	10.0100
End Position [ $^{\circ}2\theta$ .]:	89.9900
Scan Step Time [s]:	0.6000
Scan Type:	Continuous
Scan Speed	$2^{\circ}$ (degree) per minute
Current	30mA
Voltage	40kV
Anode material	Cu



## CHAPTER 4

### RESULT AND DISCUSSION

#### 4.1 YIELD RATE

The total yield ( $Y_T$ ) of activated carbon obtained was calculated as:

$$Y_T = \frac{\text{Weight of activated carbon obtained}}{\text{Weight of rice husk treated with NaOH}}$$

The yield obtain is tabulated in Table 4.1. As expected, the weight of the samples decreased after carbonization process due to loss of volatile matter.

TABLE 4.1: YIELD OF RICE HUSK-BASED ACTIVATED CARBON

Activation temperature(°C)	Yield(%)
700	28.48
750	30.76
800	32

#### 4.2 ADSORPTION CAPACITY

Adsorption capacity was calculated using equation(X) for different amount of activated carbon for a fixed period of time. For different activation temperature activated carbon adsorption capacity is tabulated in table 4.2.

TABLE 4.2: ADSORPTION CAPACITY OF ACTIVATED CARBON WITH VARYING AMOUNT

Temperature, °C	700	750	800
	$q_t$ , mg/gm		
Amount (g)			
.01	259.59	265	269.8
.013	217.93	220.49	222.41
.015	202.62	204.88	206.9
.02	157.68	157.87	158.07

