Research Group

InfoMine

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into geology, mineral resources, mining and metal industry

# Activated Carbon
# Market Research in the CIS

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## Introduction

Activated carbon is a carbonaceous adsorbent with a high internal porosity, and hence a large internal surface area. Commercial activated carbon grades have an internal surface area of 500 up to 1500 $m^2/g$ and a large pore volume of more than 30 $cm^3/100$ g.

. Related to the type of application, two major product groups exist: powdered activated carbon, particle size 1-150 micron; granular activated carbon (granulated or extruded), particle size in the 0.5-4 mm range.

The process of activated carbon generation allows using various raw carbon sources, which are selected based on design specifications since different raw sources will produce activated carbon with different properties. Some of the more common raw sources include wood, sawdust, lignite, peat, coal, coconut shells, and petroleum residues.

Steam activation and chemical activation are the two commonly used processes for the manufacture of activated carbon. Removing tars with creation branched pore system forms high-developed surface providing unique sorption properties of activated carbon.

A proper activated carbon has a number of unique characteristics: a large internal surface area, dedicated (surface) chemical properties and good accessibility of internal pores.

Unique absorption properties owe the widest range of applications of activated carbon, including decolourisation of sugar and sweeteners, drinking water treatment, gold recovery, production of pharmaceuticals and fine chemicals, catalytic processes, off gas treatment of waste incinerators, automotive vapour filters, colour/odour correction in wines and fruit juices, additive in liquorice, etc. etc.

In its numerous applications, activated carbon represents a number of different functionalities:

Adsorption: the most well-known mechanism, through physical adsorption (Van der Waals forces) or chemisorption.

Reduction: e.g. removal of chlorine from water is based on chemical reduction reactions.

Catalysis: activated carbon can catalyse a number of chemical conversions, or can be a carrier of catalytic agents (e.g. precious metals).

Carrier of biomass: support material in biological filters.

Carrier of chemicals: e.g. slow release applications colourant: activated carbon's function in liquorice is its colour.

## 1. Technology of production of activated carbon, its properties and resources used

The main raw carbon sources for production of activated carbons in Russia are raw charcoal, peat, black (stone) coal. In Table 1, the sources for production of activated carbon at Russian enterprises and grades of the product are presented.

**Table 1. Resources for production of activated carbon of various grades**

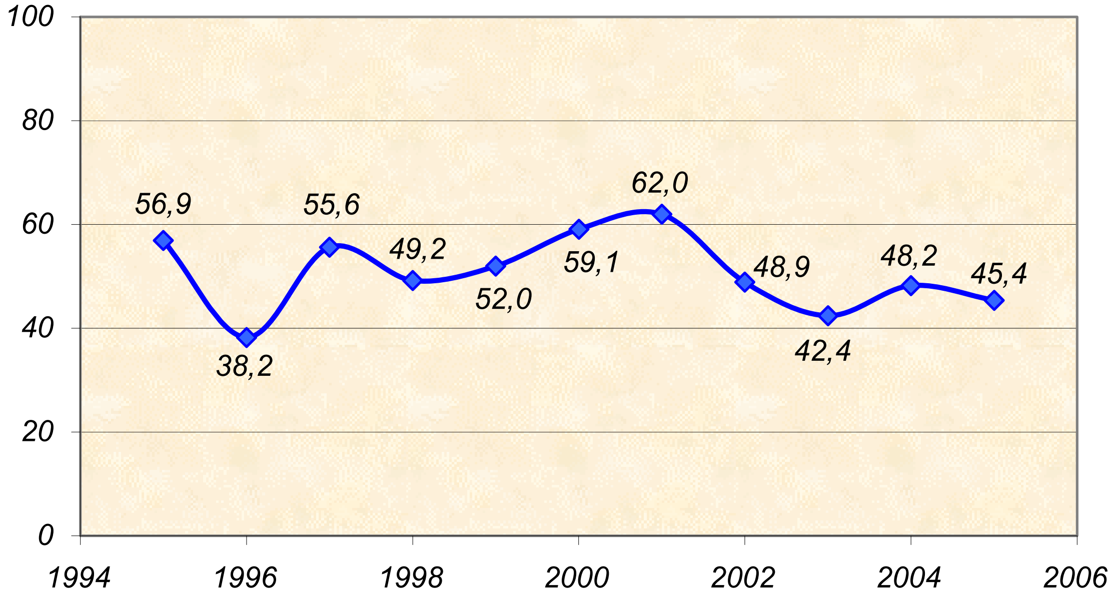
| *Company* | *Resources* | *Grade* |
|---|---|---|
| JSC «Sorbent» (Perm') | raw charcoal | BAU-A, DAK, DUB-1, OU-A, OU-B, OU-V, OU-G, ADU-V, AUP, AU-E, BAU-MF, SPKD-27D |
| | black coal | AR, AG-2, AG-3, AG-3-MVK, AG-3-KP, AG-5, AGM, SKD-515, SKDS -515, AG-OV, AG3-1, AGS-4, AGN, ARD-2, UAF |
| JSC «Zarya» (Nizhny Novgorod region, Dzerzhinsk) | black coal | AG-3, AG-90, AG-8S, UAF, UAM |
| JSC «Electrostal' chemical-mechanical plant» (Moscow region, Electrostal') | raw charcoal peat | BAU, OU-A, SKT, SKT-2, SKT-3, SKT-3S, SKT-3U, SKT-4, SKT-6A, SKT-7, SKT-10, SKT-0, OPATU, FAS, FAS-E |
| JSC «Carbochem» (Nizhny Novgorod region, Syava) | raw charcoal | BAU-A, BAU-Ats, BAU-MF, DAK, OU-A, OU-B, OU-V |
| LLC PKF «Carbon» (Kirov) | raw charcoal | BAU-A, BAU-MF, AUP |
| JSC «Amzinsky timber processing plant» (The Republic of Bashkortostan, Neftekamsk) | raw charcoal | BAU-A, OU-A |
| LLC «Priladozhsky sorbent plant» (The Republic of Karelia, Lakhdenpokh'ya) | raw charcoal | BAU-A, DAK, BAU-MF, OU-V |
| PJSC «Carbonika-F» (Krasnoyarsk) | black coal | ABG |

