International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 06, June - 2017

History, Method of Production, Structure and Applications of Activated Carbon

Sadashiv Bubanale
Department of Mechanical Engineering
Siddaganga Institute of Technology
Tumkur, India

Dr. M. Shivashankar
Department of Mechanical Engineering
Siddaganga Institute of Technology
Tumkur, India

***Abstract*— The process of adsorption is one of the physical method for separation of dissolved pollutants from the effluent. Activated carbon is the good adsorbent that can be used in both liquid and gaseous phase adsorption also used as catalyst or catalyst support. Adsorbent materials are porous and adsorption takes place on the inside walls of pore particles. From last few years, use of activated carbon has increased greatly. This review article purpose is to give the knowledge of how activated carbon uses came from historic days and also then how it is improving day by day. With this it gives the idea of production of activated carbon by different methods. The methods include physical activation and chemical activation. Adsorption capacity of activated carbon mainly depends on the structure of activated carbon.**

***Keywords*— Activated Carbon, Adsorption, Surface area**

I. INTRODUCTION

The carbon element in the carbon material has a unique bonding with itself and other elements. Based on hybridization of carbon atoms, the allotropic forms of carbon are diamond, graphite, and fullerenes [Delhaes 1998]. Major carbons exhibit allotropic form. Based on crystallographic order in third direction, the allotropic form of graphite classified into graphitic and non-graphitic carbons [Franklin 1951]. Non-graphitic carbon is divided into non-graphitizable and graphitizable carbons. By high temperature treatment if non-graphitic carbon converts into graphitic carbon that is called graphitizable carbon.

II. ACTIVATED CARBON

Activated charcoal is a non-graphitic and non-graphitizable carbon having highly disordered microstructure. It has high adsorption capacity because of it high surface area and porosity.

A. Historical background of activated carbon

In olden days (1500 B.C) activated charcoal has been used for medicinal application. Then adsorption of activated carbon was discovered in 1773 by Scheele.

Historical production and use of activated carbon has explained below:

In 18th century

Scheele et al [1773] recognized the adsorptive power of charcoal by the use of adsorption of gases on charcoal surface.

Lowitz et al [1785] studied the use of charcoal in various aqueous solution decolorization. This is the first application of charcoal in liquid phase.

Kehl et al [1793] discovered that the charcoal prepared from the animal tissue can be used in color removal from the aqueous solution.

In 1794 one of the English sugar company used wood derived charcoal for the decolorization of sugar syrup.

In 19th century

Delessert et al [1805] demonstrated use of charcoal for sugar-beet liquor decolorization.

Bussy et al [1822] prepared first activated carbon prepared from combination of physical and chemical activation by heating blood with potash. It has 50 times more effective than bone char.

Stenhouse et al [1856] prepared char by heating flour, tar and magnesium carbonate mixture.

Lipscombe et al [1862] prepared carbon for purification of portable water.

Hunter et al [1865] prepared activated carbon from coconut shell and studied adsorption of gases on it.

Winser et al [1868] prepared activated carbon from paper mill waste and phosphate heating.

In 20th century

Ostrejko et al [1900] developed commercial activated carbon through two processes (a) Use of metal chlorides before carbonization. (b) Using carbon dioxide selective oxidation of charcoal at high temperature.

In 1911 using Ostrejko method first activated carbon produced industrially and marketed with the trade name Epoint for sugar refinery industries as decolorizer.

Wunch et al [1913] studied decolorizing capacity of Epoint was increased when heated with zinc chloride.

In 1914-1918 due to first world war introduction of poisonous gas was affecting respiration in military. For this activated carbon prepared from coconut shell was developed.

Kubelka et al [1931] studied sorption phenomenon on activated carbon by the use of capillary condensation mechanism.

B. Preparation of activated carbon

For the preparation of activated carbon, the raw material used are biomass, forestry and agricultural residue. The precursor used must be rich in carbon content for the preparation of activated carbon [Prahas et al 2008]. Activated carbon can be produced through two processes (1) Physical activation (2) Chemical activation [Bansal et al 1988].

1) Physical activation:

It involves two steps in physical activation. First step is to carbonization of raw material, second step is to activation of carbonized charcoal at high temperature in the presence of oxidation agent steam, carbon dioxide and air. Carbonization takes place in the range of 400-800℃, and temperature of activation ranges from 800-1000℃. Physical activating agent and raw material used in production of activated carbon is listed in table-1.

