Activated Carbon: Filtration, Contactor or Both?

By Gary Battenberg

Uses

In the water treatment industry, activated carbon (AC) is widely used for taste and odor removal of free chlorine and chloramines (chlorine/ammonia species). Additionally, AC is specified for the reduction/removal of natural and synthetic organics, toxic organic chemicals and color bodies. Activation of carbon is accomplished by acidification of soft base materials such as peat, sawdust or soft wood. Thermal activation of hard base materials (such as hard wood and coal) is accomplished by steam heating the material up to 1,900°F (718.2°C) in a vacuum. These activation processes produce a honeycomb-type structure, whereby the base material surface area is greatly increased, which provides the adsorption sites for contaminants removal.

What is adsorption?

Adsorption is the physical process in which suspended matter, liquids or gasses ***adhere to the surface*** or in the pores of the adsorbent in the absence of a chemical reaction. Adsorption is not the same as absorption, in which one substance is ***taken into the body*** of another substance (such as the absorption of water into soil). It is important to understand the difference between these two phenomena and learn to use these terms correctly in our industry.

Application

Activated carbon has been widely used for dechlorination for many years. Because of its high affinity for chlorine, it is a proven application with excellent performance and projected life expectancy. For example, under proper operating conditions, one cubic foot (7.481 gallons or 28.32 liters) of AC will remove one ppm of free chlorine from one million gallons (3.7 million liters) of water. In point-of-fact, granular activated carbon (GAC) is generally accepted as the best all-around adsorbent available for removal of organic contaminants. In addition to the previously stated applications, others include the removal of tannins, phenols, pesticides, detergents, tri-halomethanes (THMs) and toxic organic compounds.

Which carbon to use?

Typically, the industry standard AC for dechlorination and suspended matter is a 12 x 40 mesh (1.650 mm x 0.417 mm) bituminous coal, which requires a backwash rate of 9 gpm (34 L/m) per square foot of bed surface area at 55°F (12.7°C) water temperature for a 35-percent bed expansion; whereas, an 8 x 30 mesh (2.360 mm x 0.589 mm) requires a backwash rate of 16 gpm (60.5 L/m) per square foot of bed surface area at 55°F water temperature for the same bed expansion percentage. **Note:** Activated carbon manufacturers recommend a minimum of 35-percent bed expansion during backwash to ensure flushing of the suspended solids to waste and reclassification of the carbon to expose new adsorption sites to the influent stream. Higher water temperatures require a higher backwash rate, so use caution when designing an activated carbon system that requires periodic backwashing. It is a good practice to first obtain a comprehensive water analysis from a reputable testing laboratory before consulting with your carbon supplier for assistance where issues of temperature, pH and removal efficiency must be considered. The contaminant type and calculated service flowrate will determine the mesh size and type of the activated carbon to be used, such as 12 x 40, 8 x 30 or 20 x 50 mesh in either bituminous coal, coconut shell, soft wood or other suitable media, such as catalytic carbon and organoclay products.

Backwash filter

When designing a backwash filter, it is important to remember that filter size, media type and volume are in direct proportion to the target contaminant and service flowrate. Let's look at an example of a typical residential application for chlorine removal. For a calculated service flowrate of 5 gpm, a standard 9- x 48-inch-high fiberglass tank containing one cubic foot of 12 x 40 mesh bituminous coal is generally accepted as sufficient to scrub free chlorine from the water supply. Because of its high affinity for chlorine, this size system can operate very efficiently between 10-15 gpm (37.8-56.7 L/m) per square foot. Activated carbon filters should be designed for bed depths of 30-36 inches (762-914 mm) for optimum efficiency of contaminant removal. For example:

- A 9-inch (228.6-mm) diameter tank has a square foot (ft^2) surface area of 0.440, so one cubic foot of activated carbon provides a 30-inch (762-mm) bed depth. Therefore, 5 gpm divided by 0.440 = 11.36 gpm/ft^2.
- A 10-inch (254-mm) diameter x 54-inch (1,371-mm) high tank has a square-foot surface area of 0.545. The media volume will be 1.5 cubic feet of activated carbon for a 33-inch (838-mm) bed depth. Therefore, 1.5 cubic feet of activated carbon multiplied by 5 gpm, equals 7.5 gpm calculated service flowrate or 13.75 gpm/ft^2.

Where suspended-solids matter is present in the water with chlorine, AC will function as a light sediment filter as well. Over time, however, the carbon may become plugged up due to compaction of the sediment into the pores of the activated carbon granules, which will shorten the optimal service life of the carbon. An effective way to protect the carbon bed is to use a lighter filter media on top of the carbon that will intercept the suspended matter before it migrates to the carbon.

This is what is known as a filter cap and is typically a 5- to 8-inch (127- to 203-mm) layer of Filter AG, which has an apparent density of 25 pounds/ft^3. Dry activated carbon has an apparent density of 34 pounds/ft^3. The sediment that is captured by the filter cap creates a filter cake that accumulates during the service run and is easily backwashed out of the tank every couple of weeks. Because of the difference in apparent densities, the medias remain stratified, which creates an effective dual-function filter in a single tank. **Note:** Wet carbon achieves an apparent density of 58-62 pounds, which is much higher than that of the Filter AG at approximately 40 pounds wet.