*Source: data of the companies, «InfoMine»*

The main sources are presented by charcoal, obtained from wood (mainly birch) by slow heating of the source in anaerobic conditions (in retorts or charcoal kilns. A feature of charcoal is low content of phosphorus and sulfur.

Production of charcoal in the latest 4 years ranged 40–50 kt, whereas in 2001 it exceeded 60 kt (Fig. 1). The decline was owed by decreasing demand for charcoal from manufacturers of activated carbon.

**Figure 1. Dynamics of production of charcoal in Russia in 1995–2005, kt**




*Source: Rosstat*

The main suppliers of charcoal the main at Russian market are enterprises from Nizhny Novgorod, Sverdlovsk, Kirov, Chelyabinsk regions and Bashkortostan (Table 2).

**Table 2. Production of charcoal in Russia in 1998–2005, kt**

| *Company* | *Region* | *1998* | *1999* | *2000* | *2001* | *2002* | *2003* | *2004* | *2005* |
|---|---|---|---|---|---|---|---|---|---|
| PJSC «Verkhnesinyachikhinsky wood-chemical plant» | Sverdlovsk region | 14.2 | 12.0 | 14.9 | 14.9 | 14.9 | 15.3 | 16.5 | 16.7* |
| JSC «Amzinsky timber processing plant» | The Republic of Bashkortostan | 10.3 | 10.7 | 11.5 | 11.5 | 11.4 | 11.4 | 11.9 | 9.1 |
| JSC «Molomsky wood-chemical plant» | Kirov region | 1.2 | 0.9 | 4.2 | 5.7 | 7.2 | 5.7 | 8.7 | 9.0* |
| LLC «Timber yard-1» (former JSC «Serovsky timber yard») | Sverdlovsk region | 5.8 | 8.7 | 9.6 | 9.5 | 3.2 | 4.4 | 2.7 | 3.0* |
| JSC «Sorbent» | Perm region | 1.2 | 1.5 | 2.7 | 3.2 | 3.3 | 2.3 | 0.4 | 1.4* |
| JSC «Carbochem» | Nizhny Novgorod region | 1.8 | 1.5 | 1.4 | 1.4 | 0.1 | 0.3* | 0.8 | 1.0* |
| JSC «Asha chemical plant» | Chelyabinsk region | 7.9 | 8.0 | 8.2 | 8.0 | 0.4 | – | – | – |
| *Other* | | *6.8* | *8.7* | *6.6* | *7.8* | *8.4* | *3.0* | *7.2* | *5.2* |
| ***Total*** | | ***49.2*** | ***52.0*** | ***59.1*** | ***62.0*** | ***48.9*** | ***42.4*** | ***48.2*** | ***45.4*** |

** - estimate of «InfoMine»*
*Source: Rosstat*

Typical flow sheet of activated carbon production from ***chacoal*** in Russia includes: drying resources, pyrolysis, steam activation, sieving with selection of fraction 1.0–3.6 mm (activated carbon DAK, BAU); milling the obtained product (activated carbon OU-A, OU-B), packing finished products (Fig. 2).

