EMERGING CONTAMINANTS
POLY- AND PERFLUOROALKYL SUBSTANCES (PFAS)

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Presented by

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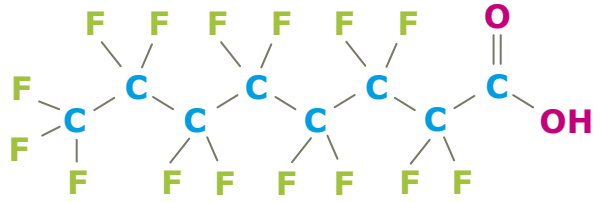
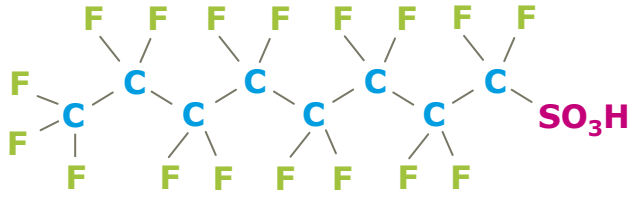
WHAT ARE PFAS?

1. PFAS is generic term for a large subclass of fluorinated chemicals
2. Used in a wide range of industrial applications, commercial products, and fire fighting foams
3. Unique because of their ability to repel oil, grease and water
4. Exceptionally stable, non-reactive chemicals, resistant to degradation naturally and heat resistant
5. Relatively mobile in the environment, moderately soluble
6. May be subject to long-range transport



PFOA – perfluorooctanoic acid



PFOS – perfluorooctanesulfonic acid

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WHAT ARE THE SOURCES OF PFAS?

→ PFAS are man-made chemicals, not naturally occurring

PFOA Historical Uses

- AFFF
- Food packaging
- Dyes, polishes, adhesives, lubricants
- Photolithographic industry
- Insecticides, herbicides
- Teflon production

PFOS Historical Uses

- AFFF
- Food packaging
- Textile, carpets, furniture, outdoor clothing (e.g., Stainmaster, Scotchguard and Goretex)
- Oil and gas industry
- Polishes, ink, paint, varnishes
- Metal and plastic coatings
- Coating of photographic films, printing plates
- Detergents, carpet cleaners
- Insecticides
- Cleaning fluids, shampoos, hand creams
- Hydraulic fluids

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PFAS: A PERSPECTIVE FROM THE US

Still considered an "Emerging Contaminant"

- Pose a real or perceived threat to human health or to the environment
- Not currently regulated or have regulations pending
- New source has been identified or a new exposure pathway to humans has been discovered
- New detection method or a new water treatment technology has been developed

