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Methodological trends in preparation of activated carbon from local sources and their impacts on production: A review

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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 has other applications. Activated carbon has high surface area, adsorption capacity, and high adsorption rates from the gas or liquid phases. Activated carbon is 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.

Capsule Summary: Preparation of activated carbon is from different resources (like lignite, peat, unburnt coal and biomass wastes such as wood, sawdust, sugar cane bagasse, coconut shell, coffee beans, oil-palm stone, 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 is discussed.

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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 $1000m^2/g$ surface area, which means 3g of AC can have surface area equal to the surface area of a football field (Kaman et al., 2017). There are two main forms of AC. Granular Activated Carbon (GAC): These are the particles of irregular shaped with size 0.2-5 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 (Wu and Tseng, 2006). As we know dyes are heavily used today in most industries such as silk, cotton, fabrics, paper and ink manufacturing industries (Ab Ghani et al., 2017). These dyes are synthesized chemically and fall bad impacts on our environment due to their inappropriate removal from industrial area (Kadirvelu et al., 2003). 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 (Mahmood et al., 2017). Others conventional techniques such as fenton-oxidation, irradiation, photochemical and membrane filtration (Fujishige et al., 2017), are also used to remove the dyes. These are best methods but create a secondary pollution which is more harmful especially for human health (Dizbay-Onat et al., 2017). 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 (Kaman et al., 2017) and high chemical reactivity, also offers dye removal efficiency (Ahn et al., 1999). AC has high surface area, adsorption capacity, and high adsorption rates (de Fatima Salgado et al., 2018) from the gas or liquid phases. Therefore, AC has wide applications. It is used in gas separation, solvents recovery and as catalyst (Gao et al., 2017). It is also used in wastewater treatment plants to remove the organic pollutants from the drinking water (Bacaoui et al., 2002). Adsorption on AC is better as compared to other chemicals and methods in wastewater treatment (Budinova et al., 2006). 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 (Bielska and Szymanowski, 2006). AC is also produced to remove the 2,4,6-Trichlorophenoles from the aqueous solution (Wang et al., 2005). 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 (Gratuito et al., 2008). 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 (Ab Ghani et al., 2017). 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 (Bielska and Szymanowski, 2006), hydrogen storage, immobilizing the biomolecules (Phan et al., 2006).

Activated carbon

Several Researchers have reported the preparation of AC from different local sources. These preparative methods are explained below.

Rice husk

AC was prepared from rice husk (RH) (Isoda et al., 2014), because RH gives batter yield of AC with high surface area. The AC from RH have critical conditions like temperatures 293.15 K, 303.15 K, 313.5 K and 323.15 K and pressure up-to 3.5 MPa. 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 1073 K for period of 2 hours in Nitrogen Environment. The activated product was constantly washed with distilled water, then this washed product was dried at 393 K in vacuum. As a result, AC was prepared.

Another way used to prepare AC is given. First of all, RH was washed with hydroflouric acid (HF) to remove impurities of inorganic material of Silica (SiO_2) (Balathanigaimani et al., 2006). 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 4 hours 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 4 hours 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.

Coconut husk

AC prepared from coconut husk (CH) have greater advantage because it was successfully optimized for basic dye adsorption (Tay et al., 2009) and (Tay et al., 2001). 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 378 K. 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 as shown in Eq. 1.

$$IR = W_{KOH} / W_{Char} \quad (1)$$

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.

Pyrolysis of physic nut waste

Physic nut is the most promising plant to produce large yield of activated carbon (Sricharoenchaikul et al., 2007). 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 pyrolized 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 24 hours' 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.

Paulownia wood

AC was prepared by paulownia wood through two methods: Physical and Chemical Activation (Yorgun et al., 2009). 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 gram of the raw material mixed with $ZnCl_2$ solution and mixture was kept at 353K 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 12 hours. Carbonization of impregnated sample was done in 316 stainless steel reactor with length 104 mm and 70 mm diameter. The final temperature varied between 673-973K. The mixture was dried at 383K for 12 hours and calculated the yield. The AC was obtained by applying functional theory method to the nitrogen adsorption isotherms.

Cattail

Preparation of AC from cattail involved five steps (Shi et al., 2010). 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.

Coconut shells

AC was prepared from physical or chemical activation of coconut shells (Gratuito et al., 2008). 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 12 hours. 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 6-7 that 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 (Yang et al., 2010). 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 (Jain et al., 2015). The raw material (coconut shell) was first dried at 378K for 24 hours. 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 298K and 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 ZnCl2 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 298K and 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 1073K at 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.

Olive tree residue

Olive tree wood in mass ratio of 3:5:1 was impregnated with H_3PO_4 solution (Tay et al., 2001) (Sricharoenchaikul et al., 2007). The impregnated samples were dried rapidly and then stored in the desiccator. 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.

Wood of thevetia peruviana

The raw material (thevetia peruviana) was subjected to carbonize at 673K, and finally activated (Baseri et al., 2012). 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.

Bamboo

In furnace, the bamboo scraps were carbonized at 673K for 1hour (Zhang et al., 2011) (Fujishige et al., 2017). 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 393 K 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 was dried for testing and analysis.