Initially the resources are subjected to ***carbonization***: an anaerobic heating process, whereby the raw material is subjected to a high temperature heating process between 300-500 °C in inert atmosphere, whereby volatiles are removed during the process. The carbon content is enriched, an initial porosity and some ordering in the carbon structure is formed.

Following ***activation*** process enhances the carbon structure to make the carbon more porous. The carbon is subjected to higher temperature, between 850-950 °C (in rotary kilns), and steam treatment (or rarely chemical treatment – by hydrochloric acid etc.). The activation of the carbon gives it the unique adsorption characteristics. The activation of the carbon creates carbon which is highly porous providing a large surface area of the carbon for adsorption.

Commercial activated carbon grades have an internal surface area of 500 up to 1500 m2/g. Related to the type of application, two major product groups exist:

Powdered activated carbon; particle size 1-150 micron, and granular activated carbon (granulated or extruded), particle size in the 0.5-4 mm range.

A proper activated carbon has a number of unique characteristics: a large internal surface area, dedicated (surface) chemical properties and good accessibility of internal pores. According to IUPAC definitions three groups of pores are distinguished:

Macropores (above 50 nm diameter);

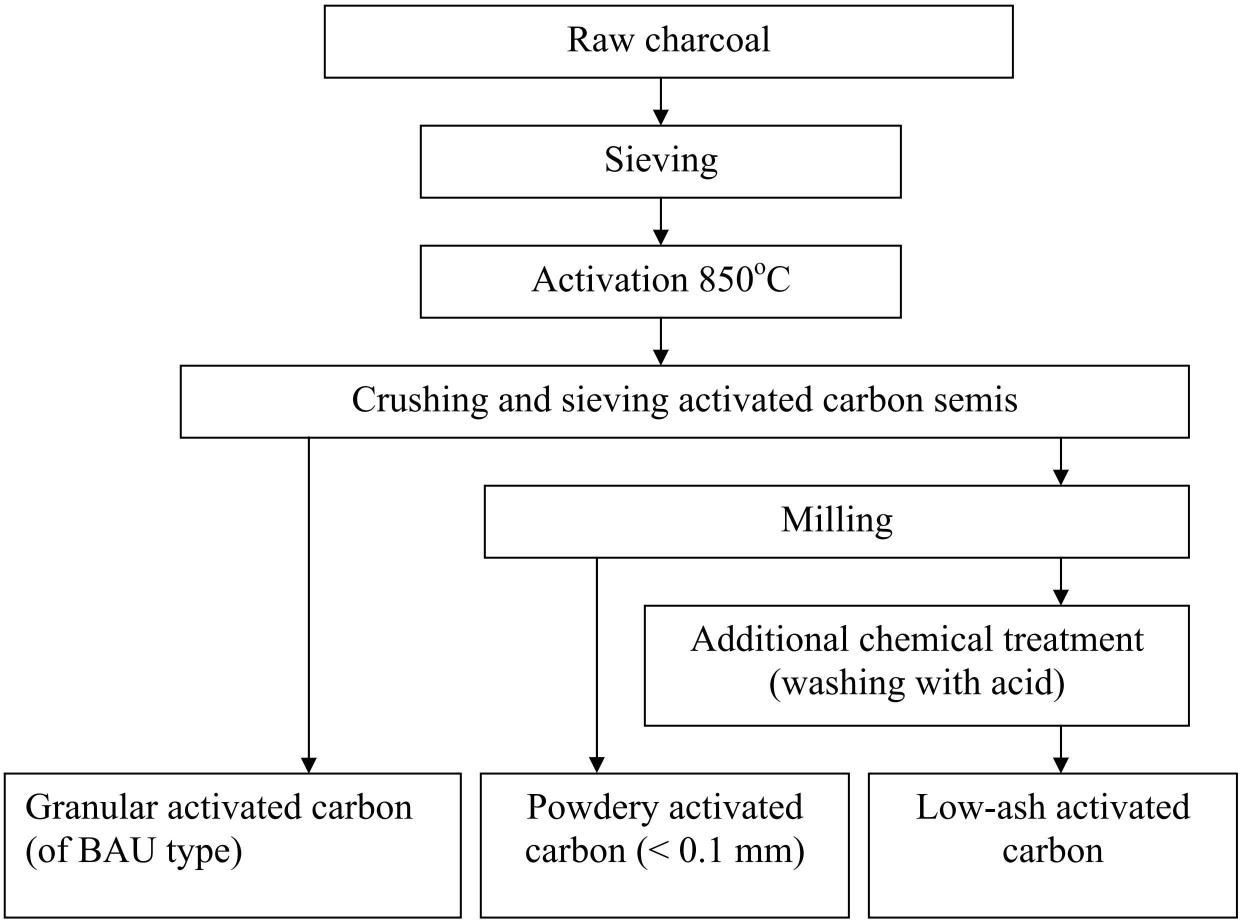
Mesopores (2-50 nm diameter);

Micropores (0.4-2 nm diameter);

Submicropores (under 0.4 nm diameter).

