GROUNDWATER INFORMATION SHEET

Perfluorooctanoic Acid (PFOA) & Perfluorooctanesulfonic Acid (PFOS)

The purpose of this groundwater information sheet is to provide general information regarding a specific chemical constituent of concern. The information provided herein relates to wells (groundwater sources) used for public drinking water, not water served at the tap.

GENERAL INFORMATION	
Constituent of Concern	Perfluorooctanoic acid (PFOA), Perfluorooctanesulfonic acid (PFOS)
Aliases	PFOA: C8, perfluorooctanoate, pentadecafluorooctanoic acid, perfluorocaprylic acid PFOS: Perfluorooctane sulfonic acid; Perfluorooctylsulfonic acid; Perfluorooctane sulfonate
Chemical Formula	$C_8HF_{15}O_2$ (PFOA), $C_8HF_{17}O_3S$ (PFOA),
CAS No.	335-67-1 (PFOA), 1763-23-1 (PFOS)
STORET Code	C2806 (PFOA), C2805 (PFOS)
Related Compounds	Perfluorononanoic acid (PFNA), Perfluorooctanesulfonamide (PFOSA), and numerous other fluorinated telomers.
Summary	PFOA and PFOS are manmade fluorinated chemicals that are part of a larger group of emerging chemicals of concern referred to as per- and polyfluoroalkyl substances (PFASs). These synthetic compounds are persistent and have been found at low levels in the environment and in humans. Toxicity studies have indicated that PFOA and PFOS can cause developmental and other adverse effects in laboratory animals. Under a PFOA Stewardship Program with the US Environmental Protection Agency (US EPA), eight manufacturers eliminated PFOA from emissions and products in 2015. PFASs are not currently regulated. On August 22, 2019, the State Water Resources Control Board issued a new drinking water notification level (NL) of 5.1 nanograms per liter (ng/L or parts per trillion) for PFOA and a NL of 6.5 ng/L for PFOS. California has tested drinking water supplies for PFOA, PFOS, and PFASs since 2013 as required by US EPA under the Unregulated Contaminant Monitoring Rule (UCMR 3). The results are published on the US EPA website referenced below.

REGULATORY AND WATER QUALITY LEVELS
The US EPA has established a lifetime Health Advisory Level (HAL) for PFOA and PFOS of 70 ng/L. When both PFOA and PFOS are found in drinking water, the combined concentrations of PFOA and PFOS should be compared with the 70 ng/L HAL. The State Water Resources Control Board (SWRCB) adopted the US EPA HAL of 70 ng/L as the California Response Level (RL). The SWRCB also established Notification Levels (NL) of 5.1 ng/L for PFOA and 6.5 ng/L for PFOS. When the NLs are exceeded, the Division of Drinking Water (DDW) recommends that the source be removed from service and treated. When the RL is exceeded, and concentrations cannot be reduced below the US EPA HAL, DDW recommends removing the source from service. https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/PFOA_PFOS.html Several states have groundwater quality regulations for PFOA. In West Virginia and Ohio, residents must be provided alternative drinking water when PFOA levels exceed 70 ng/L. Minnesota has adopted a Chronic Health Risk Limit of 300 ng/L for PFOA and PFOS in drinking water. In 2018, New Jersey recommended a health-based Maximum Contaminant Level (MCL) of 13 ng/L for PFOS, 14 ng/L for PFOA, and adopted an MCL for PFNA of 13 ng/L in drinking water.   Toxicological Data: Acceptable/Tolerable Daily Intake (ADI/TDI): PFOA - 1.5 micrograms per kilogram per day (µg/kg/day), PFOS - 0.15 µg/kg/day (Schriks et al., 2009). Reference Dose (RfD): Draft guidance indicates a RfD for PFOA of 0.02 µg/kg/day, and a RfD for PFOS of 0.03 µg/kg/day (US EPA, 2014[1]) Other health based advisory or guideline levels can be found in literature, but a complete list is beyond the scope of this fact sheet.

SUMMARY OF DETECTIONS IN PUBLIC DRINKING WATER WELLS

In 2012, US EPA revised the UCMR 3 to establish a new set of unregulated contaminants. Assessment monitoring (List 1 Contaminants) was required for all public water systems (PWS) serving more than 10,000 people and for the 800 representative PWS serving 10,000 or fewer people. Assessment monitoring was required of each PWS during a 12-month period from January 2013 – December 2015. PFOA, PFOS, and four other PFASs are included on the List 1 Contaminants. Results for California monitoring, and other participating states are published on the US EPA web site referenced below.

ANALYTICAL INFORMATION

Some analytical methods using liquid chromatography-mass spectrometry-electrospray ionization methods (LC/MS/ESI) are able to achieve reporting limits for PFOA and PFOS at the nanogram per liter level. For the UCMR 3 monitoring program, LC/MS/MS-EPA Method 537 rev 1.1 was required with minimum reporting limits of 20 ng/L and 40 ng/L for PFOA and PFOS, respectively.

In November 2018, revised EPA Method 537.1 was published. This method can detect PFOA, PFOS, and 16 others per- and poly-fluorinated alkyl substances at reporting limit from 0.63 ng/L to 6.3 ng/L.

