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Strategic Study of different Methods & Materials used for Production of Activated Carbon

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Abstract: Activated carbon is the product of an activation process of carbonaceous materials from different sources and with carbon contents in the range 72-90%.Activatedcarbon has wide range of applications such as air pollution, odour removal processes, wastewater treatment etc. However, the production of good property carbon increases the cost which adds a burden to the consumer. Therefore, alternative methods are needed to minimize the cost of activated carbon production. One major way to cut on such cost is by choosing a cheap available starting material. The present review study comprehensively addresses various experimental methods and materials for the production of activated carbon.The abundant supply of different raw materials as a waste-product from different industries and other resources makes production of activated carbon from this material more financially viable since using grain or coal as raw materials for activated carbon will require manufacturers extra amount of money for procurement. Such activated carbons are advantageous over carbons made from commercial methods and materials because of its high density, high purity, and virtually dust-free nature. These carbons are harder and more resistant to attrition.
Keywords: Activated, Carbon, carbonaceous materials, Production, Waste.

I. INTRODUCTION

A. What's Activated Carbon?

Activated carbon (AC)referred as activate charcoal, is a form of carbon under processed to have small, less volume pores that increases the surface area available for adsorption or chemical reactions. It is a carbonaceous and porous adsorptive medium that features a complex structure composed primarily of carbon atoms [1]. The networks of pores in activated carbons are channels created within a rigid skeleton of disordered layers of carbon atoms, linked together by chemical bonds, stacked unevenly, creating a highly porous structure of nooks, crannies, cracks and crevices between the carbon layers. Activated carbons are often synthesized from any carbonaceous precursor, example coal [2], discarded tires [3], lignin [4] and biomass waste [5] etc.

B. Properties

1) *Surface Area: Generally,* higher the interior surface area, higher the effectiveness of the carbon. The area of AC is impressive, 500 to 1500 m^2/g or may be more; a spoonful of AC easily equates the surface area of a soccer field.
2) *Total Pore Volume :*Refers to all or any pore spaces inside a particle of AC. Its expressed in milliliters per gram (ml/g), volume in reference to weight. Generally, more the pore volume, more the effectiveness.
3) *Pore Radius:* The mean (average) pore radius, often measured in angstroms, differs by activated charcoal/carbon type.

C. Types of Activated Carbon

1) *Granular Activated Carbon (GAC):* GAC are irregular shaped particles formed by milling and sieving. These products range from the sizes 0.2mm to 5 mm. They have the advantages of being harder and longer lasting than powdered activated carbons, clean to handle, purify large volumes of gas or liquids of a consistent quality, and can be reactivated and reused many times.

Fig 1. Granular Activated Carbon

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2) *Powdered Activated Carbon (PAC):* PACs generally have a particle size distribution ranging from 5 to 150 Å, although coarser and finer grades are available. Advantages of powdered activated carbons are their lower processing costs and their flexibility in operation. Powdered activated carbons are mainly used for liquid-phase adsorption.

Fig 2. Powdered Activated Carbon

3) *Extruded carbon:* These are cylindrical pellets with diameter ranging from 1mm to 5mm. The extrusion process, together with the raw material used, ensures that the end product is hard and suitable for heavy duty applications. The extruded pellet form gives a low system pressure drop, which is an important consideration in the gas-phase uses.

Fig 3. Extruded carbon

D. Commercial Process for Production of Activated Carbon

There are two processes for the preparation of activated carbon: physical and chemical activation. Physical activation involves carbonisation of a carbonaceous material followed by activation of the resulting char in the presence of activating agents such as CO_2 or steam. In the chemical activation, the raw material is impregnated with activating agents such as $ZnCl_2$, H_3PO_4, KOH, K_2CO_3; then the impregnated material is heat-treated in an inert atmosphere at various temperatures [8,9].

E. Requirements of Alternative Methods

Activated carbon has wide range of applications such as air pollution, odour removal processes, wastewater treatment etc. However, the production of good property carbon increases the cost which adds extra burden to the consumer. Therefore, alternative methods are needed to minimize the cost of activated carbon production. One major way to cut on such cost is by selecting a cheap available starting material. The present review study comprehensively addresses various experimental methods and materials for the production of activated carbon. The abundant supply of different raw materials as a waste-product from different industries and other resources makes production of activated carbon from this material more financially viable since using grain or coal as raw materials for activated carbon will require manufacturers extra amount of money for procurement.

