GAC as a Barrier Defense to Protect Drinking Water Supplies from Chemical Spills

Calgon Carbon's Perspective

Dated: April 11, 2014

Background

Over 200 million Americans get their drinking water from a collection of nearly 12,000 community drinking water treatment systems. These drinking water treatment systems withdraw source water from nearby surface waters, such as rivers, streams, and lakes. Many of these drinking water treatment systems are located in close proximity to a variety of industrial facilities, such as factories and storage tanks. Additionally, inland waterways which serve as a major source for drinking water are also used as water highways for recreation and to transport industrial chemicals, uses which present additional risks to the quality of the source water available to the drinking water treatment facility.

Despite the best efforts of both government and industry, chemical spills from industrial facilities and river traffic do happen. When these events occur, the potential exists for contamination of drinking water. There is understandably great interest on the parts of water utility management, state and federal regulators, elected officials, and the general public to prevent such spills or to provide an effective barrier that will protect drinking water supplies should chemical spills occur. This white paper describes how to apply a well-known and highly effective technology, granular activated carbon (GAC), to serve as part of a multi-barrier approach to defending surface water drinking facilities from chemical spills.

The Nature of Industrial Spills

Chemical spills into inland waterways have been a reality for decades, and even with today's more sophisticated operations and rigorous regulatory environment, they continue to occur. To illustrate this point, an analysis of the USEPA's Toxics Release Inventory data revealed that in 2011 alone, 194 million pounds of chemicals were spilled into US rivers, streams, lakes, and coastal areas from 1,374 facilities[1].

The U.S. government's Safe Drinking Water Act (SDWA) Amendments of 1996 included provisions which required states to complete source water assessments. These assessments were intended to determine pollution sources upstream of surface water drinking water facilities, as well as those which could potentially pollute groundwater facilities. However, the SDWA does not require the installation of source water protection systems, so it is left to the individual water utilities, both public and private, to decide for themselves what level of protection is warranted for their drinking water systems.

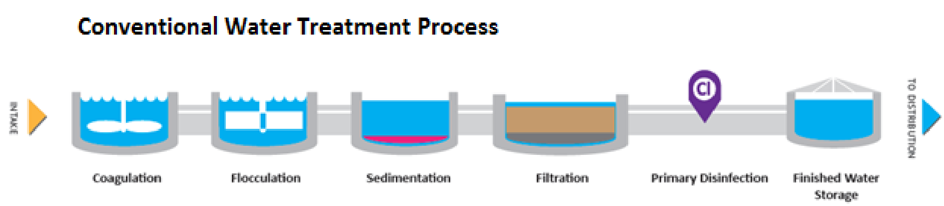
Chemical spills, by their very nature, are unpredictable and may occur for a variety of reasons, including:

- Storage tank and/or pipe leaks due to accidents or insufficient maintenance
- Accidental valve openings due to operator error
- Damage due to acts of nature, such as earthquakes and tornadoes
- Deliberate acts of sabotage
- Tanker truck accidents
- Barge accidents

When a chemical spill occurs, the drinking water facilities downstream of the event may or may not receive any warning that a hazardous or potentially hazardous chemical is headed their way. If sufficient warning is received, and if the drinking water plant to be affected has a reservoir of water stored or alternate sources of supply, such as groundwater wells, the utility may have the ability to shut off its water intakes along the affected waterway. However, there may be times when notification of a spill is received only after the chemicals have reached the drinking water plant's intakes. In these cases, it's critical to have a defensive barrier that would prevent the chemicals from entering the drinking water distribution system and ultimately into homes and businesses.