Table-1: Physical activating agent with raw materials used in production of activated carbon.

Activating agent	Material	Source
Air	Olive tree wood, Almond tree pruning	Ould-Idriss et al 2011, Ganan et al 2006, Aworn et al 2009,
CO_2	Corncob, Coconut shells, Sawdust, rice husk,	Gue atal 2009, Prakash kumar et al 2006, Zhang et al 2011
Steam		

2) Chemical activation

Preparation of activated carbon from chemical method requires only one step, both carbonization and activation takes place in single step only. The precursor is mixed with the chemical agent and kept for activation at high temperature. The chemical agent acts as an oxidant and dehydrating agent. Chemical activation has more advantageous than physical activation that include (1) Single activation step (2) Lower activation temperature < 800℃. (3) Shorter activation times (4) Higher yield (5) Good porous characteristics [Nowicki et al 2006]. The most used chemical agent for activation are KOH, K_2CO_3, $ZnCl_2$, H_3PO_4. Chemical activating agent and raw material used in production of activated carbon is listed in table-2.

Table-2: Chemical activating agent with raw materials used in production of activated carbon.

Activating agent	Material	Source
KOH	Olive seed, petroleum coke, Rice straw,	Stavropoulos and Zabaniotou 2005, Kawano et al 2008, Basta et al 2009.
K_2CO_3	cotton stalk, walnut shell.	Deng et al 2010, Hayashi et al 2002.
$ZnCl_2$	Tamarind wood, nut shell, coconut shell,	Acharya et al 2009, Ahmadpur and do 1997, Azevedo et al 2007,
H_3PO_4	Cotton stalk, date pits	Deng et al 2010, Girgis et al 2002,

C. Structure of Activated Carbon

Adsorption capacity of activated carbon mainly depends on the structure of activated carbon

1) Porous structure Activated Carbon

The higher adsorption capacity of activated carbon mainly depends on the porous characteristics such as pore volume, pore size distribution, and surface area. Activated carbon contains up to 15% of ash content in the form of mineral matter (Bansal et al 1988). Porous structure of activated carbo forms during the carbonization and further develops during activation. All activated carbons have porous structure. The pore system of activated carbon are different types and individual pore may vary in both size and shape. Activated carbons are having pores from less than nanometer to thousand nanometers. Pores are classified on their average width. Average width is the distance between the walls of slit shaped pore or the radius of a cylindrical pore. Conventional classification is proposed by (Dubinin et al 1960) and it is officially adopted by International Union of Pure and Applied Chemistry (IUPAC). The typical pore size distribution is shown in figure-1.