F. Applications

1) *Gold extraction*
2) *Catalysis [6]*
3) *Sugar decolorization*
4) *Drug injection refining*
5) *Blood purification*
6) *Human safety protection*
7) *Odor removal*
8) *Adsorption, both liquid and gas phase [7]*

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II. METHODOLOGY

A. *Production of activated carbon from coconut shell: optimization using Response Surface Methodology*

The experiment was carried out with the calculation of dependent variables (responses) analyzed which were killed bulk density average diameter of common force average diameter of small force and the number of force per unit area basically 3 (impregnation ratio, activation temperature and activation time) fractional factorial experimental design based on Box and Behnken with three center runs was used, giving a total of 15 experimental runs. impregnation ratio which is defined as the ratio of dry weight of H_3PO_4 to the weight of coconut shell based on a study by [14]. Molina-Sabio et al.(1995) taking the ratios of 1.0, 1.2 and 2.0, phosphoric acid solutions were prepared along with this the clean fiber-free and soil free coconut shells were milled to reduce the size down to the 2.4 mm diameter or to mesh 8. 10 grams of the coconut shells were used for sample and taking the soaking time for the experiment was 12 hours which was fixed taking the activation temperature of 400, 450 and 500°C, activation times of 10, 20 and 30 minute were also assessed. These times were based on the initial experimental run at 400˚C where in the smoke Revolution seized after about 7 minutes for stop it was presumed that at this time also and most of the volatiles were eliminated from the precursor does the minimum time evaluated was set at 10 minutes a steady supply of Nitrogen was provided for the whole activation time to have an inert environment for the activation process washing then followed to remove traces of acid in the activated carbon the activated samples were repeatedly was with about 100 ml of distilled water the acidity of the wash Leke was monitored until the pH reading is at 6-7. On the average commerce 78 washings were able to neutralize the sample for stop the activated carbon was then again was with 0.1 M sodium hydroxide solution and finally with distilled water the worst activated carbon samples were then placed in the electric oven with temperature set at 105°C for drying.

B. *Production of activated carbon using waste tea by chemical activation with microwave energy*

In this method, the feedstock is obtained from tea factory or household waste tea. Before experimental setup, feed stock crushed and sieved to 250-500 um size fraction. For chemical activation agent H_3PO_4 of 85% used[ppr1]. The mixing of H_3PO_4 of 85% and crushed waste tea mixed in Teflon beaker and immediately subjected to microwave treatment for 30 sec for which household microwave system used. 900W of input power and 2.45 GHz frequency used. The sample impregnated for 72hrs, not subjected to microwave energy. The heating rate for this study explain by Sudaryanto Y. et. al [10, 11]. Carbonization of each samples carried out in crucible with lid in a stainless-steel reactor placed in temperature programmable furnace under N_2 flow, heating rate of 20^0 $C*min^{-1}$ and sample held in furnace for 1 hr. when the waste tea used as feedstock, high surface area activated carbon obtain from the carbonized sample [12].

C. *Production of activated carbon from rubber wood sawdust*

The fresh sawdust generated in the process of converting the wood logs of a rubber tree (25 years old) into sawn timber in the saw mill is collected and utilized for experiments as raw material. The samples for activation are prepared by mixing the pre-dried sawdust with required ratio of phosphoric acid based on the dry weight of the sample.60% concentration phosphoric acid is allowed to soak with the sawdust overnight, so that reagents are fully adsorbed into the raw material. After impregnation 20 g of the samples are transferred to a clean Pyrex glass plate and spread as a thin layer uniformly and kept in the muffle furnace for semi-carbonization.

During semi-carbonization the carbonaceous material along with impregnation agent turns black forming a plastic mass, which turns into a dry powder on continued heating at 200◦C. The semi-carbonized materials are taken out of the furnace and stored in a desiccator until the furnace reached set activation temperature. After, the furnace attained set temperature, semi-carbonized material is kept in the furnace for activation.