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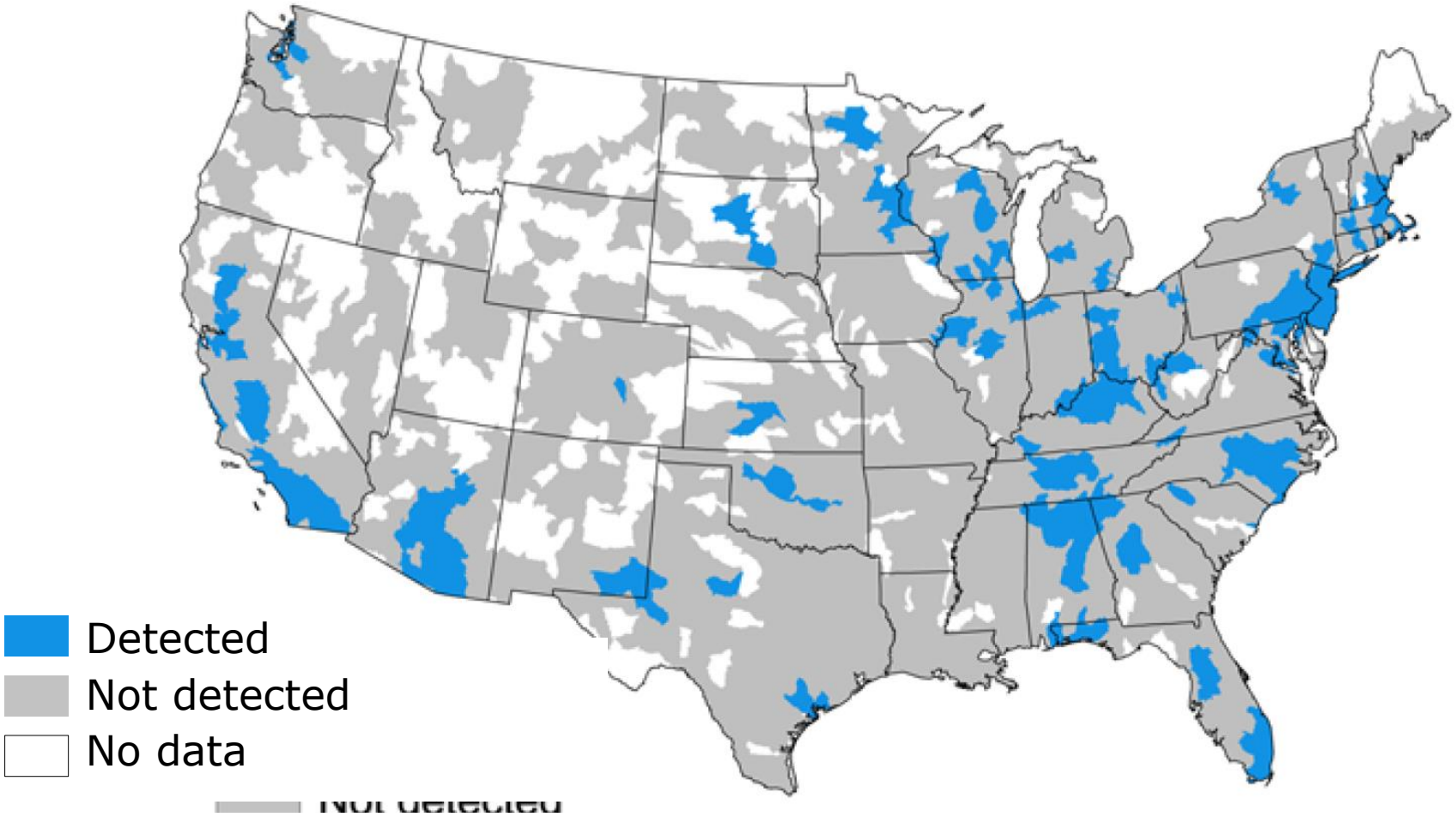
CONTINUING CONCERNS
DRINKING WATER SUPPLIES



From Hu et. al. 2015. Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants. ES&T Letters. July.

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RECENT NEWS ARTICLES IN US

Military bases' contamination will affect water for generations

August 29, 2017

Scotchgard chemical ails fish where tannery scraps litter river

August 23, 2017

Report: 15 Million Americans' Drinking Water Tainted By Toxic Chemical

The chemicals, known as PFCs, have been linked to health issues but are mostly unregulated.

June 8, 2017

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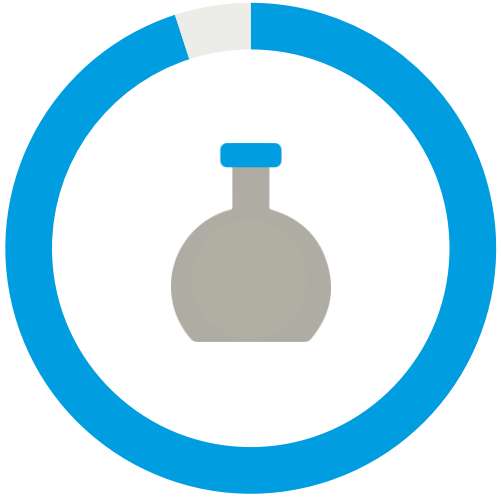
EXPOSURE



+95%

of individuals sampled detected PFAS

- Contact in the work place
- Some studies suggest principal source for general public is from food containing PFOA
- Ingestion of drinking water for individuals living in areas with PFAS-contaminated water supplies due to releases to the environment
- Direct contact with products such as treated carpets and upholstery

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IN THE BODY

Readily absorbed
Not metabolized

Distributed predominantly to the liver and blood (serum)

Leaves the body through urine and feces

Reabsorbed to the body to an extent after excretion into urine and bile

Can cross the placenta and be present in breast milk

Median elimination half life for exposed community

= 840 days (2.3 years)

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TOXICOLOGY

- Animal studies indicate impacts to the liver, changes in hormone levels and adverse developmental outcomes
- To date there is not enough information available to definitively say if there are human health effects. Possible health effects include the following:
  - Increased cholesterol levels?
  - Increased uric acid levels?
  - Increased risk for high blood pressure?
  - Liver?
  - Immune system?
  - Nervous system?
  - Endocrine system?
  - pregnancy induced hypertension?
  - Possibly carcinogenic?

