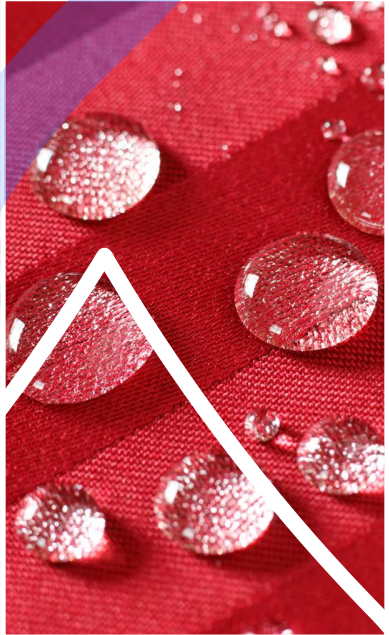
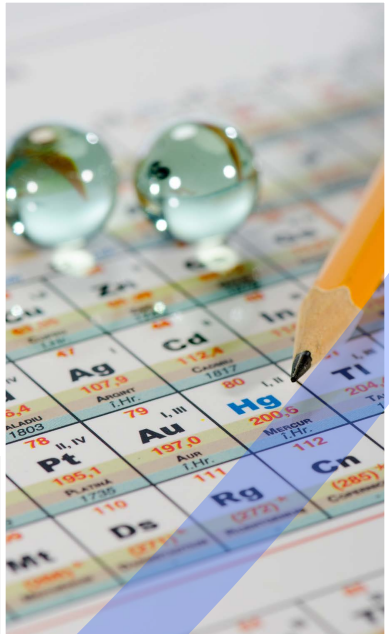


# Polyfluorinated & Perfluorinated Substances (PFAS)

## The PFAS Experts

- Responsible Party Identification
- GIS and Geomatics
- Contaminant Hydrogeology
- Fate and Transport Modeling
- Risk Assessment
- Remediation Feasibility Studies
- Soil and Groundwater Remediation
- Natural Resource Damage Assessment
- Water Resources Assessment
- Source Water Assessment and Protection
- Drinking Water Treatment
- Environmental Risk Management
- Litigation Support/Expert Witness
- Forensic Engineering
- Stakeholder/Public Participation
- Regulatory Strategy



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## Polyfluorinated and Perfluorinated Alkyl Substances in the Environment

Polyfluorinated and Perfluorinated Alkyl Substances (PFAS's) are a large group of manufactured chemicals that have been widely used for over 50 years to make everyday products more resistant to stains, grease, and water and include over 6,000 different chemicals. PFASs are used to keep food from sticking to cookware, to make sofas and carpets resistant to stains, or to make clothes and mattresses more waterproof. They are also used in some food packaging, as well as in some fire-fighting materials. Because they help reduce friction, they are also used in a variety of other industries, including aerospace, automotive, building and construction, and electronics.

In May 2016, the United States Environmental Protection Agency (USEPA) announced the release of lifetime health advisories (HAs) for the PFASs perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS). The

### Key Points

- Limited evidence of health effects on humans
- Highly soluble in water
- Extremely stable
- Resistant to hydrolysis, photolysis, or biodegradation
- Extremely persistent in the environment
- Mobile in soil and leaches to groundwater

HA identified a concentration of 0.07 micrograms per liter (ug/L), or 70 parts per trillion (ppt) in drinking water, below which PFOA and PFOS were not anticipated to result in adverse health effects over a lifetime of exposure. This updated health advisory concentration supersedes the 2009

provisional HAs for PFOA and PFOS of 400 ppt and 200 ppt, respectively. USEPA Method 537, developed in 2009, and has only been validated for only 14 different PFAS's (see table below).