### 4.3 LANGMUIR-HINSHELWOOD PLOT:

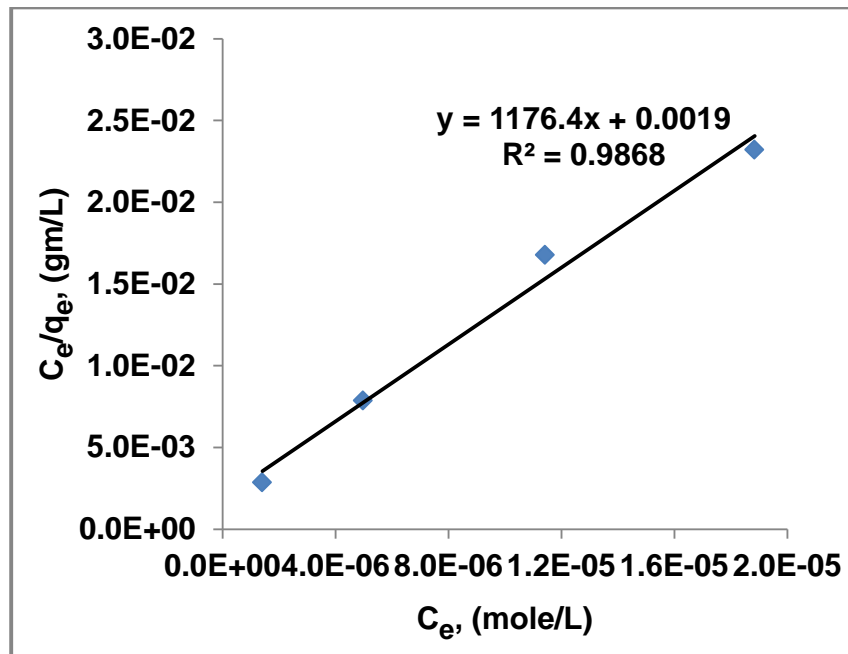


Figure 4.1: Langmuir-Hinshelwood plot for AC Activated at 700°C

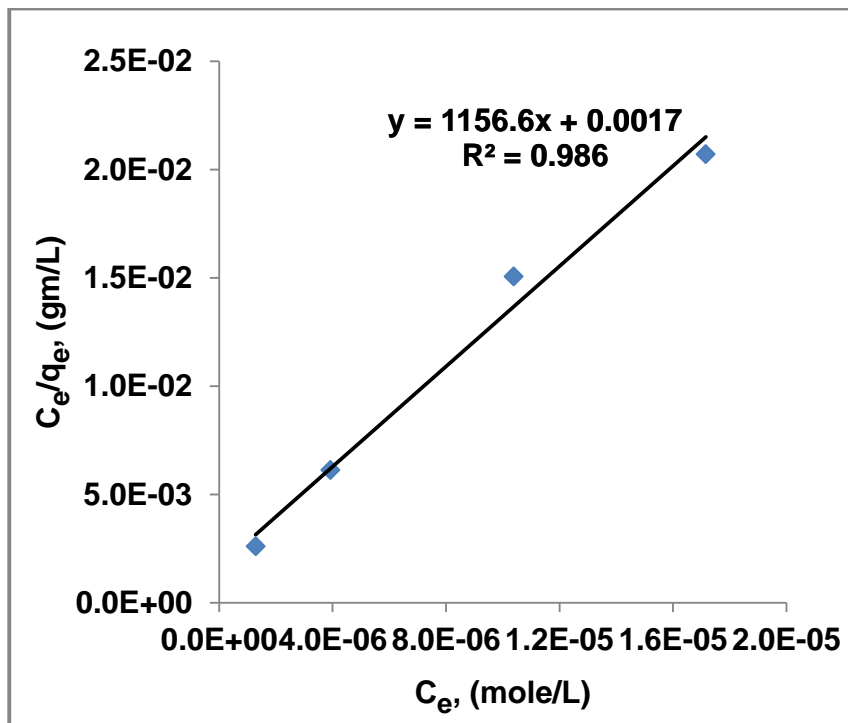


Figure 4.2: Langmuir-Hinshelwood plot for AC Activated at 750°C

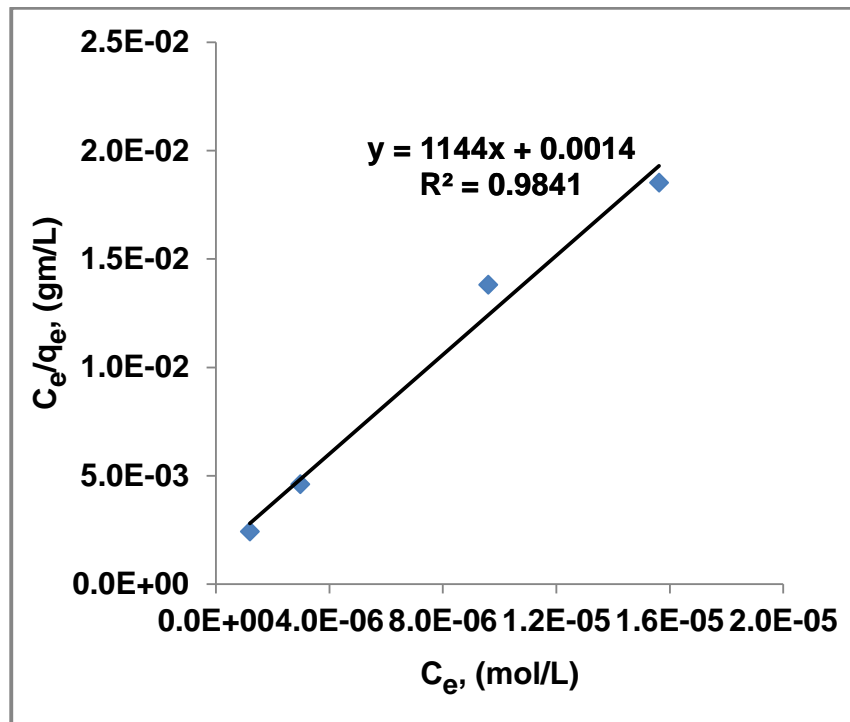


Figure 4.3: Langmuir-Hinshelwood plot for AC Activated at 800°C

Maximum adsorption capacity ( $Q_{max}$ ) of activated carbon is calculated using Langmuir-Hinshelwood isotherm equation and plot and tabulated in table 4.3. As expected, for 800°C activation temperature adsorption capacity is slightly higher than that of 700°C and 750°C.

TABLE 4.3: MAXIMUM ADSORPTION CAPACITY USING LANGMUIR-HINSHELWOOD PLOT

Activated Temperature, °C	$Q_{max}$ , mg/gm
700	271.89
750	276.55
800	279.6

#### 4.4: SPECIFIC SURFACE AREA

Specific surface area was calculated using equation X and with the help of plot. For different activation temperature activated carbon specific surface area is tabulated in table 4.4. As shown in table specific surface area increases with activation temperature increase.

TABLE 4.4: SPECIFIC SURFACE AREA OF RICE HUSK BASED ACTIVATED CARBON

Activated Temperature, °C	S, m <sup>2</sup>
700	665.25
750	676.64
800	684.1

#### 4.5: CONTACT TIME STUDY

To determine the equilibrium time a kinetic study was carried out. The time to reach equilibrium was determined by a series of measurements over the range of 60 min to 300 min at room temperature. Generally the rate of adsorption was very fast at the initial stages and there was no significant change in the extent of adsorption when the system reached equilibrium.