<u>The GAC Barrier Defense Approach</u>

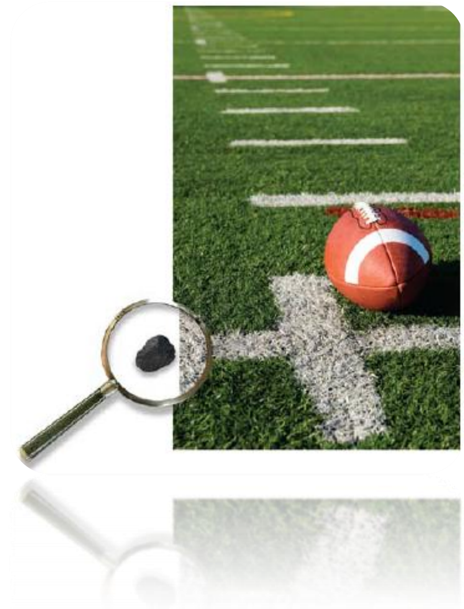
Given a scenario where there is little or no warning of a spill upstream of a drinking water plant's intakes, and the chemical finds its way into the drinking water plant, the next line of defense needs to be one or more technologies that can effectively contain the compound(s). Most drinking water treatment plants in the United States are of the "conventional" design, consisting of flocculation, coagulation, sedimentation, filtration, and final disinfection processes (as illustrated below).



In the design illustrated above, the filtration process shown is a mechanical process which removes undesirable solid particulate matter from the treated water. It does not capture chemical compounds.

While the design of these conventional plants has proven effective over the years for the treatment of the organic compounds ordinarily found in surface water, they may not be effective when faced with the often complex and sometimes exotic chemicals released from industrial sources. Some of these conventional drinking water processes can help reduce contaminant levels, but they may be quickly overwhelmed by high concentrations of chemicals. To prevent water treatment plants from discharging contaminated water into their distribution systems, an additional barrier is required. One such barrier is granular activated carbon (GAC).

GAC has been used to protect and improve drinking water treatment systems for decades. It was first used as a technology to remove unpleasant tastes and odors from water. Later, GAC was found to be effective in removing natural organic matter (NOM) from water, which among other things made GAC an effective treatment to reduce Disinfection Byproducts (DBP), a group of regulated carcinogenic compounds formed during the disinfection step in the drinking water treatment process. GAC has also been found to be effective as a means to remove Endocrine Disrupting Compounds (EDC) and Pharmaceutical and Personal Care Products (PPCP) from water. Beyond these applications, GAC is extremely effective for the removal of many of the kinds of chemicals present in industrial spills.

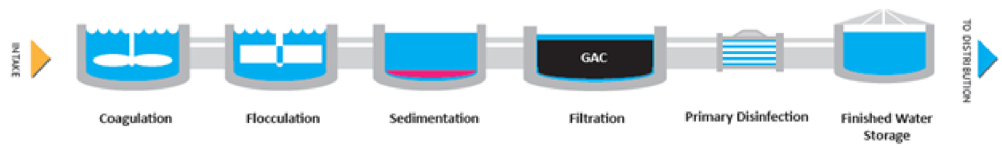


GAC works through a mechanism known as *adsorption*. Through adsorption, molecules are trapped within the structure of the GAC particle. GAC particles themselves are quite small, often around one millimeter in diameter, but GAC possessing an enormous storage capacity due to the multiplicity of channels, cracks, and crevices designed within each particle. Less than 3 grams (about the size of a single serving of sugar) of GAC has the surface area equivalent to a football field!

When chemical compounds in water pass through a filter containing GAC, the chemicals are adsorbed within the structure of the activated carbon particle. GAC will adsorb just about any organic chemical, but its ultimate capacity for any given compound may differ depending upon the chemical's basic characteristics, such as size, solubility, and density. There are many tools available to aid engineers to properly design a GAC system that will provide sufficient capacity to both remove ordinary chemical contaminants and to provide a barrier against chemical spills entering the drinking water distribution system.

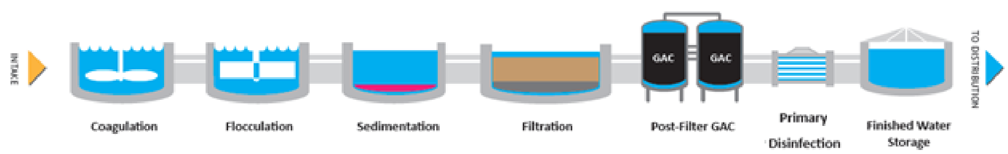
The Barrier Defense Approach envisions a GAC filtration system installed near the end of the drinking water treatment process (as illustrated below). The GAC filters would be positioned after the initial "conventional" treatment steps of coagulation, flocculation, and sedimentation. In some cases, GAC would essentially replace the existing filtration media used in the drinking water treatment process.