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WHAT REGULATORY LEVELS EXIST?

1 In 2009, USEPA issued Drinking Water Provisional Health Advisory Levels of 400 ng/L and 200 ng/L for PFOA and PFOS, respectively, for short term exposure (weeks to months)

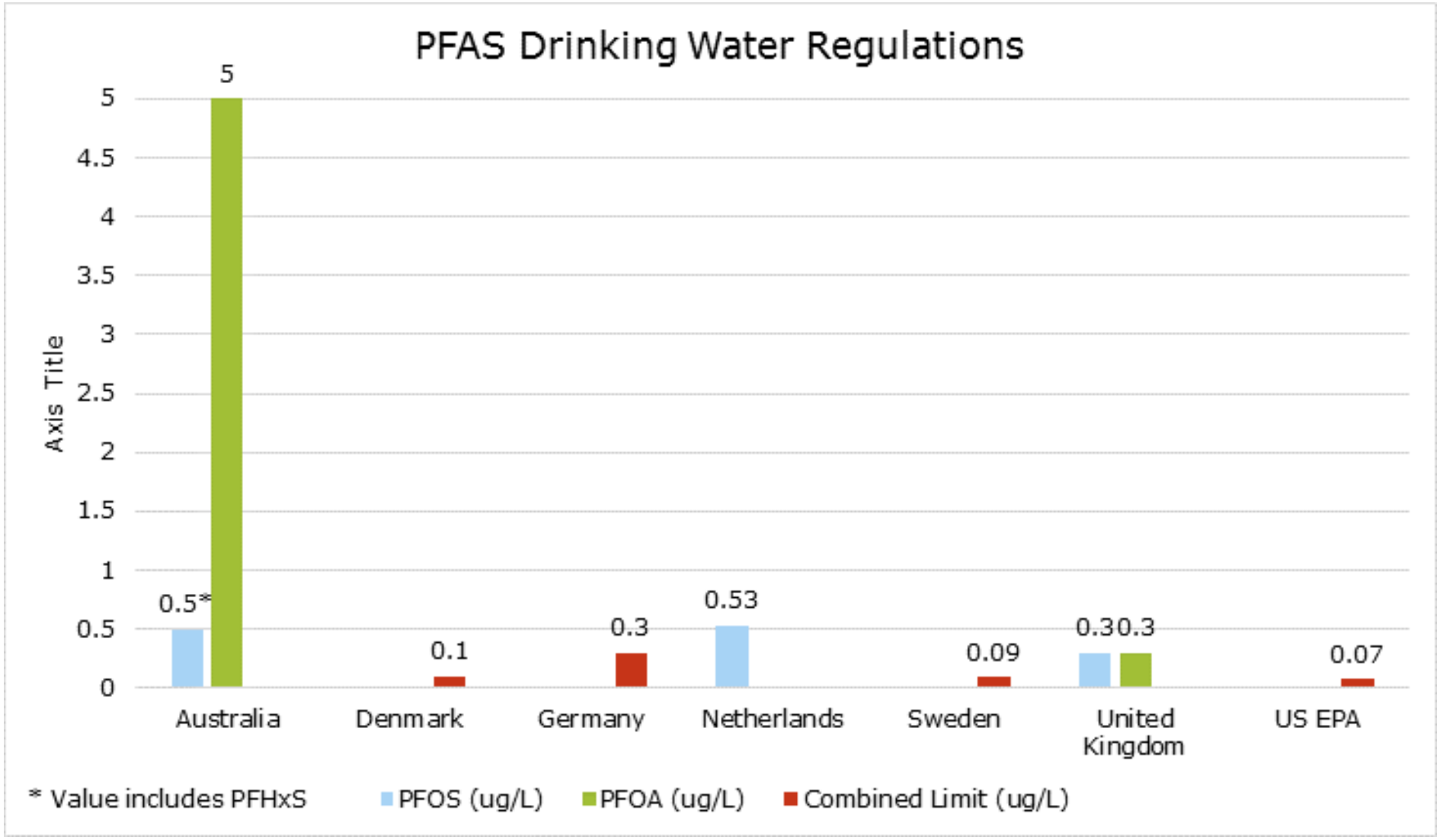
2 In 2016, USEPA issued a Drinking Water Health Advisory Levels for PFOA and PFOS with a combined concentration of 70 ng/L for long term exposure