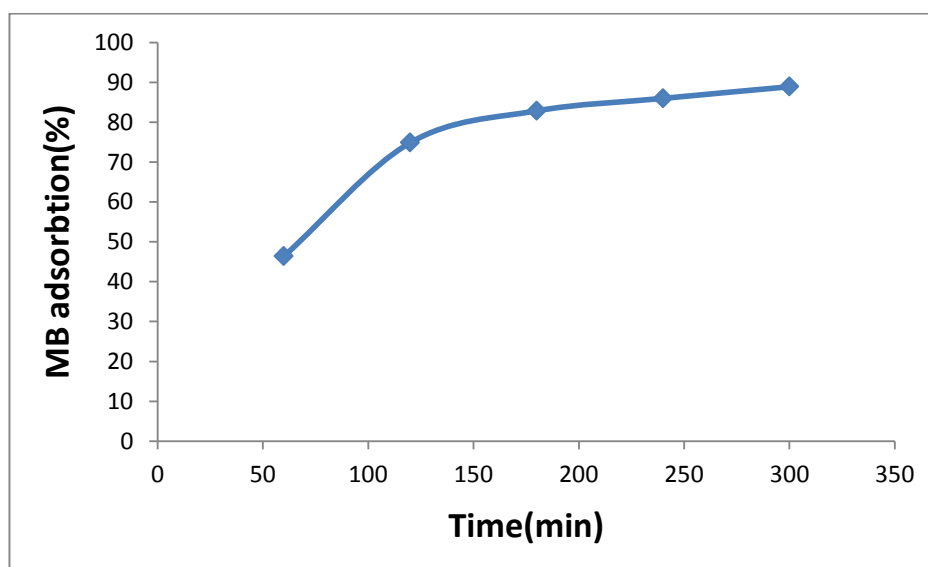


Figure 4.4: Methylene blue adsorption profile at room temperature on 700°C activation temperature activated carbon

#### 4.6 XRD – ANALYSIS

The phase analysis of silicon carbide (SiC), which have been produced from rice husk. The figures shown below are the XRD plots of Rice husk ash sample pyrolysis at 1200°C and 1500°C. The peak list with positions are also shown in tabulated form, In the plot sharper peak represents the silicon carbide is in crystalline form.

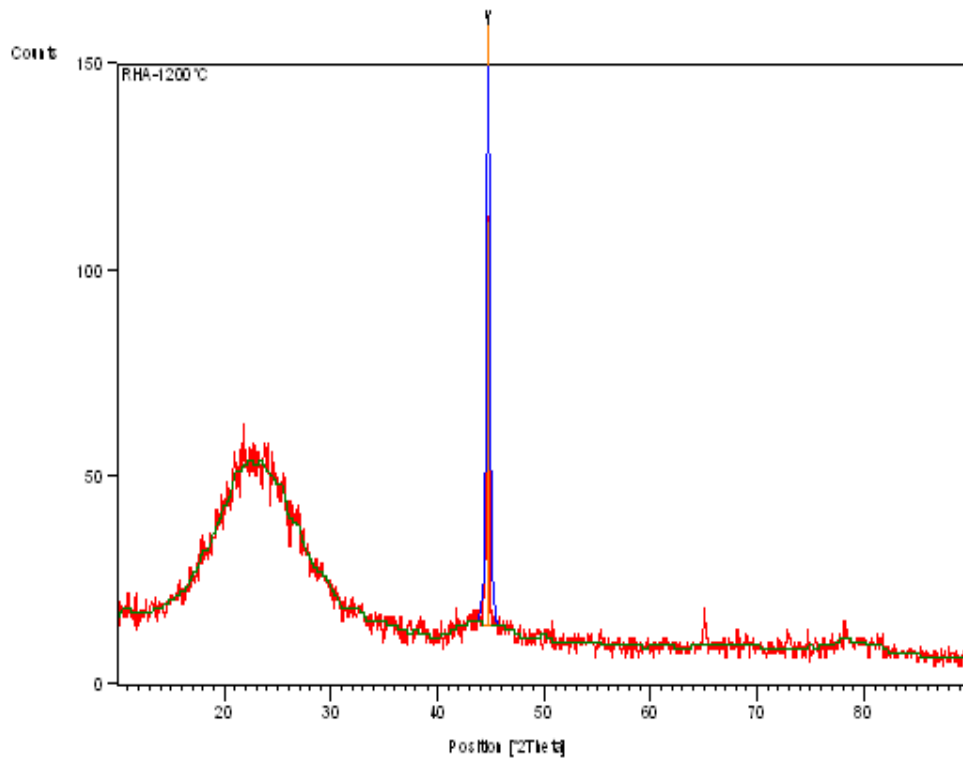


Fig4.5: XRD test of RHA pyrolysis at 1200°C

##### Peak List

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel.Int. [%]
44.7290	97.87	0.3360	2.02445	100.00

