

Application Bulletin

Catalytic Activated Carbon Offers Breakthrough for Dialysis

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A somewhat revolutionary development in activated carbon - catalytic/adsorptive carbon - has been proven to decompose monochloramine concentrations in the water used for hemodialysis treatments more efficiently and cost effectively than the traditional activated carbons currently in use. Research shows that controlling monochloramine levels reduces the risks of hemolysis, anemia, and methemoglobinemia for dialysis patients. Not only does catalytic carbon remove monochloramines more effectively, it also decreases the amount of carbon needed and decreases the overall amount of contact time required for monochloramine removal.

Monochloramine is the most common form of chloramine found in drinking water. Chloramines are often introduced into water by the municipal treatment plant itself. This is done mainly for two reasons: First, chloramines control bacterial growth, both in the water treatment plant and in the water distribution system. Second, chloramine disinfection replaces chlorine disinfection and reduces the formation of trihalomethanes (such as chloroform) that result when chlorine reacts with naturally occurring organic matter.

Although deliberate chloramination is the most likely source of monochloramine, water systems that use chlorine for disinfection can also produce monochloramine unintentionally when ammonia is present in the treatment or distribution systems.

Chloramines are most often formed by the reaction of ammonia and free chlorine. Three forms of chloramine are possible, and the particular chloramine that is produced depends upon the pH level of the water and the chlorine-to-nitrogen (Cl:N) ratio. A low pH (about 4) and high Cl:N ratios, the primary chloramine reaction product is trichloramine. At pH above 4 but less than 5 with moderate Cl:N ratios, dichloramine formation predominates. Monochloramine is formed at pH levels above 6. Since the pH of most drinking water is neutral and above, the overwhelming majority of chloramines in drinking water are monochloramines.

Using Activated Carbon to Remove Monochloramines

To produce the ultra-pure water required for safe, effective dialysis, monochloramine levels must be maintained below 0.1 mg/L, the recommended level according to an FDA-funded study.¹ To reach this degree of water purity, activated carbon is indispensable. The surfaces of all activated carbons show some degree of catalytic activity. This activity allows activated carbon to react with monochloramine, converting it to ammonia and nitrogen.

While all activated carbons undergo this reaction, those with greater catalytic activity do so at a much higher rate. The end result - greatly improved system performance - is what makes the capabilities of catalytically enhanced carbon so beneficial for dialysis applications.

Catalytic Carbon: The Treatment Breakthrough

Catalytically enhanced carbon, known as Centaur[®], was developed by Calgon Carbon Corporation using a patented process technology. Centaur is manufactured by actually altering the surface structure of activated carbon to significantly enhance its catalytic properties. All activated carbons exhibit some degree of catalytic activity. Until now, however, activated carbon had to be chemically impregnated to accelerate the rate of chemical reactions in a predictable manner - a process that made it unacceptable for dialysis applications. Centaur is specially produced to exhibit consistent and enhanced catalytic activity without being chemically impregnated.

Catalytic activity is measured by the rate at which a particular carbon decomposes hydrogen peroxide. The lower the value (the shorter the time required for decomposition of the hydrogen peroxide), the higher the catalytic activity. Therefore, the higher the rate of peroxide decomposition, the faster the rate of monochloramine decomposition.



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Table I

Catalytic activity, as measured by hydrogen peroxide decomposition, of various activated carbons.

Activated Carbon	Catalytic Activity (minutes)
Centaur catalytic carbon	8
Conventional bituminous coal-based carbon	30
Conventional sub-bituminous coal-based carbon	40

Three activated carbons with different catalytic activities (as shown in *Table I*) were tested in a continuous flow-through reactor system to compare their catalytic activity rate with their monochloramine removal performance. The carbons included catalytically enhanced bituminous coal-based Centaur carbon; conventional bituminous coal-based carbon; and conventional sub-bituminous coal-based carbon.

Exposing each carbon to a 5 mg/L monochloramine solution (measured as total chlorine), monochloramine decomposition was seen to improve with the capability for catalytic activity.

