GAVIN PUBLISHERS

# Current Trends in Chemical Engineering and Technology

Fazal-ur-Rehman M. Curr Trends chem Eng Process Technol: CTCEPT-101.

Review Article

DOI: 10.29011/ CTCEPT-101. 000001

# Methodological Trends in Preparation of Activated Carbon from Local Sources and Their Impacts on Production-A Review

**M. Fazal-ur-Rehman***

Department of Chemistry, University of Education Lahore, Vehari Campus-VEHARI (Punjab), Pakistan

***Corresponding author:** M. Fazal-ur-Rehman Department of Chemistry, University of Education, Lahore-Vehari Campus, Vehari-Punjab, Pakistan. Tel: +923467088517; Email: fazalurrehman517@gmail.com

**Citation:** Fazal-ur-Rehman M (2018) Methodological Trends in Preparation of Activated Carbon from Local Sources and Their Impacts on Production-A Review. Curr Trends chem Eng Process Technol: CTCEPT-101. DOI: 10.29011/ CTCEPT-101. 000001

**Received Date:** 11 January, 2018; **Accepted Date:** 05 February, 2018; **Published Date:** 14 February, 2018

## Abstract

Activated Carbon, also known as activated charcoal, which is crude form of graphite, substance which is used lead pencils. Activated Carbon is widely used in dye removal and also have other applications. Activated Carbon has high surface area, adsorption capacity, and high adsorption rates from the gas or liquid phases. Activated Carbonis also used in air purification, chromatography, energy storage, electrode materials for li-ion batteries biosensors, hydrogen storage, immobilizing the biomolecules. Therefore, Activated Carbon has wide applications. It is used in gas separation, solvents recovery and as catalyst. It is also used in waste-water treatment plants to remove the organic pollutants from the drinking water. For most of these applications, Activated Carbon is prepared from many resources by implementation of different chemical methods. The Activated carbon can also be prepared by different raw carbon resources like lignite, peat, unburnt coal and biomass wastes such as wood, sawdust, sugar cane bagasse, coconut shell, coffee beans, oil-palm stone, and Rice husk. Ligno-cellulosic waste materials, paulownia wood, pomegranate seeds, cattail, olive-tree, jatropha hull, bamboo, orange peel, *Thevetia peruviana*, ramie, grape stalk, pine apple waste biomass, and almond shell. Activated Carbon is also produced by pyrolysis of physic nut waste. Activated Carbon, prepared from all these sources, have high surface area, adsorption capacity, high adsorption rates for liquid gas separation, adsorption. Activated Carbon is widely used in waste water treatment to remove the pollutants. This review explores some of methods to prepare the activated carbon from different local sources reported by many researchers in recent years.

**Keywords:** Activated Charcoal; Raw Carbon; Pyrolysis; Rice Husk

## Introduction

Activated Carbon (AC), also known as activated charcoal, is crude form of graphite, substance which is used in lead pencils. It is different from graphite due to random, imperfect structure which is highly porous over a wide range of pore sizes from visible cracks and crevices to molecular dimensions. The structure of graphite gives very large surface area to AC which allows it to adsorb on compounds in wide range. AC has solidest forces for physical adsorption, or adsorbing porosity with maximum volume. AC can have greater than 1000$m^2$/g surface area, which means 3g of AC can have surface area equal to the surface area of a football field. There are two main forms of AC. Granular Activated Carbon (GAC): These are the particles of irregular shaped with size0.2-5 mm and have both liquid and gas phase applications. Powder Activated Carbon (PAC): This is pulverized carbon with a size predominantly less than 0.18mm (US Mesh 80). These are mainly used in liquid phase applications and for flue gas treatment.

AC is widely used in dye removal and also have other applications [1]. As we know dyes are heavily used today in most

industries such as silk, cotton, fabrics, paper and ink manufacturing industries. These dyes are synthesized chemically and fall bad impact on our environment due to their inappropriate removal from industrial area. These dyes actually create pollution, inhibit the light penetration into water lives. They also cause the potential mutagenic and carcinogenic effects. Certain dyes directly affect the new micronuclei, chromosomal breakage and aneuploidy in human. Others conventional techniques such as fenton-oxidation, irradiation, photochemical and membrane filtration, are also used to remove the dyes. These are best methods but create a secondary pollution which is more harmful especially for human health. Due to this reason, the production of AC, with high surface area from the local agricultural waste, is very cheaper and easily available as raw material to produce the high surface AC with high adsorptive capacity and high chemical reactivity, also offers dye removal efficiency [2]. AC has high surface area, adsorption capacity, and high adsorption rates from the gas or liquid phases. Therefore, AC has wide applications. It is used in gas separation, solvents recovery and as catalyst. It is also used in wastewater treatment plants to remove the organic pollutants from the drinking water [3]. Adsorption on AC is better as compared to other chemicals and methods in wastewater treatment [4]. The adsorption of common pollutants including methylene blue (MB), Acid blue-74, 4-chlorophenol from water was also investigated to estimate the performance of AC. Many researchers have prepared the AC for removal of harmful pollutants and chemicals from industrial and agricultural by-products [7]. AC is also produced to remove the 2, 4, 6-Trichlorophenoles from the aqueous solution [5]. An amorphous AC can absorb many gases, vapors, and colloidal solids. Coconut based AC is very useful from other carbons made from other materials due to its high density, high purity and effectively dust free nature [6]. AC is also used in gas and liquid phases including the medicinal use, gas storage, gas separation and catalysis. AC is also used to identify the new precursors for further preparation of AC. It is prominent fact that porous ACs are most important in purification of gases and liquids. AC is also used in air purification, chromatography, energy storage, electrode materials for li-ion batteries biosensors [7], hydrogen storage, immobilizing the biomolecules [8]. Several Researchers have reported the preparation of AC from different local sources. These preparative methods are explained below.

## AC from Rice Husk

AC was prepared from Rice Husk (RH) [9], because RH gives batter yield of AC with high surface area. The AC from RH have critical conditions like temperatures 293.15K, 303.15K, 313.5K and 323.15K and pressure up-to 3.5MPa.