Conventional Water Treatment Process with GAC Filtration



Alternatively, some drinking water treatment plants will install designed-for-purpose GAC contactor vessels behind the existing filters:

Conventional Water Treatment Process with Post-Filter GAC Contactors



Positioning the GAC as a post-filtration step (as shown above) provides several benefits. The GAC near the end of the treatment train would be used to 'polish' the drinking water to a high quality during normal operations and would serve as effective barriers during spill events to capture chemicals before they would enter the drinking water distribution. Utilizing post-filter contactor vessels helps facilitate the removal and replacement of GAC without shutting down the drinking water plant's filters.

The Importance of Appropriate Design and Maintenance of GAC for Barrier Defense

Critical to the successful use of GAC in the Barrier Defense concept is proper design and maintenance.

Design

GAC systems designed as a Barrier Defense to protect drinking water supply should be sized conservatively to contain the majority of chemicals that might be spilled into the source water. Sizing GAC systems is based on "empty bed contact time" (EBCT). This concept relates to how long the water "contacts" the GAC as it moves through the GAC bed and is calculated by dividing the number of bed volumes within a system divided by a given flow rate. The rule of thumb for GAC systems designed for spill protection is to design for a minimum of 8 minutes of EBCT.

A second point regarding the design of GAC barrier systems to protect drinking water supply is the selection of the GAC itself. GAC can be made from a variety of starting materials (e.g. coal, coconut, wood, etc.) and manufactured in several different ways (direct activated, reagglomerated, pelletized and crushed, etc.). To provide the maximum adsorptive capacity for the purposes of spill protection within the most compact volume (to minimize the footprint of the GAC installation), it is generally recommended that a GAC made from bituminous coal and manufactured by way of the *reagglomeration* process be utilized. This type of GAC has been shown to have excellent organics removal capacity, as measured by the removal of total organic carbons (TOC).

Normal Maintenance

GAC's capacity to adsorb chemical compounds is determined by the selection of the type of granular activated carbon being used and the chemicals which are being absorbed. Eventually, the GAC must be removed from the drinking water plant filters, thermally reactivated at a reactivation facility, and returned to be reinstalled into the drinking water plant filters. Even without a chemical spill present, and even accounting for the treatment processes present prior to the GAC filters, there are still compounds present in the water that will be adsorbed by the GAC, gradually reducing the carbon's total adsorption capacity. To assure that there is sufficient adsorptive capacity remaining to capture chemicals from a potential spill the GAC must be regularly removed from the drinking

water plant and reactivated. Given the characteristics typical of surface water sources in the United States and the impact of the overall drinking water treatment processes upstream of the GAC, it is recommended that the GAC in the filters designed primarily for spill defense be exchanged on average every 12 to 18 months.

As noted earlier, GAC has been used for decades for municipal drinking water treatment. Many drinking water treatment plants use GAC only to help remove unpleasant tastes and odors from water. It should be kept in mind that applications such as taste and odor treatment do not require a particularly rigorous level of treatment, and as a result, these drinking water treatment plants may not have an adequate Barrier Defense from chemical spills and may not be sufficiently protected from chemicals entering their drinking water distribution system.

Other types of drinking water treatment systems have come to rely, in part, on the beneficial biological activity that occurs naturally on the surface of GAC. These bacteria help digest targeted chemical compounds that may be in the treatment plant's source water. However, operating a GAC system in this manner may not allow it to function effectively as a spill defense system. Biological colonies acclimate over time to the composition of their food source, i.e. the chemicals typically in the water. When a new chemical is introduced to the drinking water treatment process, especially one at a concentration level potentially many times higher than ordinary, the bacteria will likely become overwhelmed, and perhaps even be killed off by the new and/or higher concentration chemical. The result would most likely be a reduced effectiveness of the overall drinking water treatment process and increased risk that chemicals from the spill would enter the drinking water distribution.

Post-Spill Maintenance

When a major industrial spill does occur, a properly designed and maintained GAC Barrier Defense would be expected to adsorb the chemicals and prevent their immediate release to the distribution system. However, the nature of activated carbon is such that compounds that have been adsorbed can sometimes subsequently *desorb* (i.e. come off the GAC and back into the water) due to the equilibrium state between the contaminant concentration and contaminant loading. This means that over time, the chemical which was initially captured may begin to be released back into the water. To prevent the spill chemical from eventually re-entering the water distribution system, as well as to ensure that sufficient adsorptive capacity is present to handle any subsequent spills, Best Practices would dictate that the GAC be removed from the drinking water treatment process and then either reactivated and returned – or replaced with virgin product – shortly after any spill event.