Compliance with California's new NLs of 5.1 ng/L (PFOA) and 6.5 ng/L (PFOS), will require reporting limits that are lower than can be achieved with EPA 537. US EPA Method 537.1 is reportedly able to achieve lowest concentration minimum reporting levels (LCMRL) of 0.82 ng/L (PFOA) and 2.7 ng/L (PFOS). An LCMRL is defined as the lowest true concentration for which the future recovery is predicted to fall, with 99% confidence, between 50 and 150% recovery of the matrix spike (US EPA, Method 537.1, 2018).

<table>
<tr><th colspan="2">OCCURRENCE</th></tr>
<tr><td>Anthropogenic Sources</td><td>According to the US EPA, PFASs are a class of chemicals not found naturally in the environment. PFOA and PFOS are the most extensively produced and studied of these chemicals and are very persistent in both the environment and the human body.

These compounds are used to make materials resistant to stains, water-proof, and non-stick. Examples include: non-stick cookware, furniture, carpets, mattresses, clothing, and food packaging. Additional uses include fire suppression and friction modifiers for the aerospace, automotive, construction and electronic industries. PFOA can also form as a degradation byproduct from other types of PFASs.

Some PFASs, including PFOA and PFOS are no longer manufactured in the United States (voluntary phase-out program), except for some accepted industrial processes such as in semiconductors, printed circuits, aviation equipment, defense, pesticides, and solar panels.

Although most of these chemicals are no longer manufactured in the United States, other countries still produce PFOA and PFOS and products that contain them may be imported. According to the US EPA, manufactured goods include carpets, leather and apparel, textiles, paper and packaging, coatings, and rubber and plastics.</td></tr>
<tr><td>Natural Sources</td><td>PFASs are human made substances and are not found naturally in the environment.</td></tr>
<tr><td>History of Occurrence</td><td>Production of PFASs began in 1949, with peak production years from 1970 to 2002.

In 2006, the US EPA invited eight companies producing PFASs to join a global stewardship program with a purpose to:
Achieve a 95 percent reduction in facility emissions to all media of PFOA, precursor chemicals that can break down to PFOA and other chemicals, and product content levels of these chemicals.
Commit to working toward the elimination of these chemicals from emissions and products by 2015.
According the US EPA, all eight companies have met the program goals.</td></tr>
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Contaminant Transport Characteristics	PFASs are characterized by a hydrophobic and lipophobic tail, and a polar and hydrophilic head. Perfluoroalkyl acids, including PFOA and PFOS, have high solubility and low sorption (log K_{oc} 2.06 for PFOA and 2.57 for PFOS, respectively). PFOS and PFOA can result from degradation of precursor substances but are stable end products themselves (US EPA, 2014[2]). Sorption to soil and sediment increases with carbon chain length and sulfonates are also more sportive than carboxylates. PFOA has been detected in groundwater at several sites in the United States, most frequently in locations associated with manufacturing and disposal of PFOA and related compounds. While the atmospheric half-life is 90 days for PFOA and 114 days for PFOS, their half-life in water is greater than 90 years for PFOA and greater than 41 years for PFOS (US EPA, 2014[2]).

REMEDIATION & TREATMENT TECHNOLOGIES
In treatment systems, activated carbon (GAC) has been extensively studied and for PFAS removal and has been shown to have success in removing longer chain PFAS like PFOA and PFOS. Reverse osmosis and nano-filtration are also effective in removing PFAS from water. Anionic resin-based treatment systems are currently being tested at a landfill in Minnesota. Removing PFASs from solids may require excavation and landfilling or incineration, or desorption through ex situ mixing or thermal processes (ITRC, 2018). Recent evidence suggests that many other degradation techniques may be effective. These methods include photocatalytic oxidation, photochemical oxidation, photochemical reduction, thermally-induced reduction, and sonochemical pyrolysis. The effectiveness depends upon the initial concentration of the constituent, background water chemistry, and degradation time.

HEALTH EFFECT INFORMATION
Potential human exposure pathways include ingestion of food and water, inhalation of particulate matter containing PFAS, and use of certain consumer products containing PFAS. Both PFOA and PFOS have been identified in drinking water supplies. These locations were typically associated with industrial use or disposal locations as well as manufacturing sites. The half-life of PFOA and PFOS in humans range from 2 to 9 years. Acute and intermediate-duration oral studies on laboratory rodents have raised concerns about potential developmental, reproductive and other systemic effects of PFOS and PFOA. Studies indicate that continued exposure to low levels of PFOA in drinking water may result in adverse health effects. The ingestion of PFOA-contaminated water was found to cause adverse effects on mammary gland development in laboratory mice. One study indicated that exposure to PFOS can affect the neuroendocrine system in laboratory rats; however, the mechanism by which PFOS affects brain neurotransmitters is unclear. The animal studies also show reduced birth

size, physical developmental delays, endocrine disruption, and neonatal mortality. The US EPA has also identified suggestive evidence that PFOS and PFOA may cause cancer (US EPA, 2017).

In December of 2009, California's Office of Environmental Health Hazard Assessment (OEHHA) prioritized PFOA and related salts, transformation, and degradation products for possible listing under Proposition 65. Listing under Proposition 65 would require manufacturers to disclose the presence of PFOA as a potential carcinogenic compound in materials in which PFOA and related compounds were present.

In August 2015, OEHHA proposed that PFOA and PFOS be reviewed by the Developmental and Reproductive Toxicant Identification Committee (DARTIC) under Proposition 65. These chemicals were not proposed for listing, however OEHHA is currently seeking public comments and the DARTIC consultation regarding if these chemicals should proceed to the next stage of the listing process.

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