When chloramine is the target contaminant for removal/reduction, the typical service flowrate for the previously mentioned 9- and 10-inch diameter tanks drops significantly to 2.6 gpm and 3.3 gpm (9.8 and 12.4 L/m) respectively. The reason is because chloramine removal requires more contact time with carbon to be effectively removed or reduced. The flowrate drops from 10-15 gpm/ft^2 for chlorine to 6 gpm/ft^2 for chloramine. To achieve the same 5-gpm service flowrate, the tank size would be 13- x 54-inch with 2.5 cubic feet of activated carbon and a 16- x 65-inch (406.4- x 1,651-cm) tank with 4.5 cubic feet of activated carbon for 7.5-8 gpm (28.3-30.2 L/m) service flowrate.

Contactor

An activated carbon contactor array is typically designed for tertiary (third-stage) treatment of a water supply where organic and toxic contaminant removal is required. The pretreatment ensures the influent stream into the contactor(s) is free of iron, oil and suspended matter that would shorten the life of the AC. Contactors do not use a backwashing control valve but rather are a simple down-flow configuration that utilizes a tank adapter with inlet and outlet connections. Contactors can be configured for parallel or series operation. Residential applications are generally configured for series operation where a leading and lag tanks are plumbed together with a sample valve at the inlet and outlet of the leading tank and another on the outlet of the lag tank. The purpose is to detect the breakthrough of the contamination from the leading tank, which indicates the replacement of that contactor is needed. The lag tank is rotated to the lead position and the new contactor is placed in the lag position. This allows for full utilization of the activated carbon.

A parallel contactor configuration is recommended where the required flowrate is not feasible by using larger tanks because of spatial constraints. In this case, two smaller tanks, fitted with a flow-balanced supply and return manifold, split the flowrate equally, which in turn yields the effluent quality required. The effluent from the first parallel contactors then enter a second parallel set of contactors, which provides the same level of efficiency as the series contactor configuration. The sample valves will be located at the same locations as the series contactors to detect breakthrough and indicate rotation, as is the case for the series array. **Tech tip:** Since contactors don't require a freeboard for backwash, the tanks can be filled to full capacity. This will increase both the media volume and the service flowrate. For the nine-inch diameter tank, the media load increases to 1.5/ft^3 and the 10-inch diameter tank media load increases to 2.0 /ft^3.

Organics and toxic organics require even more contact time than chlorine or chloramine. In the case for the 9-inch tank, organic removal would slow to 1.4 gpm (5.2 L/m) per cubic foot and 1.7 gpm (6.4 L/m) per cubic foot for the 10-inch tank. Toxic organic removal would drop further to 0.9 gpm (3.4 L/m) per cubic foot for the 9-inch tank and 1.1 gpm (4.1 L/m) per cubic foot for the 10-inch tank. The slowdown of the flowrates is what is known as empty bed contact time (EBCT). EBCT is equal to the volume of the empty bed divided by the flowrate. One cubic foot of activated carbon is equal to 7.48-gallons (28.3-liters) capacity (conversion factor) divided by the flowrate of the filter. For example: 2 cubic feet = 7.481 x 2 / 1.6 gpm = 9.35 minutes EBCT.

For a reference, the following EBCT times can be used for estimating the tank diameter and activated carbon bed volumes. Again, consult your carbon supplier and obtain a comprehensive water analysis to find out how many contaminants are competing for adsorption sites on the activated carbon.

Free chlorine:	**1 -2 minutes**	**10 - 15 gpm/ft^2**
Chloramines:	**3 - 4 minutes**	**6 gpm/ft^2**
Organics:	**5 - 6 minutes**	**1.0 - 1.4 gpm/ft^2**
Toxic organics:	**8 - 10 minutes**	**0.7 - 0.9 gpm/ft^2**

As you can see, activated carbon is a proven workhorse when it is properly applied to treating contaminated water supplies. As water contamination issues become more serious and urgent remediation is needed, look to activated carbon as your first line of attack to provide an effective removal/reduction of those contaminants with excellent results.

Environmental compliance

One final point to keep in mind when working with contamination remediation is to contact the local Environment Health Department (EHD) and the state US EPA office for approved methods of disposal and/or regeneration of spent activated carbon. Simply dumping contaminated carbon back into the environment is not acceptable and is subject to fines and penal detention. Protecting water resources is just as important as providing consistent and reliable performance of water treatment products that remove these contaminants. Don't compromise work ethic or personal and company reputations by sidestepping laws, rules and ordinances that apply to the work you do. Work with regulatory agencies…not against them!

About the author

♦ *Gary Battenberg is a Technical Support and Systems Design Specialist with the Fluid System Connectors Division of Parker Hannifin Corporation in Otsego, MI. He has 36 years of experience in the fields of domestic, commercial, industrial, high-purity and sterile water treatment processes. Battenberg has worked in the areas of sales, service, design and manufacturing of water treatment systems and processes utilizing filtration, ion exchange, UV sterilization, reverse osmosis and ozone technologies. He may be reached by phone at (269) 692-6632 or by email, gary.battenberg@parker.com*