After, activation at required temperature, the activated material is repetitively washed with distilled water to recover all the acid from the material. The acid from each wash is analysed for its acid content using conductivity measurements. Seventy cubic centimetre of water is used for each washing and the washing is carried out in a shaker bath at 60^0C for a minimum of 4hr to ensure that equilibrium is established between the carbon and the liquid phase. Washing is continued until the wash liquor is neutral with the conductivity of the wash liquor < 5 uS cm^{-1}.

Around 7 to 8 washings are required to remove all phosphoric acid from the carbon. Finally, the carbon is washed with 0:1 M sodium hydroxide solution and later washed thoroughly with distilled water. The product is dried in hot air oven for 4 to 5 h at 105◦C and subjected to size reduction so that the material passes through 300 um mesh [13].

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III. LITERATURE REVIEW

M.K.B. Gratuito et al. made study on production of activated carbon from coconut shell treated with phosphoric acid was optimized using response surface methodology (RSM). In this method, raw materials including clean, fiber-free, and soil-free coconut shells were milled to reduce the size down to mesh 8(2.4mm diameter). Phosphoric acid solutions were prepared to the required impregnation ratios of 1.0, 1.5 and 2.0, defined as the ratio of dry weight of H_3PO_4 to the weight of the coconut shell based on a study by Molina-Sabio et al. Ten grams of the coconut shells were used per sample. Soaking time was fixed at 12hours. Activation temperature for biomass at 400, 450, 500˚C were evaluated for this study. Activation times of 10, 20 and 30min were also assessed. A steady supply of nitrogen was provided for the whole activation time to have an inert environment for the activation process. Optimization based on the responses were evaluated. The dependent variables(responses) analyzed were yield, bulk density, average pore diameter, small pore diameter and no. of pores in a unit area were directly measured from scanning electron microscope(SEM) images and determined the optimum conditions for the production of activated carbon from coconut shell.

EmineYagmur et. al. conducted the study on a novel method for production of activated carbon from waste tea by chemical activation with microwave energy. The feedstock was obtained from a tea plant located in Eastern Black Sea region in Turkey. Activated carbons were prepared by phosphoric acid activation with and without microwave treatment and carbonisation of the waste tea under nitrogen atmosphere at various temperatures and different phosphoric acid/precursor impregnation ratios. Pore size distributions obtained from desorption data exhibited nearly the same trend and the average pore sizes were also almost the same for the samples obtained at different conditions. However differential pore volume of each sample was obviously different and the highest for the sample, MW(3:1)350, treated with microwave energy. The microwave treatment process causes considerable changes in the surface morphology and chemical structure of the waste tea.

The study on utilization of date stones for production of activated carbon using phosphoric acid made by N.M. Haimour et. al. The waste date stones have been used for production of activated carbon by chemical activation with phosphoric acid using a fluidizedbed reactor. The effects of the activation time, activation temperature, impregnation ratio, and particle size on the yield and the adsorptive capacity towards iodine were studied. The yield and the quality of the activated carbon prepared by using H_3PO_4 were compared with that prepared from date stones using the same equipment, and under similar conditions by using $ZnCl_2$ as an oxidizing agent. The maximum value of the iodine number of the activated carbon produced using H_3PO_4 in this work was about 495 under the following conditions: impregnation ratio 0.4, activation time 60 min, activation temperature 800 ^{0}C, particle size 0.60 mm. The percentage yield of the activated carbon decreased from 44 to 34 by increasing the impregnation ratio from 0.2 to 1.4 at 400 ^{0}C and increased from 11 to 25 by increasing the impregnation ratio from 0.2 to 1.4 at 800 ^{0}C. The percentage yield decreases by increasing the particle size. This abnormal behaviour could be attributed to the low-porosity and compact cellular structure of date stones and the high viscosity and low diffusion coefficient of concentrated H_3PO_4 through the particles.

Amal S. Al-Rahbi et. al. conducted the research on production of activated carbons from waste tyres for low temperature NO_X control. Shredded passenger car tyres with an average particle size of 1.7 mm were used as the carbon precursor feedstock. The sample consisted of only the rubber component of the waste tyre, with the metal and textile reinforcement already removed. Waste tyres were pyrolyzed in a bench scale reactor and the product chars were chemically activated with alkali chemical agents, KOH, K_2CO_3, NaOH and Na_2CO_3 to produce waste tyre derived activated carbons. The activated carbon products were then examined in terms of their ability to adsorb NOx (NO) at low temperature (25 °C) from a simulated industrial process flue gas.