Firstly, RH washed then dried. Dried rice husk carbonized at 1273K in the presence of nitrogen. Then, this RH was crushed, and potassium hydroxide was mixed in crushed RH. Then, this mixture was heated to 1073K for period of 2hours in Nitrogen Environment. The activated product was constantly washed with distilled water, then this washed product was dried at 393K in vacuum. As a result, AC was prepared.

Another way used to prepare AC is given. First of all, RH was washed with hydrofluoric acid (HF) to remove impurities of inorganic material of Silica ($SiO_2$) [10]. To prepare AC, 30g of RH were taken in 14mL of HF at normal temperature for about 12 hours. Raw RH (washed) was carbonized by heating it at the temperature of 673K for 4hours under Nitrogen atmosphere (100 mL/min) to achieve the better results of activating agent during impregnation. Impregnation of all material was carried out at 333K. In the presence of an activating agent; $ZnCl_2$ or NaOH, at the rate of 1/3 &1/4 (RH/Activating agent), Impregnated Product was dried at 373K for 24h. At the end, activation was done at the temperature of 873K in period of 4hours under Nitrogen atmosphere and appreciated extent of AC was prepared. By varying the temperature and time, different fractional quantity of mesopores, surface acids group, AC is obtained.

## Rice from Coconut Husk

AC prepared from Coconut Husk (CH) have greater advantage because it was successfully optimized for basic dye adsorption [11,12]. The raw material was collected locally to prepare Optimized AC. The raw material first was washed for the removal of dirty particles from the surface. Then, it was dried in oven at the temperature of 378K. Then, it was cut into desired small pieces and loaded onto a vertical tubular reactor made of stainless steel and placed in tube furnace. During the whole the process of Carbonization, pure nitrogen flown at 150 $cm^3$/min rate. The char mixed with pallets of potassium hydroxide (KOH) within different Impregnation Ratios (IR) which were calculated by given equation.

$$IR = W_{KOH} / W_{Char}$$

Then, mixture was dehydrated for removal of moisture content. AC was cooled to 298K under the flow of nitrogen. At end, AC was washed with hot water.

## AC from Pyrolysis of Physic Nut Waste

Physic nut is the most promising plant to produce large yield of activated carbon [13]. By this source, AC was prepared by two methods. First was physical method in which pyrolysis of precursor was done and resulted char was gasified in $CO_2$ stem. While other was chemical method in which pyrolyzed char was mixed within some important chemical reagents such as $ZnCl_2$, NaOH, & KOH.

Firstly, physic nut was pyrolized. Then char was then removed. Then physic nut was crushed and converted into small pieces of uniform size such as 0.4-0.5nm. Than sample was evaporated for dehydration at 353K for 24hours' period and

solution was dried. So, mixture was obtained ultimately, consisted of AC and KOH. Then activated carbon obtained by roasting the char pyrolyzed under 100mL/mm of $CO_2$ at 673K for 30min.

## AC from *Paulownia* Wood

AC was prepared by *Paulownia* wood through two methods: Physical and Chemical Activation [14]. Chemical activation was a single step method of preparing activated carbon. Paulownia wood using $ZnCl_2$(10-8 grams) were dissolved in 200 ml distilled water and then dissolved in 20 grams of the raw material mixed with $ZnCl_2$ solution and mixture was kept at353K for 7h to ensure completion of reaction between $ZnCl_2$ and wood particle. The mixture was filtered, and the remaining solid particles were dried at 383K for about 12hours.Carbonization of impregnated sample was done in 316 stainless steel reactor with length 104mm and 70 mm diameter. The final temperature varied between 673-973K. The mixture was dried at 383K for 12hours and calculated the yield. The AC was obtained by applying functional theory method to the nitrogen adsorption isotherms.

## AC from Cattail

Preparation of AC from cattail involved five steps [15]. In 1st step, Cattail was washed, dried, ground and impregnated. The resulting mass was heated and cooled down at 298K temperature. The deionized water was used to wash the produced carbonized material to reach its PH neutral and dried. In 2nd step, orthogonal experiment was applied to study the effect of impregnation time, impregnation ratio, activated time and activated temperature. In 3rd step, the textural properties of activated carbon were determined by $N_2$ adsorption by using QUDRA-SORB SI automated surface area and pore size analyzer. The surface morphology of carbon was observed by Scanning Electron Microscopy (SEM). In 4th step, adsorption characteristics were measured. In this experiment, two cationic dyes; neutral red and malachite green, were used in the experiments. In 5th step, thermal regeneration of spent activated carbon was carried out. In this experiment, 300mg of carbon was added to a 300mL dye solution and suspension was mechanically shaken. The solution was then filtered out and the amount of dye adsorbed was calculated.

## AC from Coconut Shells

AC was prepared from physical or chemical activation of coconut shells [16]. In physical activation, material was carbonized under inert atmosphere and in chemical activation, material was reacted with chemicals to help with initial dehydration. Chemical activation, commonly used as biomass material to obtain higher production and higher surface areas. In this process, lower energy values are used. Phosphoric acids ($H_3PO_4$) solution were produced according to 1.0, 1.5, 2.0 impregnation ratios. Phosphoric acid solution was defined as ratio of the dry weight of $H_3PO_4$ with respect to weight of coconut shell. 10 grams of coconut shell were used to make the sample. The fixed soaking time was at 12hours. Activation temperatures were 673K and 773K. Activation time was set as 10, 20 and 30 minutes. At 673K, moisture and volatiles were removed from the precursor. By washing the activated acid carbon, impurity of acid from AC became carbon removed. Furthermore, AC was washed with 100ml distilled water. The pH reading was 6-7that was used to remove acidity, when pH reading was noted as 7-8 for washing, then sample become neutralized. Activated carbon again, more washed with 0.1M NaOH solution and then finally washed with distilled water. After washing the sample, activated carbon sample was placed in an electric oven at 723K temperature for drying.

