Calgon Carbon Corporation IB-1016-10/93

Information Bulletin

SIX CRITERIA FOR COAL-BASED CARBON

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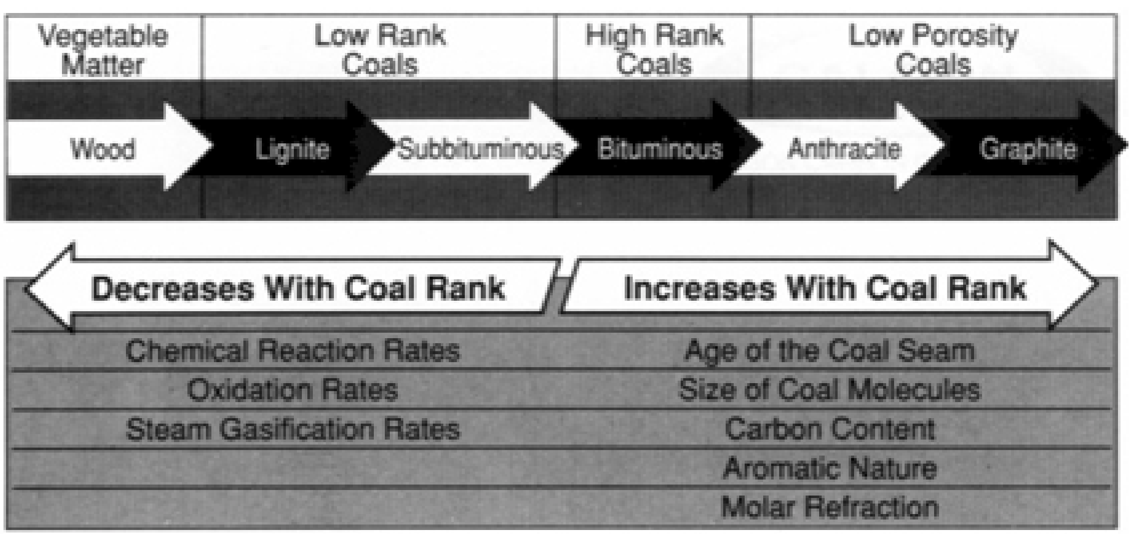
They help you use this medium to its max.

Because de-chlorinating filters may use a different activated carbon than those which remove volatile organic compounds (VOCs), knowing the difference between activated carbons helps you match the product to the job.
Almost any carbonaceous material can be converted into activated carbon if quality isn't a concern. Activated carbon's water treatment performance, however, is strongly influenced by the starting material. This is even true among carbons made from outwardly similar coals. Coal is a commonly-used raw material for activated carbon, but not two coal seams are alike; there are thousands of distinguishable coals in the U.S. alone. The simplest way to differentiate between them is by "coal rank," which indicates to what extent vegetable matter has been converted toward a graphite-like state by the process of "coalification" (see Figure 1).

Activated carbon's skeleton is composed of plates of graphitic carbon created from the starting material. This is generally done at temperatures above 750^{o}C in an inert atmosphere. In these conditions, coal molecules are either stripped out of the structure through volatilization, or they're recombined to form graphite plates. These plates tend to be small and imperfect. Their size and degree of imperfection is related to the chemical building blocks provided by the starting material. The effects of heat and chemical rearrangement during activation are also determined by source materials.

Starting materials define the size and shape of an activated carbon's graphite skeletal plates; the number of non-graphitic imperfections in a carbon; the carbon's rigidity (based on number of interconnections between graphite plates); the spacing, angle and size of gaps between neighboring plates; and the degree of the carbon's structural order. To illustrate what effect starting material has on activated carbon, compare carbons made from wood and coal. The wood-base product has smaller diameter plates with more imperfections per weight of carbon. It also has larger gaps, wider spacing and larger angles between plates.

The adsorption pore structure is determined by the voids between the plates. These influence the relationship between adsorbate concentration and adsorption capacity. The nature of adsorption pores and transport pores also defines adsorption kinetics and rates.