IV. CONCLUSION

This paper given a review that the production of activated carbon with different feed stocksminimizes the cost of activated carbon production. The abundant supply of different raw materials as waste product from different industries and other resources makes production of activated carbon more financially viable. Thus, future progress in this methods and materials, more work will be needed to be done with advance technology.

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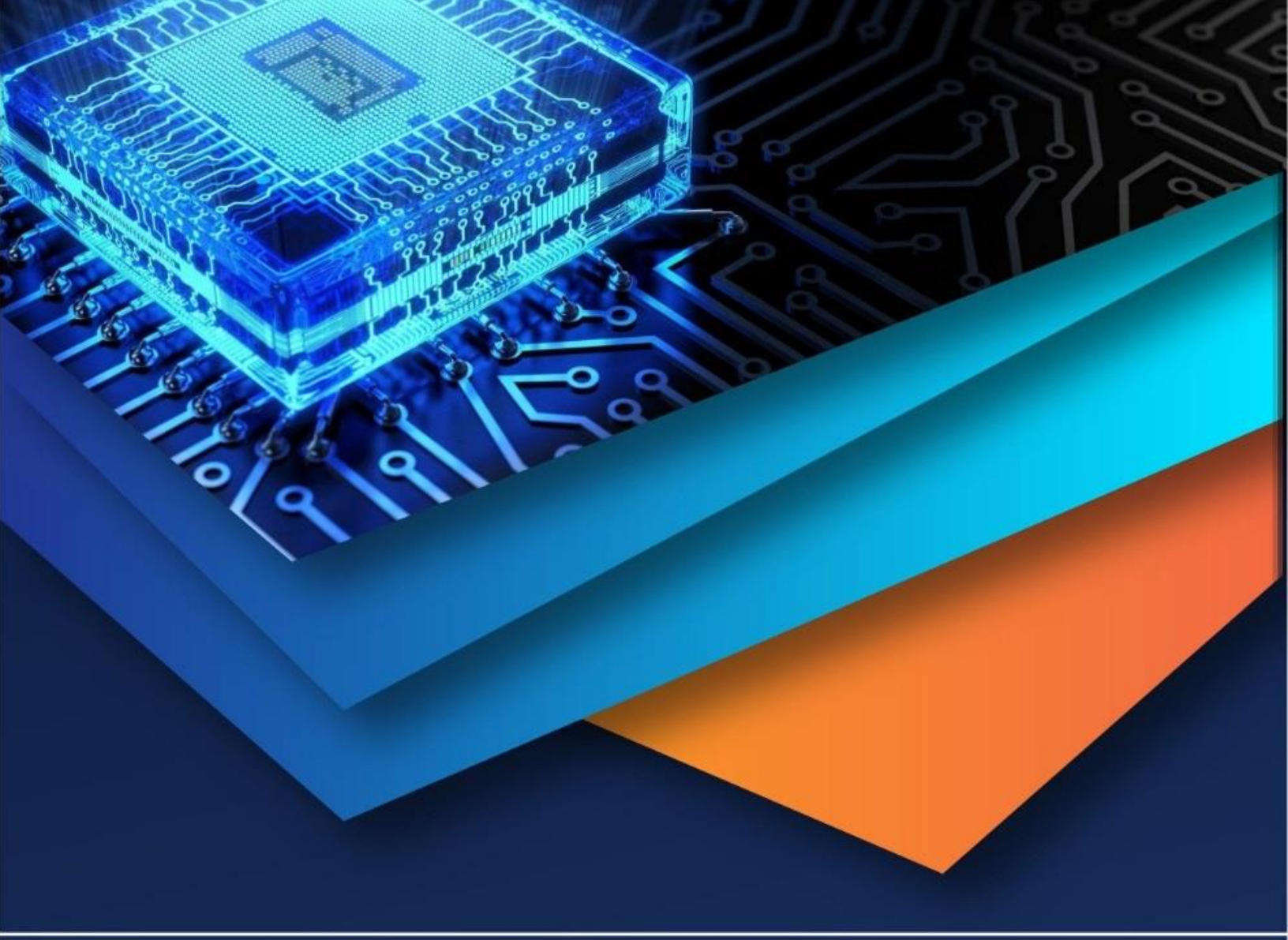

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