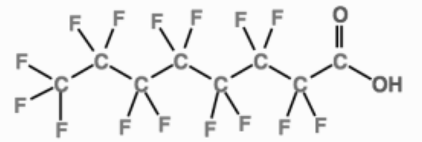
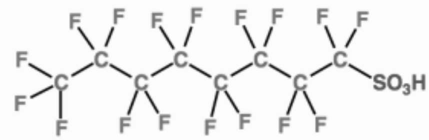
PERFLUORINATED CHEMICALS (PFCs)

Background

Perfluorinated chemicals (PFCs) are a large group of man-made compounds that are widely used in commercial products for more than 60 years. These chemicals feature unique properties of repelling both water and oil. Their unique properties come from the multiple carbon-fluorine (C-F) bonds present in their chemical structure. PFCs can resist heat, oil, stains, grease and water, and are used as coatings on clothing, carpets, furnishing, non-stick cookware, take-out fast food containers, and in fire-fighting foam. PFCs are very stable and hence persist in the environment for a very long time. Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are examples of PFCs or perfluoroalkyl substances (PFASs) that contain eight carbon atoms. PFOS and PFOA are byproducts of other commercial PFCs formulations and are released into the environment when PFC-containing products are used, made, or discarded.



PFOA - perfluorooctanoic acid



PFOS - perfluorooctanesulfonic acid

Health Concerns and Current Regulations

Due to their widespread use and resulting emissions, PFCs have been detected in surface water, groundwater, fish, birds, mammals, and humans worldwide, and even in remote regions like the Arctic (Calafat et al., 2007; Giesy and Kannan, 2001). PFOS and PFOA have been associated with developmental and reproductive toxicity (Lau et al., 2004), reduced growth metrics of newborns (Apelberg et al., 2007), and elevated total cholesterol levels in humans (Renner, 2001). In response to these concerns, PFOS and related products were phased out in the U.S. between 2000 and 2002, by their major global manufacturer. As part of U.S. Environmental Protection Agency's (U.S. EPA) stewardship program, several companies additionally committed to reduce the use and emissions of PFOA in

Table 1. Summary of U.S. state standards for PFCs (Source: ASDWA)

State	Standard	Compound	Level ($\mu g\ L^{-1}$)
California	Interim Response Level	Sum of PFOA & PFOS	70
Connecticut	Action Level	Sum of PFOA, PFOS, PFNA, PFHxS, PFHpA	70
Maine	Maximum Exposure Guidelines	Sum of PFOS & PFOA	70
Massachusetts	Office of Research & Standards Guideline	Sum of PFOA, PFOS, PFNA, PFHxS, PFHpA	70
Minnesota	Health Based Guidance	PFOA PFOS PFHxS	35 27 27
New Hampshire	Groundwater Quality Standard	Sum of PFOS & PFOA	70
New Jersey	Drinking Water Standard *Guidance Value	PFNA PFOA PFOS*	13 14 13
North Carolina	Health Advisory	GenX	140
Vermont	Groundwater Standard	Sum of PFOA, PFOS, PFNA, PFHxS, PFHpA	20
West Virginia	EPA Health Advisory	Sum of PFOA & PFOS	70

products (U.S. EPA, 2016). Currently, there is no established federal maximum contaminant level (MCL) for PFCs in drinking water. U.S. EPA has established a health advisory level of 70 parts-per-trillion (ppt) for the combined concentration of both PFOA and PFOS in drinking water. Many U.S. states have their own regulation or health advisory levels as shown in Table 1. The drinking water quality council of the New York State is currently in the process of setting a drinking water standard.

Available Treatment Technologies for PFCs

PFASs are highly resistant to biodegradation and hence are not efficiently removed in wastewater treatment plants and by naturally occurring microorganisms. PFASs are also not removed by conventional coagulation, flocculation and sedimentation processes. Additionally, advanced oxidation processes (AOP) that are effective in removing most organics, are not effective in treating PFAS. ***Granular activated carbon (GAC)*** has been successfully used to treat PFASs (Rahman et al., 2014). Greater than 90% removal for PFOS and PFOA has been observed for treatment with GAC filters. However, many studies also indicate that GAC performance is dependent on the carbon chain length of PFAS, with lower removal rates and/or shorter breakthrough times being observed for shorter chain PFAS (e.g. PFBA) compared to their longer chain counterparts. Additionally, presence of dissolved organic matter (DOM) can have competitive adsorption with PFAS and thus reduce the performance of GAC treatment. Hence, it has been suggested that frequent reactivation of carbon (~2-3 times per year) may be necessary to achieve consistent removal of PFAS from waters (Takagi et al., 2011). ***Ion-exchange (IE) treatment*** are also effective in removing PFAS from waters. Adsorption and electrostatic interactions are the two primary mechanisms proposed for removal of PFAS with IE resins. Research also indicates that IE may perform better than GAC treatment for shorter chain PFAS. IE is not a very common technique currently employed in water treatment processes but has been suggested to have the potential to be a promising technology (Rahman et al., 2014). ***Reverse osmosis (RO)*** membrane treatment is another effective technique that has shown to achieve >99% removal of PFAS from waters. However, RO is not widely used for municipal drinking water treatment due to the high cost and energy associated with the process. Additionally, the RO concentrate will be enriched with PFAS after treatment and hence its handling and disposal will serve as a challenge for scalability of this technology.

Research on PFAS at the NYS Center for Clean Water Technology

The Center is conducting research to address the increasing concern of PFAS contamination in NYS drinking water sources. The Center has established a NYS Department of Health-certified testing facility to monitor a wide suite of PFAS using state-of-the-art instrumentation and methods. The Center currently works closely with state, county, and local agencies to:

(i) evaluate the efficiency of existing treatment approaches (GAC, ion-exchange treatment, and advanced oxidation processes) in removing PFAS;

(ii) research and develop novel or refined treatment technologies (novel sorbents and/or combination of technologies) to enhance the removal of PFASs from drinking water; and,

(iii) scale-up, build and test the feasibility of using select novel/refined treatment technologies for pilot-scale treatment (point-of-use and point-of-entry) of contaminated drinking water.

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