Micropores and mesopores generally contribute to the major part of the internal surface area. Macro- and mesopores can generally be regarded as the highways into the carbon particle, and are crucial for kinetics. Macropores can be visualised using Scanning Electron Microscopy (SEM). The pore size distribution is highly important for the practical application; the best fit depends on the compounds of interest, the matrix (gas, liquid) and treatment conditions. The desired pore structure of an activated carbon product is attained by combining the right raw material and activation conditions. For instance, black coal-based activated carbons are characterized by large share of mesopores, whereas charcoal-based activated carbons have large share of macropores.

**Figure 2. Flow process of manufacturing of activated carbons on the basis of raw charcoal**

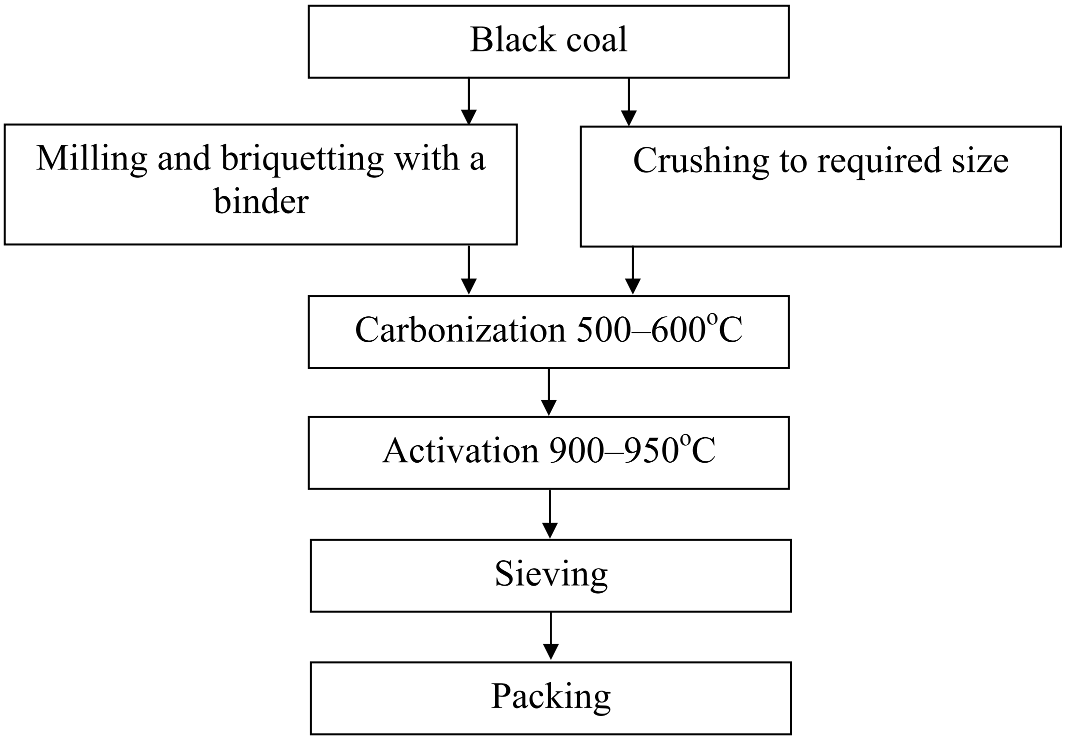



*Source: data of MTK «Sorbent»*

Production of activated carbon from ***black coal*** has some features, because grade of the coal should be taken into account here. Bituminous coals with high content of tars and volatile components are caked or swollen when heating and require so preliminary treating. Antracite contains much lesser volatile components and can be activated without preliminary treating. It is initially milled, the milled powder is briquetted with a binder, then milled again, sieved into fraction and subjected to carbonization and activation. Besides, products of various stags of coke production can also be subjected to activation.

Flow process of manufacturing black coal-based activated carbons is presented in Fig. 3.

**Figure 3. Flow process of manufacturing of black coal-based activated carbons**




*Source: data of MTK «Sorbent»*

For obtaining activated carbon from ***peat***, the best raw material is high-carbon black peat. Owing to high content of volatile components, black peat is subjectee to carbonization before activation with gases. At chemical activation, the process is conducted directly after drying peat.