Realizing Additional Benefits from GAC Installed as Part of a Barrier Defense System

Adding GAC to the drinking water treatment process provides additional benefits to the treatment process while providing a Barrier Defense against chemical spills. These additional benefits include:

- Removing natural organic matter (NOM) from the water. This is effective for:
    - Reducing the formation of disinfection byproducts
    - Reducing chlorine demand (and cost) through removal of organic compounds that otherwise react with chlorine. For example, the City of Cincinnati has indicated that their GAC has reduced their chlorine demand by 60%, resulting in a savings of $200,000 annually[2]
- Providing a barrier against contaminants of emerging concern (CEC), especially endocrine disrupting compounds (EDC) as well as pharmaceutical and personal care products (PPCP).
- Improved turbidity control
- Granting of 0.5 log credit for endospore removal, based on the USEPA's Long Term 2 Enhanced Surface Water Treatment Rule (LT2 ESWTR)
- Removing taste and odor (T&O) compounds from water, thereby improving the aesthetic qualities of the finished water and reducing consumer complaints.
- For water treatment plants that utilize ultraviolet light (UV) for disinfection, positioning GAC in front of the UV system can improve the UV transmittance (UVT) of the water, thereby reducing the UV dose required for effective disinfection, which in turn reduces operating costs. Cincinnati made the decision to position their UV systems post-GAC after conducting a pre-design study[3]. It is estimated that for each 5% improvement in UVT, UV operating costs are reduced 50%.

The Economics of the GAC Barrier Defense *Concept*

An important consideration related to implement the Barrier Defense concept is cost. As it turns out, GAC is exceptionally affordable. GAC can be implemented by a typical US drinking water utility for a cost between $10 and $40 per year for a family of four[4]. The range accounts for the size of the installation and population served. The cost will decrease on a per capita basis as the size of the drinking water treatment facility increases, due to economies of scale. These costs include engineering design, civil construction, initial purchase of the GAC (and associated equipment), and on-going operation and maintenance costs.

An example cost detail for the use of GAC is provided below for a typical mid-sized drinking water treatment facility:

Scenario: Mid-Sized Water Treatment Plant

Population Served:	160,000
Flow Rate:	17 million gallons per day (MGD)
Annual Volume of Water Treated:	6,205,000,000 gallons
Annual Household Water Use, Family of Four:	101,500 gallons
Initial Cost to Design/Construct/Install GAC System:	$6,141,000
Annual Operating and Maintenance Cost of GAC:	$227,000
Annualized 10-Year Simple Lifecycle Cost:	$841,000
Annualized Lifecycle Cost per Gallon:	$0.00014
Annual Cost for a Household of Four:	$0.00014 x 101,500 gallons = **$13.75/year**

Supporting the calculations above, the City of Cincinnati reports that the cost for treating drinking water with GAC is $5.00 per quarter for a single family household, or $20.00 per year[2]. These costs compare very favorably to the expense of providing this same family with bottled water, which can range from $950 to $1,800 per year[5].

Quality Drinking Water and Public Trust

Granular Activated Carbon used as a Barrier Defense by drinking water treatment facilities has the potential to not only support the routine delivery of quality drinking water but the added benefit of protecting that drinking water from chemical spills and enhancing public trust.

Perhaps the most important consideration related to the installation of a GAC-based Barrier Defense is to provide quality drinking water in accordance with federal and state regulations associated with the Safe Drinking Water Act. GAC is widely acknowledged as a very effective technology for the removal of a wide range of chemical contaminants from water. Compounds effectively removed by GAC include naturally organic matter, disinfection by-products, endocrine disruptors and pharmaceuticals, and industrial chemicals from spills.

Used as a Barrier Defense from the unintended introduction of chemicals resulting from spills or other situations, GAC can enhance the operations and performance of drinking water treatment facilities to help assure the delivery of safe, quality drinking water. Those enhanced operations and performance will lead to improved facility confidence and improved public trust in the drinking water supply system.

Contact for More Information

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Sources

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