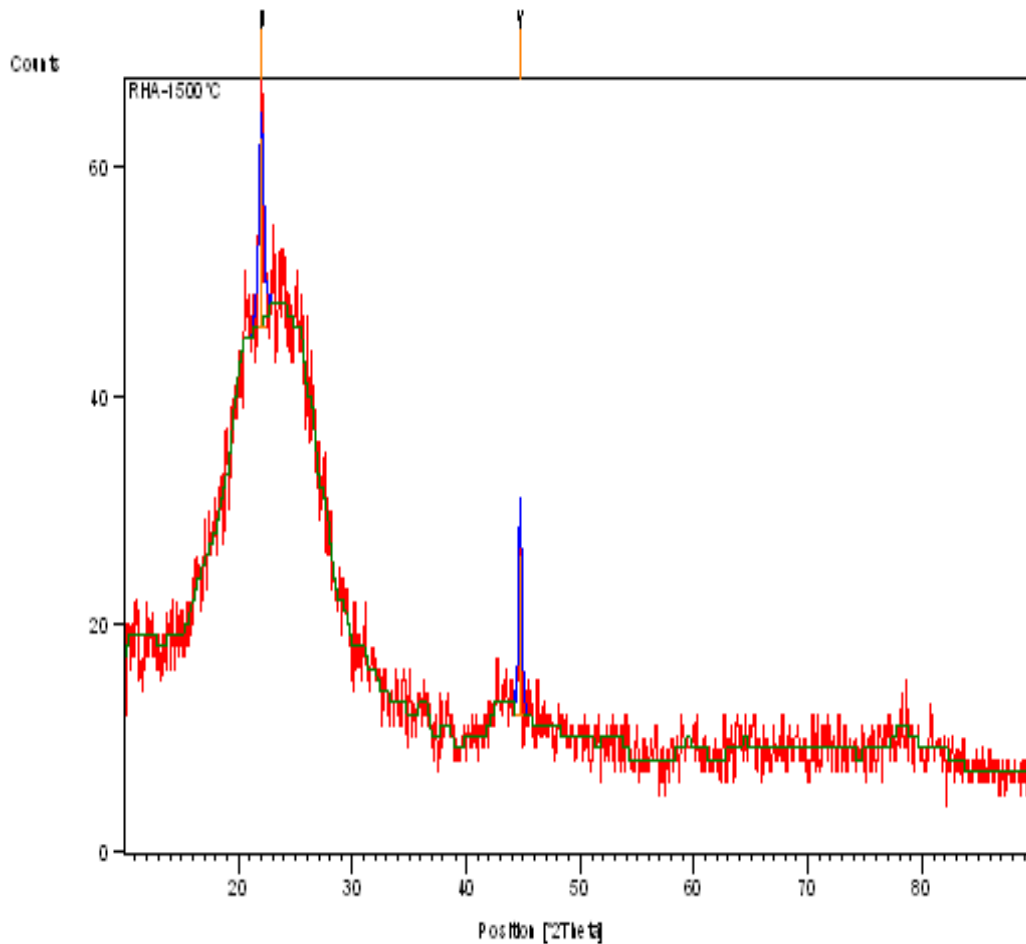


Fig4.6: XRD test of RHA pyrolysis at 1200°C

**Peak List**

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel.Int. [%]
22.0295	16.75	0.4723	4.03502	100.00
44.7171	13.95	0.2880	2.02496	83.27

## CHAPTER 5

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### CONCLUSION AND FUTURE WORK

#### 5.1 CONCLUSION

Based on the result obtained it can be concluded that Activated carbon and Silicon Carbide can be produced from Rice husk. Silicon Carbide presents in Rice Husk Ash samples is in crystalline form. Produced Rice husk-based activated carbon is a suitable adsorbent for the adsorption of Methylene blue solution. The adsorption rate and adsorption capability are considerably fast and high, respectively, making rice husk based activated carbon is a very attractive alternative for cheap adsorbent material. From adsorption studies Rice-husk based activated carbon activated at 800°C showed better result better than that of 700°C and 750°C. The yield rate (%) of activated carbon activated at 800°C is lower than that of 700°C and 750°C due to increase of temperature.

#### 5.1 SCOPE OF FUTURE WORK

The following research work should be undertaken in future:

- Study may be conducted on the production of activated carbon and silicon carbide from other natural source i.e Sugar leaf, Bagasse, Coconut shell etc.
- Study may be conducted on the application of rice husk activated carbon and silicon carbide.
- When rice husk is heated for preparation of activated carbon, combustion gas is released from the process which can be collected and used as source of regenerative energy. A study can be undertaken on the energy recovery from activated carbon preparation process.
- Study may be conducted on recovery of sodium silicate from activated carbon preparation process.
- Study may be conducted on recovery of chemicals using in this study such as NaOH, NH<sub>4</sub>OH etc.
- Study may be undertaken on the application of more efficient combustion technology in rice processing centers for reduction of biomass consumption.

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