Remove Perfluorinated Compounds From Drinking Water — Without Creating A Toxic Waste Stream

Water utility managers have a lot of responsibilities, not the least of which is to keep up with the latest in the industry—contaminants, regulations, technology, and trends. And perfluorinated compounds (PFCs) are on the horizon as contaminants that may affect the public health.

Calgon Carbon Corporation has been helping utilities provide clean drinking water to their customers for over 30 years and has more than 15 years of experience in successfully treating PFCs. As a global leader in the activated carbon industry, with expertise in ultraviolet disinfection and oxidation, Calgon Carbon has developed cutting-edge water purification systems.

Water Online spoke with Calgon Carbon about these important emerging contaminants and how best to remove them.

Water utilities are already required to test for hundreds of contaminants in drinking water. What are emerging contaminants, and why are they important?

Emerging contaminants are chemicals or materials that have been found in global drinking water supplies and pose threats to human health. While these contaminants may have always been present in drinking water, advances in technology have only recently made it possible to detect them.

Contaminants are classified as "emerging" if a new source or direct pathway to humans has been determined. PFCs, such as Perfluorooctane sulfonate (PFOS) and Perfluorooctanoic acid (PFOA), have been identified as both persistent and mobile in the atmosphere and aqueous environments. They are, therefore, considered emerging contaminants of concern.

The U.S. Environmental Protection Agency (EPA) seems to have a special concern about PFCs. Where do PFCs come from, and why are they such a concern?

PFCs are man-made, fully-fluorinated compounds not naturally found in the environment. PFCs have been used in a range of common household products, such as non-stick cookware and stain-resistant carpeting or fabrics. They are also present in firefighting foams and coating additives. For many years, PFOS and PFOA were the most commonly produced PFCs.

Due to their chemical stability and low volatility, PFOA and PFOS are persistent and itinerant in aqueous environments and airborne dust. In their anionic form, PFCs are water soluble. They can readily migrate from soil to groundwater, at times traveling long distances. Also, these materials stay in the human body for long periods of time, and levels in the body can increase with continued exposure.

The EPA issued a health advisory for two specific PFCs, PFOA and PFOS in May, 2016. What adverse health effects brought about this advisory?

Both PFOS and PFOA are on the U.S. EPA's

Drinking Water Contaminant Candidate List 4 (CCL 4). The CCL 4 lists contaminants that are not currently subject to or proposed for national primary drinking water regulations but are known or anticipated to occur in public water systems. Recently, to provide Americans with a margin of protection from exposure to PFOA and PFOS, the EPA established a health advisory level at 70 parts per trillion (ppt or ng/L).

Studies in animals have found effects on the liver, development, and immune system responses. PFOA and PFOS were also associated with tumors in laboratory animals exposed long-term to high levels. Some (but not all) studies in humans have shown that certain PFCs may:

- Affect a developing fetus and child, including possible changes in growth, mental development, and behavior;
- Decrease fertility and interfere with the body's natural hormones;
- Increase cholesterol;
- Affect the immune system; and
- Increase the risk of cancer.

PFCs are resistant to direct oxidation, photolytic degradation, biodegradation, and air stripping/vapor extraction, making their removal very difficult.

Does the EPA health advisory create a regulatory compliance issue for drinking water utilities?

EPA health advisories are not enforceable regulations. They provide information and recommendations to state agencies and public health officials on drinking water contaminants that may have human health effects. If PFOA and PFOS are detected in drinking water at individual or combined levels above 70 ppt, the EPA recommends that water systems:

- Perform additional sampling to confirm contamination levels;
- Notify the state drinking water agency and consumers;
- Take action to limit exposure from the drinking water supply.

What methods are successful in removing PFCs from drinking water, and which are most cost-effective?

Granular Activated Carbon

Granular activated carbon (GAC) has been used to treat drinking water for PFC removal for more than 15 years and can readily remove PFOA and PFOS to non-detectable levels. Recent laboratory column testing has also shown the successful removal of a variety of the smaller and harder to remove "short-chain" PFCs, including the butyl, pentyl, and hexyl compounds. Testing is critical to determine the expected carbon use rates and the economics of using GAC for PFC removal, since each water source contains varying levels of PFCs and total organic carbon (TOC). Spent GAC containing PFCs can be thermally reactivated, destroying the compounds and eliminating disposal liabilities. Reactivation is an attractive alternative, since the reactivated material can be reused with little to no effect on PFC removal efficiency, while reducing costs to roughly 80 percent of fresh media.