3 No Maximum Contaminant Level (MCL) established yet for drinking water

4 Most states do not yet regulate PFAS in groundwater. Some defer to EPA's drinking water health advisory level, and a few are even lower (NJ and VT).

5 Most states do not yet regulate PFAS in soil. Only a few states have established regulatory thresholds.

INTERNATIONAL REGULATORY THRESHOLD VALUES



TREATMENT OPTIONS

Challenges

- Extremely stable
  - Do not hydrolyze, photolyze, or biodegrade under typical environmental conditions
- Are extremely persistent in the environment
- For example the half-life (at 25º C) in water for PFOA and PFOS is > 92 years and > 41 years, respectively
- High potential to absorb to substrates
  - Migration depends upon groundwater flow and the charge of the substrate
  - Existing treatment processes ineffective / limited
- Waste disposal costs
- Unintended (and unknown) end products

Currently in use

- Adsorptive Media – GAC proven for water, but expensive and may not be broadly applicable to treat full suite
- Ion Exchange - expensive
- Thermal – requires high temp, expensive
- Excavation & Landfill – prohibited or require pre-treatment

Emerging?

- Biological – not proven
- Chemical – emerging, but efficacy not proven
- Fixation -

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TREATMENT OPTIONS – DRINKING WATER

- Granular activated carbon (GAC) is most preferred & implemented technology
- Other adorptive media available
- Ion exchange resins or reverse osmosis (RO) can also be utilized

RECOMMENDATION ON PERFLUORINATED COMPOUND TREATMENT OPTIONS FOR DRINKING WATER. NEW JERSEY DRINKING WATER QUALITY INSTITUTE TREATMENT SUBCOMMITTEE, JUNE 2016

Treatment option	Notes	Removal rates		
		PFNA	PFOA	PFOS
Activated carbon	**Granulated – GAC is the most common treatment method for long-chain PFC removal. Competition for adsorption with other contaminants can reduce effectiveness. Thermal regeneration of GAC is effective.** Powdered – High concentrations of PAC necessary. PAC may be useful in responding to spills but the required high concentrations may make this an infeasible option. PAC combined with waste residuals may create a challenge for disposal of waste products.	>90%	**>90%**	>90%
Membrane filtration	Multi-contaminant removal. Rejection rate can be high. Waste/byproducts must be managed. Mineral addition may be necessary.	>90%	>90%	>90%
Anion exchange	Single-use systems do not produce contaminant-containing brine but required replacement and proper disposal. Regenerable systems produce brine that must be disposed of responsibly; such systems are automated, have small footprints and high regeneration efficiencies. Competition with common ions for binding sites on resins can impact effectiveness.	>67%	10-90%	>90%
Advanced oxidation	Low removal rate. Can destroy pollutants to produce less complex compounds. Other organic contaminants will compete for hydroxyl radicals and reduce efficiency.	<10%	<10%	<10-50%

Sources: Hohenstein, Gary. Overview of Remediation Technologies. Presentation at Emerging Contaminants Summit. Denver, CO. March 2016.
NJDEP, Recommendation on Perfluorinated Compound Treatment Options for Drinking Water, New Jersey Drinking Water Quality Institute Treatment Subcommittee, June 2015.