Another way is discussed as; Coconut shells were washed with deionized water for cleaning, dried and browned using rural mill and sealed for the experimentation [17]. In the 1st step, carbonization of coconut shells was done. Coconut shell was placed inside a stainless steel and kept in horizontal tube furnace where it was electrically heated. The temperature was up-to carbonization temperature. After carbonization, carbonized sample was cooled to 298K. In 2nd step, activation was done in self-made microwave tubular furnace. In this, approximately, 25 grams of carbonized compound was placed in reactor and heated with $N_2$-flow. Three types of activation were involved which were steam activation, $CO_2$-activation and Activation by steam with $CO_2$.

Another way to prepare AC from coconut shells is also discussed now [18]. The raw material (coconut shell) was first dried at 378K for 24hours. Then, it was crushed with the help of laboratory blender; it was grounded and then sieved into the coarse granules. $ZnCl_2$ & $CO_2$ were taken as activating agent to activate the reaction, while $H_2O_2$ were used to oxidize the products. These pre-treatment procedures were performed to produce AC. The samples were soaked within the $ZnCl_2$ solution in 1:1, 2:1, 3:1 ratio and then samples were dried at 378K. After soaking, the sample was refluxed with $H_2O_2$ at 373K for 60 min to get a solid product. The solid product was separated from the $H_2O_2$ by filtering it and then washed with de-ionized water. The product was dried at 378K. The sample granules obtained after filtration were added to the reactor which was a PARR-4848 autoclave at 473K. The reactor was allowed to cool to 298Kand products were dried at 378K. Now the temperature preferred for treatment was 473K to deliver hydrochar having maximum Oxygenated Flouro Groups. Hydrochar obtained by hydrothermal treatment of 25g of sample was mixed with 125 mL water and $ZnCl_2$ to get $ZnCl_2$: Raw material with 2:1 or 3:1 ratios. The mixed samples, at different temperatures (473K,548) for 20 minutes in parr autoclave, were treated. The reactor was allowed to cool to 298Kand product was dried at 378K. Precursor was activated by physio-chemical activation. These precursors were loaded on alumina boats in furnace. In the presence of nitrogen, temperature was increased to 1073Kat the 10 $^oC$ / min at 50mL/min rate flow. The $CO_2$ was used, and nitrogen was replaced

at 40mL/min rate flow. The furnace was allowed to cool to 298K. The product was kept to stirring for 30min in 250mL HCl and then washed with excess distilled water to get the pH=6. The final product which was AC, was dried and consumed for analysis.

## AC from Olive Tree Residue

Olive tree wood in mass ratio of 3:5:1was impregnated with $H_3PO_4$ solution [19-21]. The impregnated samples were dried rapidly and then stored in the desiccators. The samples were carbonized in a furnace which was equipped along with Euro-therm 904 temperature controllers and 1m long tubular ceramic insert. The temperature in furnace was first calibrated. The carbonization of samples was occurred at the temperature of 623-723K with 283K/min heating rate under constant $N_2$-flow of 100 $cm^3$/min while carbonization time was 1hour. All the products were washed with distilled water using vacuum to reach the pH=6 in residual liquid. The disappearance of phosphate ions in solution was determined by adding the barium nitrate. The resulted products were oven-dried and further dried in closed container.

## AC from wood of *Thevetia peruviana*

The raw material (*Thevetia peruviana*) was subjected to carbonize at 673K, and finally activated [22]. After the activation, material was washed with distilled water. The precursor was soaked in different solutions like (sodium sulphate, $H_3PO_4$, $ZnCl_2$, KOH, sulfuric acid, hydrochloric acid, and calcium carbonate, $H_2SO_4$ + $H_2O_2$). After this, liquid material was dried, carbonized and then activated at different temperature. The AC was washed with excess of distilled water to remove the impurities.

## AC from Bamboo

In furnace, the bamboo scraps were carbonized at 673K for 1hour [23]. The sample was cooled at room temperature. During the carbonization, $N_2$ was flushed for maintenance of inert atmosphere. With the impregnation ratios of 0.5, 1, 1.5, 2, and 2.5, $K_2CO_3$ was mixed with carbonized solid. After mixing, sample was dried at 393K in oven for 12 hours and impregnated sample was prepared. The AC was produced when this impregnated sample was heated under these conditions; activation temperatures of 1073K, 1123K, 1173K, 1223K and 1273K, nitrogen flow rate of 200mL/min and activation times were 1, 1.5, 2, 2.5 and 3 hours. Then with continuous flush of $N_2$, AC was cooled in furnace tube at room temperature with deionized water. The cooled solid was washed and filtered up-to the neutral pH value. Finally, the sample were dried for testing and analysis.

## AC from Lingo-cellulosic Waste Biomass

There are two main methods that are used in the preparation of AC from lingo-cellulosic biomass under Temperature 800$^oC$ and in absence of $O_2$ [24].AC are produced by three process Chemical activation ii. Physical activation iii. Physio-chemical activation and activated agent $CO_2$ is used in the production of AC. Activation process was used to prepare AC from the lingo-cellulosic biomass by three processes; chemical activation, physical activation and physio-chemical activation. In this, unwanted carbon was removed, $CO_2$ agent was used in the preparation of AC because this was very effective for the AC and also temperature was important in the production of the AC. Some other also chemicals such as $ZnCl_2$, NaOH, KOH was used in AC preparation.

## AC from Grape Stalk

First of all, grape stalk obtained from raw material is impregnated at different ratios with $ZnCl_2$ [25]. Then grape stalk is reacted with $Zncl_2$ in flask shaker (impregnation rate 150 rev/min) at a specific time of 24,36 & 48h. After that it is extracted out, filtered & dried at temperature of 378K.At the end activation process is occurred in cylindrical steel reactor of height 15cm & diameter 6cm at the temperature of 773K, 873K, & 973K respectively in periods of 30,60 & 90 minutes' duration & also $CO_2$ stream(0.1$dm^3$/min) is passed through the reactor and the system was heated in a muffle furnace. After the activation, the wet sample of AC was obtained. AC was cooled under the $CO_2$ flow & washed with 3M HCl solution to remove zinc compounds (side product) & at the end it was cooled down and dried. After all these work, prepared yield of activated carbon was calculated by dividing the mass of the produced AC by the initial mass of grape stalk residue.

