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

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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 allotrope forms of carbon are diamond, graphite, and fullerenes [Delhaes 1998]. Major carbons exhibit allotrope form. Based on crystallographic order in third direction, the allotrope 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 its 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.

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

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

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


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°C, and temperature of activation ranges from 800-1000°C. Physical activating agent and raw material used in production of activated carbon is listed in table-1.

<table>
<thead>
<tr>
<th>Activating agent</th>
<th>Material</th>
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</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steam</td>
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</tbody>
</table>

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 advantages than physical activation that include (1) Single activation step (2) Lower activation temperature < 800°C (3) Shorter activation times (4) Higher yield (5) Good porous characteristics [Nowicki et al 2006]. The most used chemical agent for activation are KOH, K₂CO₃, ZnCl₂, H₃PO₄. Chemical activating agent and raw material used in production of activated carbon is listed in table-2.

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</tr>
<tr>
<td>H₃PO₄</td>
<td>Cotton stalk, date pits</td>
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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 carbon 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-1: Physical activating agent with raw materials used in production of activated carbon.

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

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

3) Crystalline structure
During carbonization, microcrystalline structure of activated carbon 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 microcrystallites 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.
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