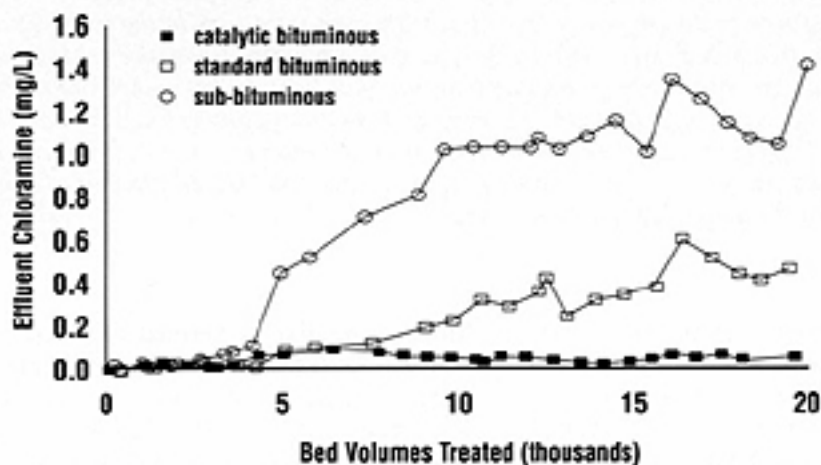


Figure 1 shows the chloramine breakthrough with each carbon for a 2-minute empty bed contact time (EBCT) reactor system. In this system, Centaur catalytic carbon significantly outperformed the two conventional activated carbons. Through 5 months of operation, the catalytic carbon bed treated 88,000 bed volumes without ever exceeding the 0.1 mg/L treatment objective.

Figure 1. The chloramine breakthrough for each of three carbons with a 2-minute empty bed contact time. The water treated using the catalytic carbon bed never exceeded the 0.1 mg/L treatment objective.

Designing a Water Treatment System for Dialysis

When designing a dialysis water treatment system for monochloramine decomposition, there are many factors to consider, including the chloramine concentration level, the water temperature, the catalytic activity of the activated carbon, and other design issues which are often overlooked, such as empty bed contact time and carbon particle size.

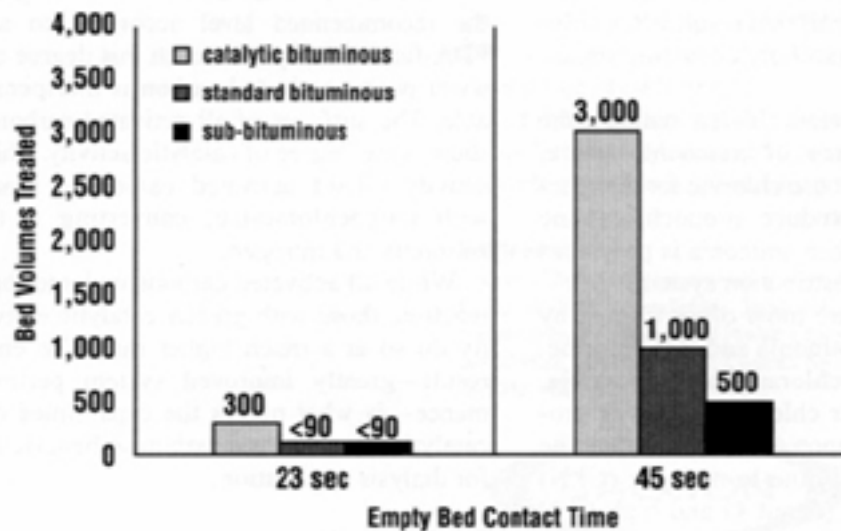


Figure 2. Increasing the empty bed contact time increases the life of the carbon. As shown, roughly doubling the contact time from 23 to 45 seconds more than doubles the volume of water that can be treated using each carbon (treatment objective - 0.1 mg/L chloramine).