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 (Nor et al., 2013) (Nayak et al., 2017). AC are produced by three process, i. Chemical activation, ii. physical activation and 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.

Grape stalk

First of all, grape stalk obtained from raw material is impregnated at different ratios with $ZnCl_2$ (Ozdemir et al., 2014). 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.

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 (Hu and Hsieh, 2014). 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°C/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.

Pineapple waste biomass

The solid pineapple waste biomass was washed with tap water for removal of impurities (Mahamad et al., 2015). Then, it was 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 24 hours for further utilization.

Almond shells

Almond shell was washed and dried at 378K for period of 24 hours to remove the moisture content (Omri et al., 2013). 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.

Orange peel

Orange peel (OP) was the precursor used to prepare AC (Foo and Hameed, 2012). 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 shown in Eq. 2.

$$IR = WK_2CO_3 / Wchar \quad (2)$$

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 frequency was used to perform 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 shown in Eq. 3.

$$Y = Wt\ of\ AC / Wt\ of\ Char \quad (3)$$

Pomegranate seeds

The pomegranate seeds (PS) based AC was prepared from with $ZnCl_2$ activation passing through the basic four stages (Uçar et al., 2009). 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 within solution 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 as shown in Eq. 4.

$$Yield\ of\ AC\ (Wt\%) = (Wt\ of\ AC / Wt\ of\ PS) \times 100 \quad (4)$$

Soybean oil cake

The soybean oil cake (SOC) was utilized to prepare AC by passing it through the basic four stages (Tay et al., 2009). 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 21 cm.

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 Eq. 5.

IR = (Wt of impregnated sample) – (Wt of SOC) / Wt of SOC (5)

The resulted yield of required product was calculated using Eq. 6.

Yield of AC (%) = (Wt of AC / Wt of SOC) × 100 (6)

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 (Hayashi et al., 2000). To carried out the impregnation of sample, the mixture was oven-dried at 383K. Ratio of impregnation (I.R) was calculated using Eq. 7.

I.R = (Wt of impregnated Sample) – (Wt of Ln) / Wt of Ln (7)

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.

The AC was also prepared from lignin passing through four steps (Jin et al., 2012). i. 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^{o}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 as shown in Eq. 8.

$$Y\ (\%) = (M_1/M_2)\times100 \quad (8)$$

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

Un-burnt coal

The Unburnt Coal (UC) from bottom ash was used as precursor in this study (Wu et al., 2010). 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 of 1053K 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 353K for 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.

Jatropha hull

The raw material (Jatropha hull) was washed with distilled water for the removal of the impurities. Then, it was dried at 388 K in oven (Xin-Hui et al., 2011). 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 100cm^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.

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 (Moon et al., 2006). When the fibers were immersed, then samples were oven-dried for period f of 24 hours at 363 K. These fibers were brought in nitrogenous atmosphere for pyrolysis and heated many times to 1073 K 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.

Coal pitch

The raw material coal pitch and n-pentene were mixed with mass ratios of 1:10 and continuously stirred (Zhong et al., 2016). 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.

Bagasse and rice husk

Bagasse and rice husk (RH) were used as raw materials to prepare the AC (Kalderis et al., 2008). 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 2.0 mm. 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.

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 (Budinova et al., 2006). 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 60 minutes. 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.

Jackfruit peel waste

The raw precursor, for AC production, collected was jackfruits (Prahas et al., 2008). 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 desiccator. 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.

Fibers from ramie

Ramie Fibers (RFs) were cut into pieces of 5mm length (Ozdemir et al., 2014). 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). The AC sources are freely, abundantly and locally available, which could be economically viable for wastewater treatment (Kadirvelu et al., 2003) as an adsorbent for the reidiation of metal ions, dyes and other pollutants (Adeel et al., 2017; Aftab et al., 2017; Ahamd et al., 2017; Akram et al., 2017; Bhatti et al., 2017a; Bhatti et al., 2016; Bhatti et al., 2017b; Iqbal et al., 2013; Iqbal et al., 2017a; Iqbal et al., 2016; Kanwal et al., 2017; Kausar et al., 2017; Manzoor et al., 2013; Mushtaq et al., 2016; Nadeem et al., 2016; Naeem et al., 2017; Rashid et al., 2016; Shoukat et al., 2017; Tahir et al., 2016a; Tahir et al., 2016b; Ullah et al., 2013). Under the current scenario of environmental pollution (Abbas et al., 2018a; Abbas et al., 2018b; Abbas et al., 2017; Ahamd et al., 2017; Bibi et al., 2017; Iqbal, 2016; Iqbal et al., 2015; Iqbal and Bhatti, 2015; Iqbal and Nisar, 2015; Iqbal et al., 2017b), there is a need to develop new adsorbents form local sources.

CONCLUSIONS

AC prepared from all these sources have high surface area, adsorption capacity, high adsorption rates for liquid gas separation, adsorption. AC prepared from these sources is widely used in waste water treatment 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. AC is also used in medical fields to manufacture the various medicines. AC is very useful in waste water treatment, in gas liquid separation, gasification, medical sciences. 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.

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