Reducing PFAS in Drinking Water with Treatment Technologies

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Per- and Polyfluorinated substances (PFAS) are a group of man-made chemicals that persist in the environment. These chemicals have been used for decades in consumer products to make them non-stick and water resistant. They are also found in firefighting foams and are applied in many industrial processes. Unfortunately, the characteristics that make them useful are the reason they persist in the environment and can bioaccumulate, or build up, in our bodies and the bodies of animals.

PFAS also dissolve in water, and combined with their chemical properties mean traditional drinking water treatment technologies are not able to remove them. Therefore, 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.

Certain technologies have been found to remove PFAS from drinking water, especially Perfluorooctanoic acid (PFOA) and Perfluorooctanesulfonic acid (PFOS), which are the most studied of these chemicals. Those technologies include activated carbon adsorption, ion exchange resins, and high-pressure membranes. 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 the point-of-use, such as in 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 natural organic compounds, taste and odor compounds, and synthetic organic chemicals in drinking water treatment systems. Adsorption is both the physical and chemical process of accumulating a substance, such as PFAS, at the interface between liquid and solids 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 (GAC) 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. EPA researcher Thomas Speth says, “GAC can be 100 percent effective for a period of time, depending on the type of carbon used, the depth of the bed of carbon, flow rate of the water, the specific PFAS you need to remove, temperature, and the degree and type of organic matter as well as 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.

Another type of activated carbon treatment is powdered activated carbon (PAC) which is the same material as GAC, but it is smaller in size, powder like. 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 with the other natural particulates in the clarification stage (conventional water treatment or low-pressure membranes - microfiltration or ultrafiltration). Used in this way, PAC is not as efficient or economical as GAC at removing PFAS. Speth says, “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 used, however, there is an additional problem with what to do with the 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, polymeric material that is acid, base, and water insoluble. The tiny beads that make up the resin 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 resins. AER has shown to have a high capacity for many PFAS; however, it is typically more expensive than GAC. Of the different types of AER resins, perhaps the most promising is an AER in a single use mode followed by incineration of the resin. One benefit of this treatment technology is that there is no need for resin regeneration so there is no contaminant waste stream to handle, treat, or dispose.

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

High-pressure Membranes

High-pressure membranes, such as nanofiltration or reverse osmosis, have been extremely effective at removing PFAS. Reverse osmosis membranes are tighter than nanofiltration membranes. This technology depends on membrane permeability. A standard difference between the two is that a nanofiltration membrane will reject hardness to a high degree, but pass sodium chloride; whereas reverse osmosis membrane will reject all salts to a high degree. This also allows nanofiltration to remove particles while retaining minerals that reverse osmosis would likely remove.

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 (treated water). Approximately 20 percent of the feedwater is retained as a high-strength concentrated waste. A high-strength waste stream at 20 percent of the feed flow can be difficult to treat or dispose, especially for a contaminant such as PFAS, according to Speth. Perhaps this technology is 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 more easily with less cause for concern.

For more information about drinking water technologies available for removing PFAS, please visit EPA's Drinking Water Treatability Database <https://oaspub.epa.gov/tdb/pages/general/home.do>. 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.

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