Table-3: Classification of pore

Type of Pore	Width
Micro	<2 nm
Meso	2-50 nm
Macro	>50 nm

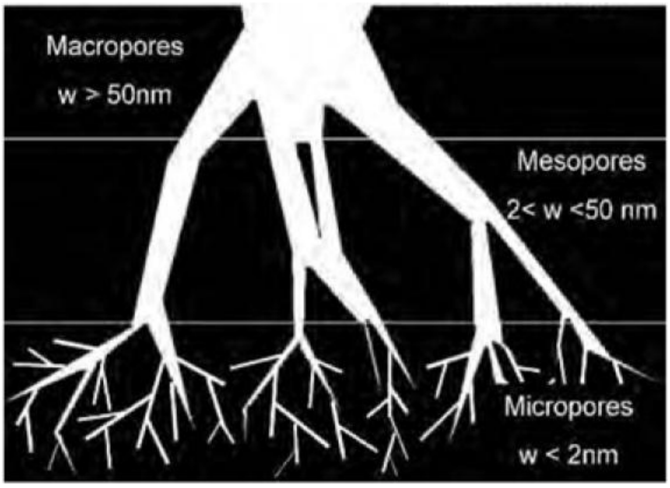

Figure-1: Graphical representation of pore structure on activated carbon

2) Crystalline structure

During carbonization, microcrystalline structure of activated carbo develops. Activated carbon structure is different from that of graphite with respect to the interlayer spacing. In graphite interlayer spacing is 0.335 nm and in activated carbon is 0.34 to 0.35 nm. Activated carbons are classified into two types, based on graphitizing ability, these are graphitizing and non-graphitizing carbons. In graphitizing carbon, it contains number of graphene layers oriented parallel to each other. The carbon obtained was delicate due to the weak cross linking between the neighbor micro-crystallites and had a less developed porous structure. The non-graphitizing carbons are hard due to strong cross linking between crystallites show well developed micro pores structure (Franklin 1951, Jenkins and kawamura 1976). The formation of non-graphitizing structure with strong cross-links is promoted by the presence of associated oxygen or by an insufficiency of hydrogen in the original raw material. The schematic representations of the structures of graphitizing and non-graphitizing carbons are shown in figure-2.

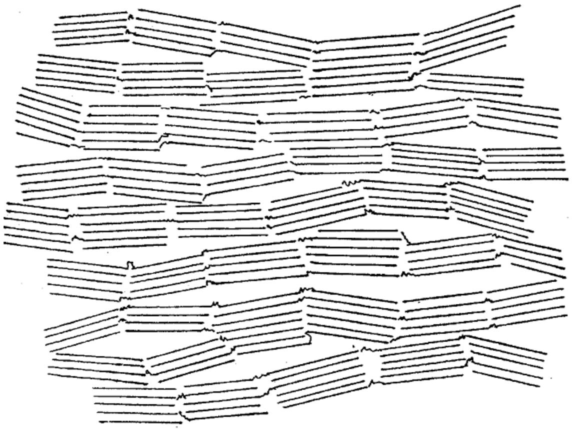

Figure-2 (a) Graphitized carbon

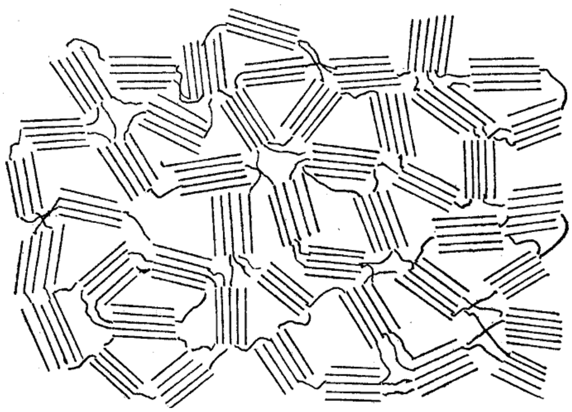

Figure-2 (b) Non-graphitized carbon

3) Chemical structure

Activated carbon has porous and crystalline structure, with this it also has chemical structure. Though the adsorption capacity of activated carbon is determined by its porous structure but is strongly influenced by a relatively small amount of chemically bonded heteroatoms (mainly oxygen and hydrogen) (Bansal et al., 1988). The variation in the arrangement of electron clouds in the carbon skeleton results in the creation of unpaired electrons and incompletely saturated valences which influences the adsorption properties of active carbons, mainly for polar compounds.

D) Applications of Activated Carbon

- In automobile canister helps to control the gasoline vapor emission.
- It is used as air cleaning filters.
- To adsorb the harmful components of tobacco in cigarette filters impregnated graded activated carbon is used.
- It is also used as catalyst or catalyst support
- In water treatment to remove the mercury, cadmium and lead metal ions.
- In aqueous solution for removing poisonous heavy metal ions.

REFERENCES

[1] Acharya, J., Sahu, J.N., Mohanty, C.R., Meikap, B.C. Removal of lead (II) from wastewater by activated carbon developed from tamarind wood by zinc chloride activation. Chemical Engineering Journal, 149, 2009, 249-262

[2] Aworn, A., Thiravetyan, P., Nakbanpote, W. Preparation of CO_2 activated carbon from corncob for methylene glycol adsorption. Colloids and Surfaces A: Physicochemical Engineering Aspects, 333, 2009, 19-25.

[3] Ahmadpour, A., Do, D. The preparation of activated carbon from macadamia nutshell by chemical activation. Carbon, 35, 1997, 1723-1732

[4] Azevedo., D.C.S., Araujo, J.C.S., Bastos-Neto, M., Torres, A.E.B., Jaguaribe, E.F., Cavalcante, C.L. Microporous activated carbon prepared from coconut shells using chemical activation with zinc chloride. Microporous and Mesoporous Materials, 100, 2007, 361-364.