## AC from Rice Straw

First of all, extraction process was done in which fraction extraction of lignin-hemicellulose (LH) from rice straw by treating with $NaClO_2$ and first washed and dried at the same time [26]. By obtaining de-waxed rice straw (94.7%) powder which was placed in 1.4 Wt% $NaClO_2$ under acidic condition (PH=5 by 10% $CH_3COOH$) at 15 mL/g liquid to solid ratio at the temperature of 343K for period of 6 hours to yield hemi-cellulose. Ethanol s added to the filtrate to produce alkal-soluble lignin together with hemicellulose. The LH powder was dried in oven which was placed in quartz tube of 2cm inner diameter and then it was passed through furnace for further drying at 333K for 12h (5$^oC$/0.5h). Then LH heated at the temperature of 1073K under the flow of $N_2$ at 100 ml/min. Finally activated carbon was obtained & cooled and particles of AC were washed with 5% HCl to remove impurities and dried at 378K for half an hour.

## AC from Pineapple Waste Biomass

The solid pineapple waste biomass was washed with tap water for removal of impurities [27]. Then, itwas oven-dried at 383K until 5-10% moisture content was obtained. After drying the samples, were cut into little pieces of random shapes. The method of chemical activation was used to prepare the AC, which is given as follows; Raw material was added into a beaker (500 ml) which

contains activation agent ($ZnCl_2$, 136.28 g/mol, AR grade, QReC) with 1:1 ratio (SPWB: $ZnCl_2$) and left to immersed for 1day at 298K through occasional stirring with glass rod. Then sample was dried at 383K for 24 hours performed by carbonization at 773K for 1 hour (Carbolite ELF). Then, it was cooled to reach 298K temperature. After that, the activated sample was washed by hot distilled water (303-308K) to remove unused activating agent and then oven-dried at 373K for period of 24hours for further utilization.

## AC from Almond Shells

Almond shell was washed and dried at 378K for period of 24 hours to remove the moisture content [28]. The dried samples were ground and sieved to the size of 1-2 mm. Carbonization and activation chars were both carried out in a vertical stainless-steel reactor placed in an electrical furnace 'Nabertherm'. During the carbonization, 15g raw material was used to prepare the chars. Nitrogen gas at 150 $cm^3$/min flow rate was passed through the reactor from the beginning of the carbonization process. The furnace temperature was increased at a rate of 5°C/min from room temperature to 450°C and held at this temperature for 1 hour. After pyrolysis, the furnace was cooled down to room temperature with $N_2$ flushing through the sample. The resulting chars were then activated by a $CO_2$ flow to prepare for the final product at fixed heating rate at 10°C/min.

## AC from Orange Peel

Orange peel (OP) was the precursor used to prepare AC [29]. The precursor was passed through washing with deionized water for removal of dirty particles. Then, OP was passed through drying, cutting, grounding and then, screening to a particle (1-2 mm). The 500g of dried precursor was loaded to carbonization it into a tubular furnace, and then, heated up to reach its carbonization temperature (973K) along with flow of purified nitrogen. The resulted char and$K_2CO_3$ pellets were mixed with IR, defined as:

$$IR = WK_2CO_3 / Wchar$$

Where $WK_2CO_3$is the weight(g) of pellets of $K_2CO_3$and Wchar is the Weight (g) of char, respectively. A microwave with 2.45 GHz frequencywas usedto performs the activation of sample. Nitrogen gas with flow rate of300 $cm^3$/min was used to remove the air from the reactor before the initiation of microwave heating and also during the activation. The oven with a power controller to choose different levels of power and also with timer for several exposure times at adjusted microwave power level. The resulted AC was washed several times with hydrochloric acid (0.1M) and then washed with distilled water to reach the pH 6–7of residual liquid. The yield of resulted AC was defined as follows;

$$Y = Wt\ of\ AC / Wt\ of\ Char$$

## AC from Pomegranate Seeds

The Pomegranate Seeds (PS) based AC was prepared from with $ZnCl_2$ activation passing through the basic four stages [30]. i. The mixing of Seeds and activating agent ($ZnCl_2$) solution was done for period of 24 hours under 1000rpm agitation continuously. ii.To form impregnated sample, mixture oven-dried at 383K for period of 24 hours. iii. The sample was kept in a stainless-steel reactor of fixed bed design whose diameter was 6cm while height was 21cm. Carbonization of sample was done at 873K and 1073K for 60 minutes under the 30 ml/min $N_2$-flow at the 278K/min heat rate. iv. AC was obtained through the above step. The boiling of AC withinsolution of HCl was done under the action of reflux for the removal of impurities and to reduce the ash. Then AC was washed repeatedly with hot water and at the end, with cold water to remove the Chloride ions. After that AC dried at 383K. The resulted yield of prepared AC with respect to pomegranate seed was calculated by given formula;

$$Yield\ of\ AC\ (Wt\%) = (Wt\ of\ AC / Wt\ of\ PS) \times 100$$

## AC from Soybean Oil Cake

The Soybean Oil Cake (SOC) was utilized to prepareAC by passing it through the basic four stages [31]. i. Solution of activating agents (KOH or $K_2CO_3$) and SOC were passed through mixing for period of 24 hours under 1000rpm agitation continuously. ii. To form impregnated sample, that mixture dried at 383K for 24 hours. iv. The sample was kept in a stainless steel reactor whose diameter was 6cm while height was 21cm. Pyrolysis of sample was done at 873K and1073K for 60 minutes under the 30 ml/min $N_2$-flow at the 278K/min heat rate. v. AC was obtained through the above step. Then boiling of AC with solution of HCl was done under the action of reflux for the removal of the impurities and for reduction of ash from AC. Then AC was washed repeatedly with hot water and ultimately with cold water. After that AC was oven-dried at 383K. The IR was calculated from the given equation.