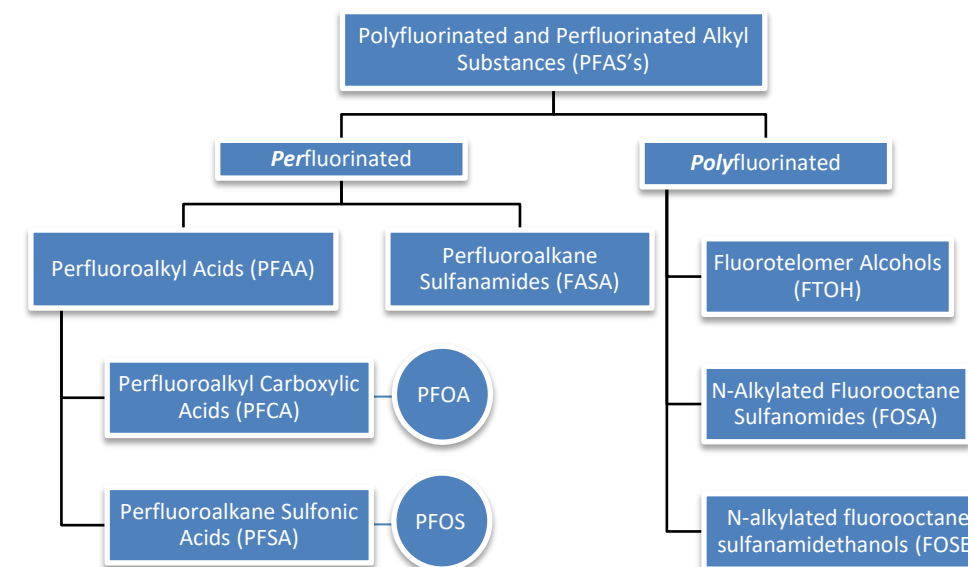
PFOS and PFOA compounds are highly soluble in water and have very low volatility due to their ionic nature, and as a result, the use of conventional treatment technologies can be difficult. In groundwater, the most common treatment is extraction and filtration through granular activated carbon (GAC). This technology has been shown to consistently remove PFOS to parts per billion concentrations with an efficiency of 90%; however, it is not as efficient at removing PFOA and other PFASs. Alternative treatment technologies for groundwater include ion exchange, surfactant and ultrasonic (sonochemical) treatment, reverse osmosis and advanced oxidation (AOP).

### PFAS's Commonly Evaluated in Drinking Water

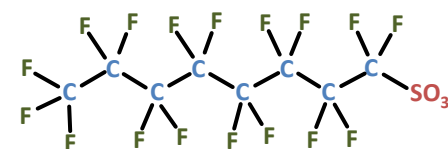
PFAS	Acronym	Under Study by NIEHS and NTP <sup>1</sup>	Included in EPA Method 537
Perfluorobutane sulfonate	PFBS (C4)	•	•
Perfluorohexanesulfonic acid	PFHxS (C6)	•	•
Perfluorohexanoic acid	PFHxA (C6)	•	•
Perfluoroheptanoic acid	PFHpA (C7)		•
Perfluorooctanesulfonic acid	PFOS (C8)	•	•
Perfluorooctanoic acid	PFOA (C8)	•	•
Perfluorononanoic acid	PFNA (C9)	•	•
Perfluorodecanoic acid	PFDA (C10)	•	•
Perfluoroundecanoic acid	PFUnA (C11)		•
Perfluorodecanoic acid	PFDoA (C12)		•
Perfluorotetradecanoic acid	PFTA		•
Perfluorotridecanoic acid	PFTTrDA		•
N-ethyl perfluorooctanesulfonamidoacetic acid	NEtFOSAA		•
N-methyl perfluorooctanesulfonamidoacetic acid	NMeFOSAA		•

1. Currently studied by National Institute of Environmental Health Sciences (NIEHS) and National Toxicology Program (NTP)

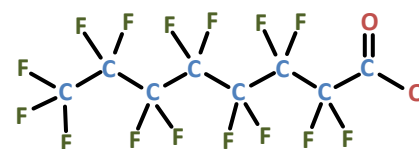
## PFAS Classification System



### PFOS - Perfluorooctanesulfonic Acid



### PFOA - Perfluorooctanoic Acid



### Selected Properties of PFOA and PFOS

Property	Units	PFOS	PFOA
Molecular Weight	gram/mole	538	414
Density	g/cm <sup>3</sup>	1.8	1.8
Melting Point	(°C)	> 400	40 - 50
Boiling Point	(°C)	133	188
Vapor Pressure	mm Hg at 20°C	2.48e <sup>-6</sup>	0.017
Solubility	mg/L at 25°C	570	9,500
Henry's Constant (K <sub>h</sub> )	atm*m <sup>3</sup> /mole	3.05e <sup>-9</sup>	Not Measurable
Partition Coefficient (log K <sub>ow</sub> )	---	Not Measurable	Not Measurable
Sorption Coefficient (log K <sub>oc</sub> )	---	2.57	2.06
Half-Life in Water	years at 25°C	> 41	> 92
<b>Health Advisory (2016)</b>	<b>ug/L</b>	<b>0.07 (combined)</b>	
<b>Health Advisory (2009)</b>	<b>ug/L</b>	<b>0.2</b>	<b>0.4</b>

U.S. EPA. (2012). Emerging Contaminants – Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA). May.  
 U.S. EPA. (2016). Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). May  
 U.S. EPA. (2016). Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOA). May