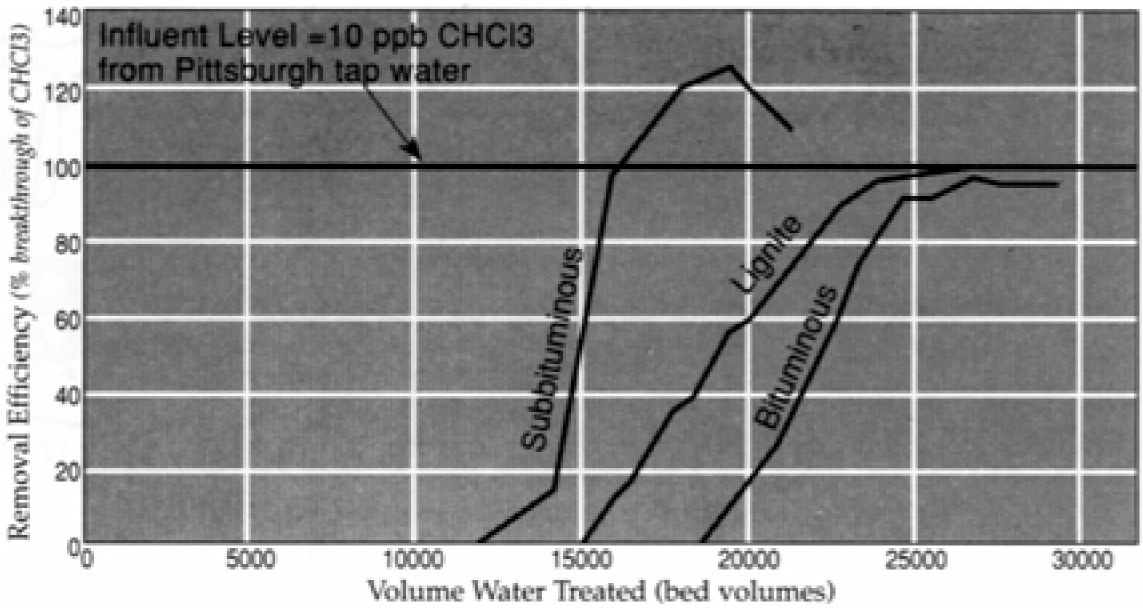
Inherited Properties

Starting Material Defines Carbon's:

- **Maximum Possible Density** During activation, product density is reduced as carbon atoms are removed from the carbon skeleton. As activation time increases, more carbon atoms are removed, making the product more porous and structurally weaker than the starting material. Low density starting materials produce lower density activated carbon with inherent hardness, abrasion-resistance and dustiness.
- **Transport Pore Properties** for mid-sized transport pores. Because activation has little effect on them, mid-sized transport pores retain the structure they had in the starting material. As a result, non-porous starting materials like a high-ranking anthracite coal produce few transport pores in activated carbon.
- **Inorganic Impurity Levels** High-ash coals produce high-ash activated carbons. Ash can be toxic, can change pH or leach soluble salts into water. Leaching characteristics depend on both ash level and the ash constituents.

VOC Performance of Coal-Based Carbons

Starting material has an effect on coal-based carbon's ability to reduce levels of Volatile Organic Compounds (VOCs) in water.



Picking a Carbon

Based on the inherent differences in coal and activated carbon types, some generalizations can be made about activated carbon products for home water treatment. It's generally better to use carbons with these six traits:

- ***High Apparent Density*** These carbons can be backwashed at higher water velocities without loss of carbon through the overflow. The required backwash rate is dictated by the size and density of the material to be removed. A fine, low density floc requires only a low flow rate, but a higher density, large precipitate may require a high backwash rate. Higher density carbons provide better opportunity to use the backwash for density separation with the contaminant on top of the bed.
  Additionally, during de-chlorinating, each hypochlorous acid molecule removes one carbon atom from the carbon structure and weakens the carbon granules. Denser carbons have more carbon atoms per particle and thus maintain structural integrity after de-chlorinating. Bituminous products have the greatest density and are more durable.
- ***Greater Hardness/Abrasion Resistance*** Harder and more abrasion-resistant products produce fewer fines during backwashing or reactivation. Fewer fines reduce carbon loss and carbon dust in product water.
- ***Greater Total Adsorption Pore Volume*** Higher total adsorption pore volume means better adsorption capacity in high-concentration streams.

- ***Stronger Average Adsorption Force***. Stronger adsorption forces translate to better trace removal capacity and less sensitivity to concentration changes.
- ***Faster Adsorption Rates*** Fast-adsorbing carbons usually have a better pore structure to allow mass transfer of the adsorbate to the adsorption pore. This cuts necessary contact times and enables you to use smaller beds or higher flow rates with only a small reduction in carbon efficiency. In well-designed, long contact-time adsorbers, this usually isn't a concern.
- ***More Chemically-Reactive Properties***. These carbons de-chlorinate in a smaller bed or at higher flow rates. For hypochlorous acid, however, the reaction rates with carbon are fast enough that most commercial carbons have more than adequate kinetics and minimum bed depth requirements.

Different activated carbons lend themselves to different applications. For VOC removal from potable or ground water, carbon should have maximum adsorption capacity in the trace region. Bituminous coal-base carbons are preferred because of the stronger average adsorption force and trace removal capacities, presumably due to their larger graphite plate size.

For backwashing systems, bituminous-coal based carbons are also preferred because of their higher density and better abrasion/hardness resistance.

All carbon work well for de-chlorinating. For typical home water filters, the slowest activated carbons are fast enough. The carbon should have a small enough graphite plate size or enough reactive sites to de-chlorinate in a reasonable amount of time. If contact time is a problem, a reduction in particle size should suffice; changing carbon starting materials is usually unnecessary.

by Dr. Mick Greenbank and Steve Spotts

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