$$IR = (Wt\ of\ impregnated\ sample) - (Wt\ of\ SOC) / Wt\ of\ SOC$$

The resulted yield of required product was calculated by

$$Yield\ of\ AC\ (\%) = (Wt\ of\ AC / Wt\ of\ SOC) \times 100$$

## AC from Lignin

Lignin (Ln) and different chemical agents ($K_2CO_3$, KOH, $Na_2CO_3$, NaOH, $ZnCl_2$, $H_3PO_4$) were mixed together in water and were kneaded [32]. To carried out the impregnation of sample, the mixture was oven-dried at 383K. Ratio of impregnation (I.R) was calculated by the given equation;

$$I.R = (Wt\ of\ impregnated\ Sample) - (Wt\ of\ Ln) / Wt\ of\ Ln$$

In this work, I.R for all the samples were 1.0.This sample was kept in the ceramic boat, then added into stainless steel tube

with diameter of 35mm. To Proceed the Carbonization of sample, it was heated to reach its carbonization temperature under Nitrogen flow with 283K/min heat rate. Here it was kept for 60 minutes at carbonization temperature. This temperature varied between 773K-1173K. Carbonization was done, washing of sample was done many times with ho distilled water and at end with cold water. Washing was done to remove the residuals. To get AC, this sample was further dried at 383K.

## Activated Carbon from Unburnt Coal

The Unburnt Coal (UC) frombottom ash was used as precursor in this study [33]. First, The Screening and Activation of coal particles of size 0.83-1.65mm was done. The Activation process was done in beaker of stainless steel by adding UC in beaker and by dissolving it in aq. solution of KOH. 2:2:1, 3:3:1, and 4:4:1 were taken as the weight ratios of water, UC and KOH and KOH/UC was 2, 3 & 4 respectively. These are mixed at 403K and kept in oven of high temperature. Introduction of Nitrogen was performed in oven to heat it to the temperature of1053K for 1 hour. The neutralization of product was done with the addition of HCl solution- equalent to solution of KOH as the most of Carbon dioxide gas bubbles were finished to disappear, in which 10% HCl solution was added in large amount. It was kept at water bath at 353Kfor 60 minutes. Then washing of product was done with deionized water continuously as water turned into neutral. So, the final product was obtained which was AC.

## AC from *Jatropha* hull

The raw material (*Jatropha* hull) was washed with distilled water for the removal of the impurities. Then, it was dried at 388K in oven [34]. Then, pieces of 2mm-5mm were sieved and then stored in a container to perform further experiments. The analysis of raw material showed the weight percentage which was 9.5% moisture content, 60.78% volatile matter, 25.48%fixed carbon and 3.8% ash content. The raw material was carbonized as 100 grams dried sample was loaded in muffle furnace with 100 $cm^3$/ min flow of nitrogen gas. Then it was heated to its carbonization temperature (873K) with 283K/min heating rate. When the carbonization temperature was reached, the sample was kept for 60 minutes to carbonize it. After that, the sample was cooled to 298K under 100$cm^3$/min flow of Nitrogen gas. After cooling, 40% char was obtained as yield. The carbonized sample was activated by microwave tube furnace. This furnace used the single mode controllable power continuously to perform the experiment. The frequency of microwave was 2.45 GHz while output power was adjusted to maximum value as 3000 Watt. During the process of activation, the activation temperature was controlled by microwave input power and measured by thermo-element of nichrome-nickel silicon armor type with diameter of 8mm and 450mm length and 273K-1523K temperature range with ±0.5 precision of measurement. The carbonized sample was placed in reactor and adjusted to the desired temperature with 200 $cm^3$/min flow rate of Nitrogen gas. When the temperature of reactor was reached to adjusted temperature value, steam was passed through reactor with a desired rate of flow to start the process of activation. It was done in 7 to 10 minutes with respect to adjusted temperature. It was noted that heating process by microwave was very efficient and effective as the heat rate was approx. 150/min in excess. All these experiments were performed under same conditions of activation. The activation process completion with adjusted activation conditions was noted by stopping the flow of steam and with allowing the flow of nitrogen gas to reactor as the AC was cooled to 298K. These all procedures were performed by fulfilling the activation parameters which were temperature of 1073-1273K, 1-6g/min steam flow rate and 15-30 minutes' activation time. The product (AC) was subjected for to examine its iodine number, also called its iodine adsorption capacity and BET surface area. The resulted yield was defined as number of grams of AC/grams of char which was used for activation process.

## AC from Polyacrylonitrile (PAN) Fibers

The polyacrylonitrile (PAN) fibers were used for impregnation with 0.5M to 0.2M aqueous solution of Potassium hydroxide or Sodium hydroxide for 24 hrs [35]. When the fibers were immersed, then samples were oven-dried for period f of 24 hours at 363K. These fibers were brought in nitrogenous atmosphere for pyrolysis and heated many times to 1073K for one an hour. Then pyrolyzed samples were washed again and again in solution of HCl and then in distilled water as $Cl^-$ ions were eliminated totally. Then, samples were oven-dried again at 373K for 24hours. The resulted fiber product was added in aqueous solution of silver nitrate for 24h to immerse for measurement of noble metal recovery from waste waters.

## AC from Coal Pitch

The raw material coal pitch and n-pentene were mixed with mass ratios of 1:10 and continuously stirred [36]. The mixed sample was placed at 298K for period of 2 hours. After that, soluble part of sample was separated from the sample with the help of vacuum filtration by doing this step was done at least three times. After performing three times, asphaltene was obtained and passed through the process of drying. This resulted asphaltene was used as solvent and it had contaminants. So, it was filtered to produce a fine and clean product. Then, cleaned asphaltene in 10grams and KOH were mixed within specific ratios of 0, 1:10, 1:4, 1:2 and 1:1. The resulted mixture was passed through heating at different temperatures (673K, 723K, 773K, and 823K) for time period of 60 minutes under the 400mL/min flow of purified Nitrogen gas. The KOH was used to enhance the carbonization of sample mixture and to reduce tarr formation. After the reaction of carbonization, resulted char was passed through the washing with 1mol/L HCl solution and washed again with hot distilled water to reach pH=7of

washings. After washing, separation of the residuals in solid form was carried out with the help of vacuum filtration, then oven-dried at 373K for period of 12 hours. After drying, the activation of char was carried out by steam with nitrogen at different temperatures for period of half an hour. At the extreme conditions of temperature, carbon and steam was treated to produce the CO and $H_2$ with the pore generated in large amount. The gas carrying out the reaction was provided to flow at the rate of 400mL/min, while steam in amount varying from 4g/hour to 16g/hour in carrier gas was present.

