

## PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES (PFAS)

### Technologies for Reducing PFAS in Drinking Water

#### PFAS in the Environment

Per- and polyfluoroalkyl substances (PFAS) are a very large class of man-made chemicals that includes PFOA, PFOS and GenX chemicals. Since the 1940s, PFAS have been manufactured and used in a variety of industries in the United States and around the globe. PFAS are found in everyday items such as food packaging and non-stick, stain repellent, and waterproof products, including clothes and other products used by outdoor enthusiasts. PFAS are also widely used in industrial applications and for firefighting. PFAS can enter the environment through production or waste streams and can be very persistent in the environment and the human body. There is toxicological evidence that some PFAS can potentially cause adverse health effects in animals and humans.

EPA researchers have been studying a variety of technologies at bench-, pilot-, and full-scale levels to determine which methods work best to remove PFAS from drinking water. Some PFAS are soluble in water, and left unchecked, can make their way into our drinking water. Because of the chemical properties of PFAS, researchers have found that certain technologies are better able to remove some PFAS from drinking water than others, specifically perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), which are the most studied of these chemicals. Other PFAS, like Gen-X chemicals, can also be removed but to varying degrees.

Effective technologies include activated carbon adsorption, ion exchange resins, and high-pressure membranes, such as nanofiltration or reverse osmosis. These technologies can be used in drinking water treatment facilities, in water systems in hospitals or individual buildings, or even in homes at the point-of-entry, where water enters the home, or at a point-of-use, such as a kitchen sink or a shower.

#### Activated Carbon Treatment

Activated carbon treatment is the most studied treatment for PFAS removal. Activated carbon is commonly used to adsorb organic compounds in drinking water treatment systems. Adsorption is a process of accumulating a substance, such as PFAS, at the interface between liquid and solid phases. Activated carbon is an effective adsorbent because it is a highly porous material and provides a large surface area to which contaminants may adsorb. Activated carbon is made from organic materials with high carbon contents such as wood, lignite, and coal; and is often used in granular form called *granular activated carbon (GAC)*.

GAC has been shown to effectively remove PFAS from drinking water when it is used in a flow-through filter mode after particulates have already been removed from the water via conventional sand filtration, or a similar process. According to the research, GAC can be 100 percent effective for a period of time, depending on the specific PFAS that needs to be removed, the type of carbon used, the depth of the bed of carbon, flow rate of the water, temperature, and the degree and type of organic matter as well as the presence of other contaminants, or constituents, in the water.

For example, GAC works well on longer-chain PFAS like PFOA and PFOS, but shorter chain PFAS like perfluorobutanesulfonic acid (PFBS) and perfluorobutyrate (PFBA) do not adsorb as well resulting in earlier breakthrough, making GAC a more expensive treatment because it would need to be replaced, or reactivated, more often to have high efficiency. In addition, disposal of the PFAS removed during reactivation of the GAC must also be considered.

Another type of activated carbon treatment is *powdered activated carbon (PAC)* which is the same material as GAC, but it is smaller in size. Because of the small particle size, PAC cannot be used in a flow through bed, but can be added directly to the water

and then removed through filtration or in a clarification stage. Used in this way, PAC is not as efficient or economical as GAC at removing PFAS. Research finds that even at very high PAC doses with the very best carbon, it is unlikely to remove a high percentage PFAS; however, it can be used for modest percent removals. If PAC is used, the drinking water treatment plant will need to determine what disposal options are appropriate for the resulting sludge that contains adsorbed PFAS.

### Ion Exchange Treatment

Another treatment option is anion exchange treatment, or resins. Ion exchange resins are made up of highly porous, insoluble polymeric material. The resin beads that are used in a filtration mode are made from hydrocarbons. There are two broad categories of ion exchange resins: cationic and anionic. The negatively-charged ***cationic exchange resins (CER)*** are effective for removing positively-charged contaminants, and positively-charged ***anion exchange resins (AER)*** are effective for removing negatively-charged contaminants, like PFAS. Ion exchange resins are like tiny powerful magnets that attract and hold the contaminated materials from passing through the water system. Negatively charged ions of PFAS are attracted to the positively charged anion exchange resins. AER has shown to have a high removal capacity for many PFAS; however, it is typically more expensive than GAC. Of the different types of AER resins, perhaps the most promising are the PFAS-selective class of AER in a single use mode. Because this treatment technology does not need resin regeneration, there is no liquid contaminant waste stream from the regeneration process to consider, but the spent resin will need to be managed by either disposal or incineration.

Like GAC, AER removes 100 percent of the PFAS for a time that is dictated by the type of PFAS that needs to be removed, the choice of resin, bed depth, flow rate, and the degree and type of background organic matter and other contaminants or constituents.

### High-Pressure Membranes

High-pressure membranes, such as nanofiltration or reverse osmosis, have been extremely effective at removing PFAS. Of the two, reverse osmosis

membranes are tighter than nanofiltration membranes, and have higher percent removals.

Research shows that these types of membranes are typically more than 90 percent effective at removing a wide range of PFAS, including shorter chain PFAS. With both high-pressure membrane types, approximately 80 percent of the feed water (the water coming into the membrane) passes through the membrane to the effluent (the treated water). Approximately 20 percent of the feedwater is retained as a high-strength concentrated waste. A high-strength waste stream can be difficult to treat or dispose, especially for a contaminant such as PFAS. This technology may be best suited as a point-of-use technology for a homeowner, since the volume of water being treated is much smaller and the waste stream could be disposed of down the drain with less cause for concern. Use of high-pressure membranes used at the point-of-entry to a home or building may have a waste disposal problem because it is treating all the water used in that building and the waste stream will have a similarly higher flow rate. Also, high pressure membranes produce a treated water that is corrosive, and care must be taken (as is done at water utilities) to make sure this doesn't result in metal (lead and copper) corrosion of the building's premise plumbing and fixtures.

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For more information about drinking water technologies available for removing PFAS, please visit [EPA's Drinking Water Treatability Database](#).

This interactive literature review database contains more than 65 regulated and unregulated contaminants and covers 34 processes commonly employed or known to be effective. Users can search by contaminant or technology.