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WATER TECHNOLOGY

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Fundamentals of Catalytic Activated Carbons

They work faster, last longer

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Catalysts in water treatment speed chemical reactions so equipment can be scaled down or contact times shortened. Because the speed of a reaction can affect equipment price or useful life, it could mean the difference between a sale and a "no, thanks."

Thus, recently developed catalytic activated carbons may enable water treatment dealers to take advantage of activated carbon's properties for applications previously deemed too costly for carbon, such as removing chloramine or hydrogen sulfide from drinking water.

Catalysts Count

Activated carbon has traditionally been used for its adsorptive properties, so most considerations regarding its functionality involve its surface area and pore structure. Yet carbon's electrochemical nature can also promote chemical reactions.

These catalytic properties have been reported to exist to varying degrees in most activated carbons. With catalytic carbons, however, they're controlled and enhanced for certain adsorbates without catalytically active impregnants.

Carbon's catalytic properties are measured by the rate at which carbon decomposes hydrogen peroxide. The resulting "Peroxide Number" (PN), measured in minutes, estimates the carbon's utility in a variety of applications. Lower PNs mean higher catalytic activity.

Catalytic carbons usually have a PN of less than 20 minutes, about half that of some conventional bituminous coal-based products and considerably less than most coconut- or wood-based products (see Table 1).

It's likely catalytic activity is intrinsic to carbon's structure. Although catalysis can be inhibited by the presence of adsorbed or chemisorbed materials, these adsorbates can usually be removed by extraction or thermal procedures to restore most of the carbon's catalytic activity.

Sites on a catalyst carbon function similarly to the metal impregnants that enhance the catalytic properties of conventional carbons, but they eliminate the potential liabilities of these impregnants including toxicity, thermal instability, inability to be regenerated and disposal limitations.

Catalytic carbons can catalyze a wide variety of chemical reactions. Of these, oxidation/reduction (redox) reactions are most significant. Conventional carbon can also catalyze certain reactions, but results have been inconsistent because of inconsistencies in materials and a lack of understanding of catalysis.

While some conventional carbons exhibit catalytic activity, carbons specifically produced to have catalytic properties widen the range of reactive conditions and enhance reaction efficiency or selectivity. In fact, use of these carbons may produce any combination of these effects.

Table 1

Comparing Carbons as Catalysts	
CARBON	PEROXIDE NUMBER
Catalytic Bituminous Coal-Based	10
Conventional Bituminous Coal-Based	40
Subbituminous Coal-Based	40
Lignite Coal-Based	60
Wood-Based	>120
Coconut-Based	>120

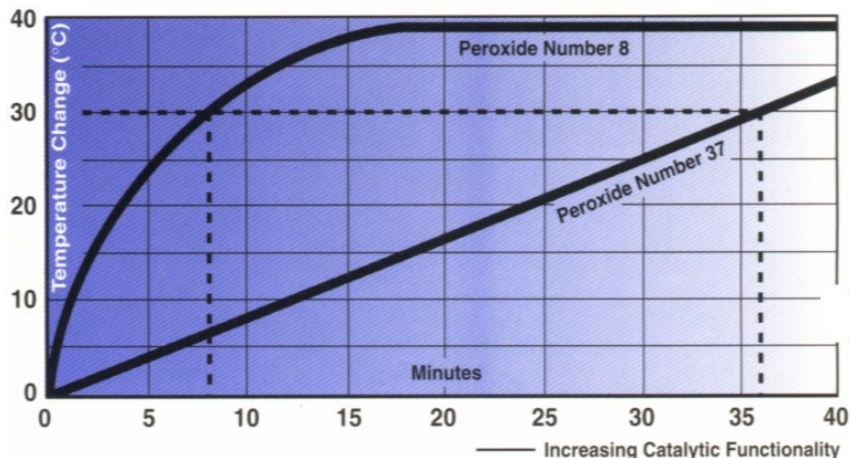
When applying catalytic carbons, consider:

- **Redox reactions.** These probably constitute the largest category of potential reactions speeded by catalytic carbon, especially where oxygen is the principal oxidant. One reason for the enhanced redox performance of catalytic carbon may be that oxygen is transformed at some catalyst sites into highly reactive oxy- or hydroxy-radical anions.

Where oxygen is limited, the efficient reaction of each available oxygen molecule can be crucial to reaction kinetics. In these cases, the principal mechanism of catalysis may be reactant concentration within the carbon pore space before the chemical reaction takes place.