## AC from Bagasse and Rice Husk

Bagasse and Rice Husk (RH) were used as raw materials to prepare the AC [37]. Bagasse materials were oven-dried at 383K for period of 6 hours. Then materials were passed through grounding with the help of micro hammer cutter mill and then passed sieving to particles of size 500 μm to utilize in process of activation. Bagasse particles of size 500 μm were used to produce the AC.

Another way used as RH was passed through washing with distilled water to filter it and to remove the dust particles. Then oven-dried at 383K for period of 6 hours, cut into particles of small sizes and then sieved to the particles of size 2.0mm. Then 4grams of raw materials with chemical reagent were mixed in a beaker with reagent to sample ratio (W/W) of 0.25, 0.5, 0.75 and 1.0. The distilled water (ten times more in amount than mixture) was added to the mixture of raw materials. Sample mixture was passed through stirring, heating to convert the sample mixture into homogenous mixture and then through impregnation at 358K to form a uniform thick paste of sample mixture. Then a sample of paste containing 75% water was used to weigh it and rest of paste was used ion determination of moisture. U-shaped fixed bed reactor, made up of stainless steel with length of 480mm and internal diameter of 30mm, was used to perform this experiment. The reactor was adjusted with other instruments which were gas inlet pipes as well as outlet pipe to pyrolise the gaseous by-products. Nitrogen gas passed to the reactor with the flow rate of 200ml/min to eliminate the air from this reaction system. As the value of temperature was reached the target temperature, then nitrogen gas supply was replaced by $CO_2$ gas with 4l/min flow rate. Then reactor was placed in a furnace to pass the sample through activation in pre-fixed time period. In this literature, investigation of $ZnCl_2$, NaOH, and $H_3PO_4$ as impregnating agents on the surface air of AC was done with the ratios of agents to raw materials of 0.25, 0.5, 0.75 and 1. Then activation was carried out at 673K, 873K and 973K with 30 & 60 minutes' time of retention.

## AC Produced by $H_3PO_4$ and Water Vapor Activation

The Woody Biomass Birch (BW) of particle size of 0.5-1.0 was utilized as raw material for production of AC [38]. The raw material BW and impregnating agent (20-50%W/W Phosphoric acid) were mixed together and then kneaded with alternating ratios of 1, 1.5 and 2 (acid solution: BW) to form impregnated sample. After that, the samples were utilized for thermo-chemical treatment with different chemical atmosphere in a reactor. Some different steps were followed to conduct this experiment. i. These samples were passed through heating with 276K/min heat rate in nitrogenous atmosphere to reach the temperature of 873K and was placed at 873K for 1hour. ii. The pyrolyzed samples were being used for further pyrolysis at the temperature of 673K in a steam flow with flow rate of 120ml/min for the period of 60minutes. iii. Then the samples were cooled and the resulted carbons were passed through washing repeatedly with hot distilled water to neutralize the pH. Then washed with cold distilled water to filter the excess of compounds of phosphorous. Then they were oven-dried at 383K to get the AC.

## AC from Lignin

The AC was prepared from lignin passing through four steps [39].i.e Samples were placed in oven to dry at 378K for period of 4hours. ii. 3grams of dried sample and 40% solution of KOH with $K_2CO_3$ were mixed together in different ratios of mass for period of 16hours. iii. Then mixtures were placed in furnace to pyrolize at 773K to 1173K with 20°C/min heat rate to activate the sample and then cooled. iv. The activated samples were passed through washing many times by hot water to separate the chemical activating agents and then washed with cold water to neutralize the pH of water. After washing, activated sample was dried in oven at 378K for period of 6hours to produce the AC. The product of AC was determined by given equation;

$$Y(\%) = (M_1/M_2)\times 100$$

As, $M_1$ represented the weight of AC and $M_2$ represented weight of lignin while Y was the yield in percentage.

## AC from Jackfruit Peel Waste

The raw precursor, for AC production, collected was jackfruits [40]. Then jackfruit peel (JFP) was separated and carpel fibers were removed to clean it. The JFP was washed repeatedly with distilled water for the removal of impure contents. Then JFP was oven-dried at 378K to obtain the dried sample of constant weight. Then dried sample was ground with the help of JANKLE and KUNKEL micro hammer mill to reduce the size of particles of sample. After that, dried JFP was placed in desiccator as precursor to prepare the AC. The precursor material was passed through approximated analysis to determine the other contents present in JFP, which were 4.22% of moisture content, 10.19% of ash, 50.17% of volatile matter while 35.42% of fixed carbons. The precursor materials in amount of 20grams along with phosphoric acid an 85% Wt concentration were passed through impregnation with stirring. The ratio of concentration of $H_3PO_4$ was fixed to bring the impregnation ratios of 1:1, 2:1, 3:1 and 4:1 (Wt of activating agent: Wt of JFP). The slurry was resulted which was placed in

desiccators. When time period of 24 hours was passed, slurry became ready to pass through two steps. In 1st step, slurry was placed in horizontal tubular reactor. Then placed in muffle furnace to proceed the semi-carbonization at 473K for period of half an hour. Then slurry became black colored, producing black colored sticky dry powder. When the semi-carbonization was done, this powder passed through heating to reach the activation temperature. Then process of carbonization was carried out under 100cm$^3$/min of flow rate of nitrogen gas at standard temperature-pressure for period of 45minutes. After that, powder was activated which converted into AC. AC product was passed through collection and then cooling in desiccator, washing repeatedly with hot distilled water at 343K to neutralize the pH of solution of washings. At the end, AC was vacuum oven-dried at 383K for period of 24hours and stored in desiccator for further analysis.