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Extending the empty bed contact time can have a positive impact on system performance. Increasing the contact time dramatically increases the life of the carbon. As shown in *Figure 2*, roughly doubling the contact time from 23 to 45 seconds more than doubles the volume of water that can be treated using each carbon. Referring back to *Figure 1*, further extending the contact time from 45 seconds to 120 seconds increases the treated water volume from 500 to 4,000 bed volumes and from 1,000 to 6,000 bed volumes for the two standard carbons, respectively. While the data stop at 20,000 bed volumes, catalytically enhanced carbon continued to operate through 88,000 bed volumes. It is significant to note that the testing was stopped after treating 88,000 bed volumes without the monochloramine exceeding the treatment objective of 0.1 mg/L.

Table II
Effect of catalytic carbon particle (mesh)size on monochloramine removal.

EBCT(seconds)	20 x 50 Mesh(BVs)	30 x 70 Mesh(BVs)	30 x 140 Mesh(BVs)
10	250	2,000	6,000
20	4,000	8,000	16,000
30	11,000	28,000	40,000

EBCT = empty bed contact time; BVs = bed volumes treated; Centaur catalytic carbon.

Another method to improve the performance of a monochloramine removal system is to decrease the carbon particle size. As seen in *Table II*, reducing the mesh size of catalytic carbon from 20 x 50 mesh to 30 x 70 mesh, and then to 30 x 140 mesh, significantly increases the volume treated until breakthrough (when the effluent water from the system has a monochloramine concentration of 0.1 mg/l).

Overall, significant gains in system performance are attainable when contact time and carbon particle size are combined with improved catalytic activity. It is because of this that catalytic carbon can be particularly useful and cost efficient in dialysis water treatment.

The Effect of Monochloramine Concentration and Water Temperature

While it is possible for system engineers to adjust the particle size and contact time, and even to specify the carbon catalytic activity for a chloramine removal system, there are other factors affecting performance that are often beyond their control. Issues such as the concentration level of monochloramine in the influent and the water temperature are subject to the natural variations of the water treatment plant and seasonal temperature fluctuations. Nonetheless, it is important to understand the effects of these variables on monochloramine decomposition.

Table III
Effect of influent monochloramine concentration on water volume treated using catalytic carbon.

EBCT(seconds)	2 mg/L Conc.(BVs)	5 mg/L Conc.(BVs)
10	350	240
20	4,000	1,500
30	11,000	4,000

EBCT = empty bed contact time; BVs = bed volumes treated; Centaur catalytic carbon.

As one would expect, when the influent concentration increases, the volume treated until the treatment objective is exceeded decreases. As shown in *Table III*, as the influent chloramine concentration is increased from 2 to 5 mg/L, the volume treated until a treatment objective of 0.1 mg/L monochloramine concentration is exceeded decreases. In this example, an extreme case of very short contact times is used to demonstrate the effect. Proper system design, however, will take into account the range of concentrations expected for adequate monochloramine control.



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Table IV

Effect of water temperature on watervolume treated using catalytic carbon.*

EBCT(seconds)	14°C Water Temperature(BVs)	22°C Water Temp(BVs)
10	<90	240
20	300	1,500
30	1,500	4,000

*Influent monochloramine concentration = 5 mg/L; EBCT = empty bed contact time; BVs = bed volumes treated; Centaur catalytic carbon.

Adsorbing organic compounds typically results in decreased adsorbate loading and, consequently, shortened bed life. With catalytic carbon, raising the temperature in the catalytic decomposition of monochloramine actually heightens the rate of reaction and extends the life of the carbon. *Table IV* shows that raising water temperature from 14°C to 22°C markedly increases the bed life of the reactor. With this realization, system engineers can anticipate improved monochloramine removal during summer operations.

Conclusion

The recent development of catalytically enhanced Centaur carbon offers dialysis treatment centers exciting new opportunities. Replacing traditional activated carbon with catalytic carbon significantly improves the performance of dialysis water treatment systems, while at the same time increasing the volume of water that can be treated before experiencing chloramine breakthrough.

Catalytic carbon makes it possible to use smaller systems that provide equivalent performance at less cost.

Reference

1. Critical Review of Documentation of Artificial Kidney Systems: Hemodialysis. Food and Drug Administration, Department of Health, Education, and Welfare, November 1979, Contract No. 223-78-5046.

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The logo for Chemviron Carbon, with "Chemviron" in a bold, sans-serif font above "Carbon" in a similar font.