Membrane Filtration

Membrane filtration, a technique that uses a semi-permeable membrane filter to separate ions, dissolved molecules, and particles from fluids, also affords high levels of PFC removal. Membrane filtration results in a concentrated PFC waste stream that creates a disposal concern.

Ion Exchange

Ion exchange is a process that uses functionalized polymeric beads to separate substances based on their charge. Researchers have reported the removal of a variety of PFCs with various ion exchange resins. Ion exchange resins offer the attractive feature of being regenerable with a solvent. However, similar to the use of membranes, the ion exchange process results in a concentrated PFC waste stream that can be a disposal problem.

Some water treatment facilities have implemented GAC filtration systems to remove PFCs. What is GAC, and how does it work to remove these contaminants?

Activated carbon is a porous, high-surface area material. It is obtained via the controlled, thermal processing of carbonaceous materials like coal, coconut shells, or wood. This results in a material with randomly oriented graphitic plates that create a network of pores, many of which are less than 2 nm across. Attractive forces at the molecular level within these pores enable activated carbon to strongly adsorb a wide variety of organic species, including PFCs. In general, the larger and heavier an organic compound is, the more readily it will adsorb on activated carbon. Similarly, compounds with low solubility in water tend to adsorb better than highly-soluble species. Some fluoride-containing compounds can be less strongly adsorbed. However, given the long chain structure, high molecular weight, and moderate solubility in water, PFCs are very well adsorbed by GAC.

Can GAC remove additional contaminants, or are there other benefits to using GAC as a solution?

The U.S. EPA and most state-based health departments consider adsorption by GAC to be the best available technology for the removal of many organic materials in drinking water. On its own or paired with an ultraviolet (UV) disinfection system, GAC can facilitate the removal of:

- Disinfection byproducts (DBPs) associated with chlorine and alternative disinfectants;

- Volatile organic compounds, including carcinogenic compounds, such as 1,2,3 TCP, tetrachloroethylene (PCE), and trichloroethylene (TCE);
- Taste and odor-causing compounds;
- Organic materials from decaying plants and other naturally occurring matter which serve as the precursors for DBPs;
- Algal toxins, such as microcystin-LR, cylindrospermopsin, and anatoxin-A;
- Endocrine-disrupting compounds; and
- Pharmaceuticals and personal care products.

How is a GAC system properly sized to accommodate the flow and concentration of PFCs to ensure adequate removal of the contaminants — and are there options for expansion as flows increase due to growth?

Laboratory or pilot scale column tests, using a representative water sample, are recommended to accurately determine the required amount of activated carbon and predicted service life of the GAC system. If system expansion is required later, this can be accomplished by adding additional carbon adsorber vessels.

Systems operating in lead-lag or series configuration are recommended to protect consumers in the event of contaminant breakthrough. Once breakthrough occurs in the lead bed, flow would be diverted to the lag vessel while the GAC in the lead bed is replaced. After the GAC is replaced, the flow will be switched, so that the lag vessel is now the lead vessel and vice versa. This process ensures there is always fresh GAC in the second vessel to act as a polishing unit.

Does GAC need to be backwashed, replaced, or recycled on a regular basis, and if so, how often?

While GAC is in service, the activated carbon pores will begin to fill with adsorbed contaminants. Eventually, there will not be sufficient room or energy in the pore structure to effectively remove the contaminants, leading to breakthrough. At this point, the GAC should be replaced and recycled.

The frequency with which the GAC will need to be replaced depends on multiple factors. These include contaminant concentration, presence of background organics (TOC), and flow rate, which vary among utilities. Laboratory or pilot scale testing is needed with a representative water source to accurately determine GAC replacement frequency.

GAC systems can require periodic backwash, but this will vary on a case-by case basis. GAC will generally act as a 10 µm filter, catching any larger particulate matter. This accumulation will lead to an increased pressure differential in the system, which is alleviated through backwash.

If GAC adsorbs and filters contaminants from the drinking water, what ultimately happens to those concentrated wastes? How are they further treated or prevented from entering the water or air?

Incineration of any concentrated PFC waste is required for complete destruction — spent activated carbon containing adsorbed compounds can be thermally reactivated, destroying the adsorbed contaminants and allowing the activated carbon to be recycled and reused.

Reactivation furnaces are maintained under negative pressure ensuring there will be no leaks to the outside environment. ■