### AC Hollow Fibers from Ramie

Ramie Fibers (RFs) were cut into pieces of 5mm length [41]. Then these were dried in oven at 373K for 6 hours. Then this dried samples were impregnated with activating agent solution 20% ($ZnCl_2$). Then its dehydration was done in oven at 353K for 2 hours. These impregnated sample fibers were kept in stainless steel boat and its pyrolysis was done in horizontal tubular furnace within Nitrogen flow. The range of temperature was kept between 673-1023K with 278K/min heating rate, retaining the time 1-2hours. After it, AC was obtained and washed with 1mol/L HCl and rinsed within distilled water to neutralize it. Then its filtration was done and dried to obtained fine Activated Carbon Hollow Fibers (ACHFs).

## Conclusion

AC prepared from all these sources have high surface area, adsorption capacity [42], high adsorption rates for liquid gas separation, adsorption [43]. AC prepared from these sources is widely used in waste water treatment [44] to remove the pollutants. Another benefit was that these waste materials, which were used to prepare the AC, also used to overcome the environmental pollution [45]. AC is also used in medical fields to manufacture the various medicines [46]. AC is very useful in waste water treatment, in gas liquid separation [47], gasification [48], and medical sciences [49]. It is also use full in adsorption of pollutants. It decreases the environmental pollution. Activated Carbon, prepared from all these sources, have high surface area, adsorption capacity, high adsorption rates for liquid gas separation, adsorption. Activated Carbon is widely used in waste water treatment to remove the pollutants. By the above discussion, it is cleared that the waste materials are very useful to prepare the AC. In this way, not only AC is produced, but those waste materials are also re-used [50].

## References

1. Wu FC, Tseng RL (2006) Preparation of highly porous carbon from fir wood by KOH etching and $CO_2$ gasification for adsorption of dyes and phenols from water. Journal of Colloid and Interface Science 294: 21-30.
2. Ahn DH, Chang WS, Yoon TI (1999) Dyestuff wastewater treatment using chemical oxidation, physical adsorption and fixed bed biofilm process. Process Biochemistry 34: 429-439.
3. Bacaoui A, Dahbi A, Yaacoubi A, Bennouna C, Maldonado-Hódar FJ, et al. (2002) Experimental design to optimize preparation of activated carbons for use in water treatment. Environmental science & technology 36: 3844-3849.
4. Bandosz TJ, Ania CO (2006) Surface chemistry of activated carbons and its characterization. Interface Science and Technology 7: 159-229.
5. Wang S, Zhu ZH, Coomes A, Haghseresht F, Lu GQ (2005) The physical and surface chemical characteristics of activated carbons and the adsorption of methylene blue from wastewater. Journal of Colloid and Interface Science 284: 440-446.
6. Gratuito MKB, Panyathanmaporn T, Chumnanklang RA, Sirinuntawittaya NB, Dutta A (2008) Production of activated carbon from coconut shell: optimization using response surface methodology. Bioresource Technology 99: 4887-4895.
7. Bielska M, Szymanowski J (2006) Removal of methylene blue from waste water using micellar enhanced ultrafiltration. Water research 40: 1027-1033.
8. Phan NH, Rio S, Faur C, Le Coq L, Le Cloirec P, et al. (2006) Production of fibrous activated carbons from natural cellulose (jute, coconut) fibers for water treatment applications. Carbon 44: 2569-2577.
9. Isoda N, Rodrigues R, Silva A, Gonçalves M, Mandelli D, et al. (2014) Optimization of preparation conditions of activated carbon from agriculture waste utilizing factorial design. Powder Technology 256: 175-181.
10. Balathanigaimani MS, Kang HC, Shim WG, Kim C, Lee JW, et al. (2006) Preparation of powdered activated carbon from rice husk and its methane adsorption properties. Korean Journal of Chemical Engineering 23: 663-668.
11. Tay JH, Chen XG, Jeyaseelan S, Graham N (2001) Optimising the preparation of activated carbon from digested sewage sludge and coconut husk. Chemosphere 44: 45-51.
12. Tan IAW, Ahmad AL, Hameed BH (2008) Preparation of activated carbon from coconut husk: optimization study on removal of 2, 4, 6-trichlorophenol using response surface methodology. Journal of hazardous materials 153: 709-717.
13. Sricharoenchaikul V, Pechyen C, Aht-ong D, Atong D (2007) Preparation and characterization of activated carbon from the pyrolysis of physic nut (*Jatropha curcas* L.) waste. Energy & Fuels 22: 31-37.
14. Yorgun S, Vural N, Demiral H (2009) Preparation of high-surface area activated carbons from Paulownia wood by $ZnCl_2$ activation. Microporous and Mesoporous Materials 122: 189-194.

15. Shi Q, Zhang J, Zhang C, Li C, Zhang B, et al. (2010) Preparation of activated carbon from cattail and its application for dyes removal. Journal of Environmental Sciences 22: 91-97.

16. Gratuito MKB, Panyathanmaporn T, Chumnanklang RA, Sirinuntawittaya NB, Dutta A (2008) Production of activated carbon from coconut shell: optimization using response surface methodology. Bioresource Technology 99: 4887-4895.

17. Yang K, Peng J, Srinivasakannan C, Zhang L, Xia H, et al. (2010) Preparation of high surface area activated carbon from coconut shells using microwave heating. Bioresource technology 101: 6163-6169.

18. Jain A, Balasubramanian R, Srinivasan MP (2015) Production of high surface area mesoporous activated carbons from waste biomass using hydrogen peroxide-mediated hydrothermal treatment for adsorption applications. Chemical Engineering Journal 273: 622-629.

19. Ould-Idriss A, Stitou M, Cuerda-Correa EM, Fernández-González C, Macías-García A, et al. (2011) Preparation of activated carbons from olive-tree wood revisited. I. Chemical activation with $H_3PO_4$. Fuel processing technology 92: 261-265.

20. Tay JH, Chen XG, Jeyaseelan S, Graham N (2001) Optimising the preparation of activated carbon from digested sewage sludge and coconut husk. Chemosphere 44: 45-51.