[5] Bansal, R.C., Donnet, J.B., Stoeckli, H.F. Active carbon. Marcel Dekker, 1988, New York.

[6] Basta, A.H., Fierro, V., El-Saied, H., Celzard, A. 2-steps KOH activation of rice straw: An efficient method for preparing high-performance activated carbons. Bioresource Technology, 100, 2009, 3941-3947

[7] Betancur, M., Martinez, J.D., Murillo, R. Production of activated carbon by waste tire thermochemical degradation with CO_2. Journal of Hazardous Materials, 168, 2009, 882-887.

[8] Delhaes, P. Design and control of structure of activated carbon materials for enhanced performance, Rand, B., Appleyard, S.P., Yardim, M.F. (Eds.), NATO Science Series, Series E; Applied Sciences, Kluwer Academic Publishers, 347, 1998, 3-27, The Netherlands.

[9] Deng, H., Zhang, G., Xu, X., Tao, G., Dai, J. Optimization of preparation of activated carbonfrom cotton stalk by microwave assisted phosphoric acid – chemical activation. Journal of Hazardous Materials, 182, 2010, 217-224.

[10] Dubinin, M.M., The potential theory of adsorption of gases and vapors for adsorbents with energetically nonuniform surfaces. Chemical Reviews, 60 (2), 1960.

[11] Ganan, J., Gonzalez, J.F., Gonzalez-Garcia, C.M., Ramiro, A., Sabio, E., Roman, S. Airactivated carbons from almond tree pruning: Preparation and characterization. Applied Surface Science, 252, 2006, 5988-5992.

[12] Girgis, B.S., EI-Hendawy, A.N.A. Porosity development in activated carbons obtained from date pits under chemical activation with phosphoric acid. Microporous and Mesoporous Materials, 52, 2002, 105-117.

[13] Guo, S., Peng, J., Li, W., Yang, K., Zhang, L., Zhang, S., Xia, H. Effects of CO_2 activation on porous structures of coconut shell-based activated carbons. Applied Surface Science, 255, 2009, 8443-8449.

[14] Hayashi, J., Horikawa, T., Takeda, I., Muroyama, K., Ani, F.N. Preparing activated carbon from various nutshells by chemical activation with K_2CO_3. Carbon, 40, 2002, 2381-2386.

[15] Kawano, T., Kubota, M., Onyango, M.S., Watanabe, F., Matsuda, H. Preparation of activated carbon from petroleum coke by KOH chemical activation for adsorption heat pump. Applied Thermal Engineering, 28, 2008, 865-871.

[16] Nowicki, P., Pietrzak, R., Wachowska, H. Siberian anthracite as a precursor material for microporous activated carbons. Fuel, 87, 2008, 2037-2040.

[17] Ould-Idriss, A., Stitou, M., Cuerda-Correa, E.M., Fernandez-Gonzalez, C., Marcias-Garcia, A., Alexandre-Franco, M.F., Gomez-Serrano, V. Preparation of activated carbons from olive-tree wood revisited. II. Physical activation with air. Fuel Processing Technology, 92, 2011, 266- 270.

[18] Prahas, D., Kartika, Y., Indraswati, N., Ismadji, S. Activated carbon from jackfruit peel waste by H3PO4 chemical activation: Pore structure and surface chemistry characterization. Chemical Engineering Journal, 140, 2008, 32-42

[19] Prakash Kumar, B.G., Shivakamy, K., Miranda, L.R., Velan, M. Preparation of steam activated carbon from rubberwood sawdust (*Hevea brasiliensis*) and its adsorption kinetics. Journal of Hazardous Materials B, 136, 2006, 922-929.

[20] Ramakrishna Gottipati, Preparation and Characterization of Microporous Activated Carbon from Biomass and its Application in the Removal of Chromium(VI) from Aqueous Phase, 2012, 1-242

[21] Stavropoulos, G.G., Zabaniotou, A.A. Production and characterization of activated carbons from olive-seed waste residue. Microporous and Mesoporous Materials, 82, 2005, 79-85.

[22] Zhang, J., Fu, H., Lu, X., Tang, J., Xu, X. Removal of Cu(II) from aqueous solution using the rice husk carbons prepared by the physical activation process. Biomass and Bioenergy, 35, 2011, 464-472.