Graphing Catalysts in Carbons

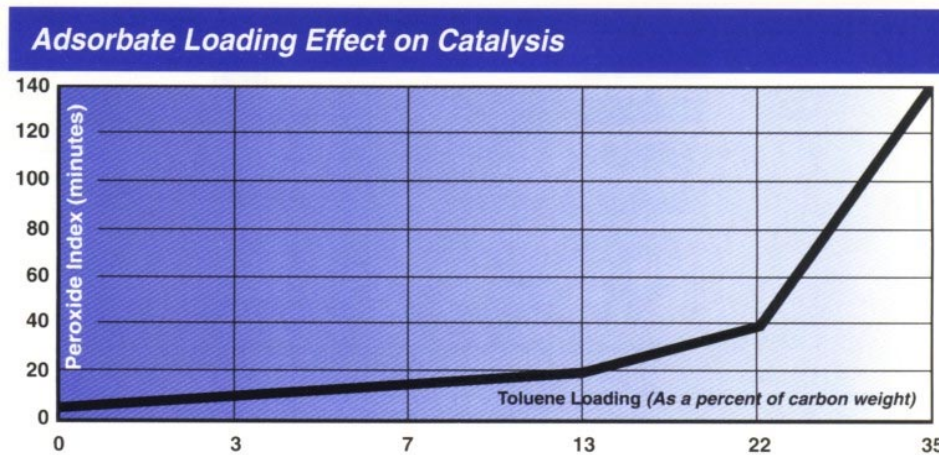
Temperature rise over time induced by the catalytic removal of hydrogen peroxide for two different catalytic carbons is illustrated. Dotted lines indicate the point at which 75 percent of the temperature rise is reached, which is also the point where 75 percent hydrogen peroxide is removed. The corresponding time is the "Peroxide Number" in minutes.



- **Adsorbate loading.** Reaction by-products may affect the choice of materials used in an application and the

ability to regenerate or reactivate catalytic carbons. Reaction by-products may eventually occlude the catalyst sites so the carbon must be regenerated, reactivated or replaced with virgin catalytic carbon.

Non-reactive adsorbates in the influent may eventually produce similar results regardless of the nature of catalysis, but adsorbate loadings of up to 10 percent of the weight of the carbon don't significantly affect catalyst site functionality. Because potable water treatment typically deals with adsorbate concentrations in the parts per million (ppm) range, loading won't affect catalytic carbon efficiency much.



- **Secondary reactions.** Because catalytic carbons may convert adsorbates into other species, monitoring the inlet and outlet of the carbon bed for the reactant of interest won't suffice. The chemistry of removal must be understood to ensure reaction by-products don't create problems including unwanted secondary reactions.

Removal chemistry also identifies catalyst site selectivity, an essential consideration when recovery of reaction by-products is a goal.

- **Induction periods.** Catalysis differs from physical adsorption in terms of adsorbate breakthrough. In some applications, the conditions for a reaction must be established on the carbon surface and, as a result, initial breakthrough of a contaminant may be observed.

Over time, however, levels subside to a steady state within the carbon bed and contaminant removal then becomes fairly constant. This represents the ideal catalyst behavior; it's more likely contaminant concentration in effluent will slowly approach influent concentration as adsorbable by-products mask catalytic sites.

- **Aging.** Reactions involving oxygen may induce a slow decline in catalytic activity as a result of oxygen chemisorption on carbon surfaces. Such aging can be initiated with exposure to ambient air and moisture and becomes a factor when catalytic carbons are formed into carbon blocks.

Temperatures to 200°C speed aging in air, especially when air and moisture are both present. Lower oxygen concentrations, however, may extend the application range to temperatures as high as 350°C.

Exposure to dry air has little effect on aging, and where oxygen concentrations are low aging effects are of little concern.° Likewise, where other factors determine catalyst carbon life, aging is unimportant.

Where aging is a concern it appears to affect all carbons equally. thus, a catalytic carbon with 10 times the catalytic activity of a conventional carbon retains 10 times the activity when both have aged. Aging can also be reversed by inert calcination, indicating catalyst sites are merely masked - not destroyed - by the aging process.

- **Using carbon's PN.** Although a carbon's° PN is a reasonable predictor of catalytic activity in many applications, it's far from perfect. The mechanism of catalysis in some applications may not involve the type of catalyst sites measured by the PN test. Even when peroxide-active sites are involved, many catalyst carbon advantages depend on the conditions under which reactions are carried out.

CONTAMINANT	POTENTIAL APPLICATION AREAS
Monochloramine	Residential Water Treatment (POE & POU) Beverage Bottling Aquariums Hemodialysis High Purity Water (pre-RO, pre-DI)
Hydrogen Sulfide	Residential Groundwater Treatment (POE) Municipal Groundwater Treatment Industrial Wastewater
Hydrogen Peroxide	Industrial Wastewater

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