21. Stavropoulos GG, Zabaniotou AA (2005) Production and characterization of activated carbons from olive-seed waste residue. Microporous and Mesoporous Materials 82: 79-85.

22. Baseri JR, Palanisamy PN, Sivakumar P (2012) Preparation and characterization of activated carbon from Thevetia peruviana for the removal of dyes from textile waste water. Adv Appl Sci Res 3: 377-383.

23. Zhang J, Zhong Z, Shen D, Zhao J, Zhang H, et al. (2011) Preparation of bamboo-based activated carbon and its application in direct carbon fuel cells. Energy & Fuels 25: 2187-2193.

24. Nor NM, Lau LC, Lee KT, Mohamed AR (2013) Synthesis of activated carbon from lignocellulosic biomass and its applications in air pollution control-a review. Journal of Environmental Chemical Engineering 1: 658-666.

25. Ozdemir I, Şahin M, Orhan R, Erdem M (2014) Preparation and characterization of activated carbon from grape stalk by zinc chloride activation. Fuel Processing Technology 125: 200-206.

26. Hu S, Hsieh YL (2014) Preparation of activated carbon and silica particles from rice straw. ACS Sustainable Chemistry & Engineering 2: 726-734.

27. Mahamad MN, Zaini MAA, Zakaria ZA (2015) Preparation and characterization of activated carbon from pineapple waste biomass for dye removal. International Biodeterioration & Biodegradation 102: 274-280.

28. Omri A, Benzina M, Ammar N (2013) Preparation, modification and industrial application of activated carbon from almond shell. Journal of Industrial and Engineering Chemistry 19: 2092-2099.

29. Foo KY, Hameed BH (2012) Preparation, characterization and evaluation of adsorptive properties of orange peel based activated carbon via microwave induced $K_2CO_3$ activation. Bioresource technology 104: 679-686.

30. Uçar S, Erdem M, Tay T, Karagöz S (2009) Preparation and characterization of activated carbon produced from pomegranate seeds by ZnCl 2 activation. Applied Surface Science 255: 8890-8896.

31. Tay T, Ucar S, Karagöz S (2009) Preparation and characterization of activated carbon from waste biomass. Journal of Hazardous Materials 165: 481-485.

32. Hayashi JI, Kazehaya A, Muroyama K, Watkinson AP (2000) Preparation of activated carbon from lignin by chemical activation. Carbon 38: 1873-1878.

33. Wu FC, Wu PH, Tseng RL, Juang RS (2010) Preparation of activated carbons from unburnt coal in bottom ash with KOH activation for liquid-phase adsorption. Journal of environmental management 91: 1097-1102.

34. Xin-Hui Duan, Srinivasakannan C, Jin-Hui PENG, Li-Bo Z, Zheng-Yong Z (2011) Preparation of activated carbon from Jatropha hull with microwave heating: optimization using response surface methodology. Fuel Processing Technology 92: 394-400.

35. Moon SY, Kim MS, Hahm HS, Lim YS (2006) Preparation of activated carbon fibers by chemical activation method with hydroxides. In Materials science forum (Vol. 510, pp. 750-753). Trans Tech Publications.

36. Zhong L, Zhang Y, Ji Y, Norris P, Pan WP (2016) Synthesis of activated carbon from coal pitch for mercury removal in coal-fired power plants. Journal of Thermal Analysis and Calorimetry 123: 851-860.

37. Kalderis D, Bethanis S, Paraskeva P, Diamadopoulos E (2008) Production of activated carbon from bagasse and rice husk by a single-stage chemical activation method at low retention times. Bioresource technology 99: 6809-6816.

38. Budinova T, Ekinci E, Yardim F, Grimm A, Björnbom E, et al. (2006) Characterization and application of activated carbon produced by $H_3PO_4$ and water vapor activation. Fuel Processing Technology 87: 899-905.

39. Jin XJ, Yu ZM, Wu YU (2012) Preparation of activated carbon from lignin obtained by straw pulping by KOH and K2CO3 chemical activation. Cellulose Chemistry and Technology 46: 79.

40. Prahas D, Kartika Y, Indraswati N, Ismadji S (2008) Activated carbon from jackfruit peel waste by H 3 PO 4 chemical activation: pore structure and surface chemistry characterization. Chemical Engineering Journal 140: 32-42.

41. Du X, Zhao W, Wang Y, Wang C, Chen M, et al. (2013) Preparation of activated carbon hollow fibers from ramie at low temperature for electric double-layer capacitor applications. Bioresource technology 149: 31-37.

42. Lahaye L, Ehrburger P (2012) Fundamental issues in control of carbon gasification reactivity. Springer Science & Business Media: 192.

43. Rodriguez-Reinoso F (1991) Controlled gasification of carbon and pore structure development. In Fundamental issues in control of carbon gasification reactivity. Springer Netherlands: 533-571.

44. Rodriguez-Reinoso F, Molina-Sabio M, Gonzalez MT (1995) The use of steam and $CO_2$ as activating agents in the preparation of activated carbons. Carbon 33: 15-23.

45. Russell BP, Levan MD (1994) Pore size distribution of BPL activated carbon determined by different methods. Carbon 32: 845-855.

46. Seaton NA, Walton JPRB (1989) A new analysis method for the determination of the pore size distribution of porous carbons from nitrogen adsorption measurements. Carbon 27: 853-861.

47. Gübelin EJ. The Quarterly Journal of The Gemological Institute of America.

48. El-Sayed Y, Bandosz TJ (2004) Adsorption of valeric acid from aqueous solution onto activated carbons: role of surface basic sites. Journal of colloid and interface science 273: 64-72.

49. Erdoğan S, Önal Y, Akmil-Başar C, Bilmez-Erdemoğlu S, Sarıcı-Özdemir Ç, et al. (2005) Optimization of nickel adsorption from aqueous solution by using activated carbon prepared from waste apricot by chemical activation. Applied surface science 252: 1324-1331.

50. Gao NF, Kume S, Watari K (2005) Zeolite-carbon composites prepared from industrial wastes:(I) Effects of processing parameters. Materials Science and Engineering A 399: 216-221.