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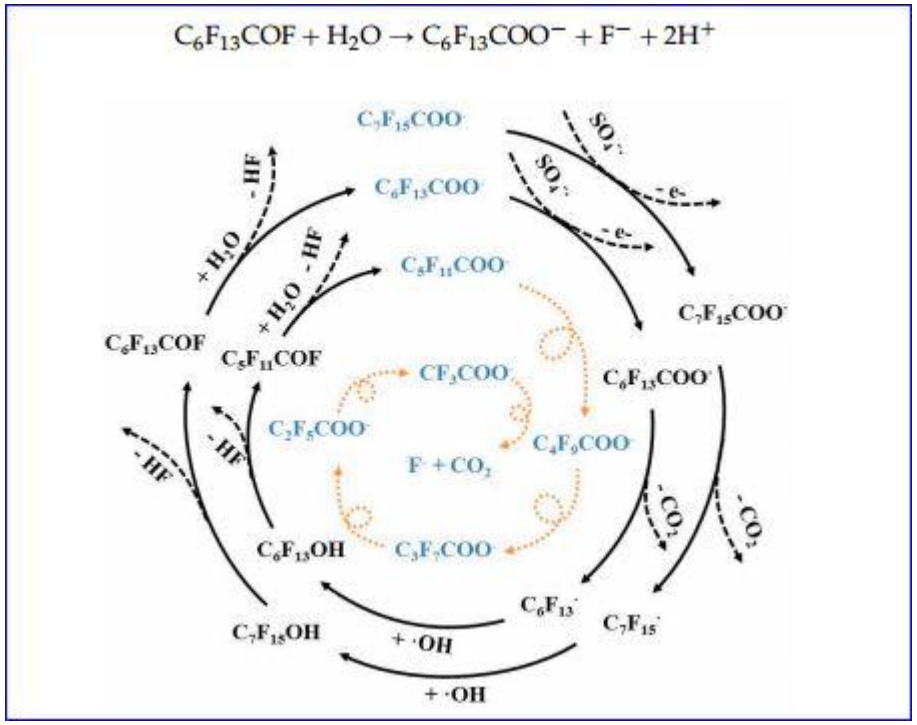
TREATMENT OPTIONS – EMERGING TECHNOLOGIES

- Oxidation via conventional methods is difficult due to strength of the C-F bond and may lead to higher PFCA / PFSA levels as a result of precursor breakdown using oxidants
- Approaches being evaluated include
  - Persulfate under acidic conditions + high temperature
  - Ozonation



Activated Persulfate Oxidation of Perfluorooctanoic Acid (PFOA) in Groundwater under Acidic Conditions. P. Yin, et al. 2016

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REMEDIATION TECHNOLOGY SUMMARY

Technology	Status	Media		In-Situ	Ex-Situ	Treatment Type	Precursor Concerns	Cost	Efficiency	Other
		Soil	Groundwater							
P&T, with GAC	🟢		🟢	?	🟢	A	🟢	🔴	🟢	Secondary treatment/disposal required for adsorptive media, not as efficient for PFOA and other PFAS
P&T, with synthetic resin (ion exchange)	🟡		🟢	?	🟢	A	🟢	?	🟢	Media can be regenerated on-site, still in research stage
Advanced Chemical Oxidation	🟡	🟡	🟢	🟢		D	🔴	🔴	🟡	Conditions to destroy PFAS are difficult to apply at full scale for in-situ remediation
Sonochemical Decomposition	🟡		🟢		🟢	D	🔴	?	🔴	28% PFOS decomposition achieved in studies, still in early stages of research
Air Separation	🟡		🟢	?	🟢	S	🟢	🔴	🟢	Secondary treatment/disposal required for separated concentrate
Filtration, Reverse Osmosis	🟡		🟢		🟢	S	🟢	?	🟢	Pretreatment required to increase filtration efficiency, still experimental
Nanofiltration	🟡		🟢		🟢	S	🟢	?	🟡	Pretreatment required to increase filtration efficiency, limited in total processing capacity
Excavation and Incineration	🟢	🟢			🟢	D	🟢	🔴	🟡	High temperature incinerators required to completely destroy PFOS and PFOA
Stabilization	🟡	🟢	🟡	?	🟢	A	🟢	🟢	?	RemBind and matCARE are emerging PFAS in-situ treatment options
A=Adsorption										
D=Destructive										
S=Separation										

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SOME TAKEAWAYS

1. Unique properties → stable, mobile, and degradation resistant
2. Found in GW mostly in areas where used in manufacturing or at fire training sites
3. Exposure predominantly via food or in drinking water in areas with impacted drinking water supplies
4. Not metabolized in body, can remain in body for longer periods of time
5. Standards are changing → different Agencies making different science-policy choices
6. Proven treatment technologies are limited

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THANK YOU

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