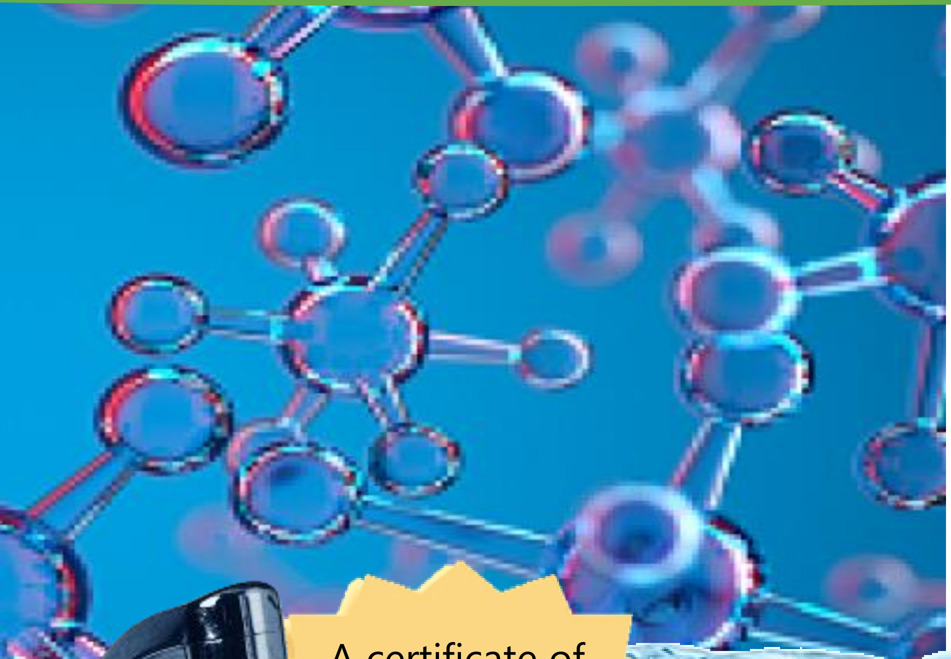
Small Drinking Water Systems Webinar Series

Hosted by EPA's Office of Research and Development and Office of Water

epa.gov/water-research/small-drinking-water-systems-webinar-series



April 30, 2024

PFAS Drinking Water Regulation and Treatment Methods

A certificate of attendance will be provided for this webinar

Webinar Slides: Will be attached to the chat.

To Ask a Question: Select **Q&A** at the bottom of the screen. Type your question in the compose box, and then select send**.** You have the option to submit questions anonymously.

Participation Poll

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- There is one question: *"How many participants are viewing this webinar at your location?"*
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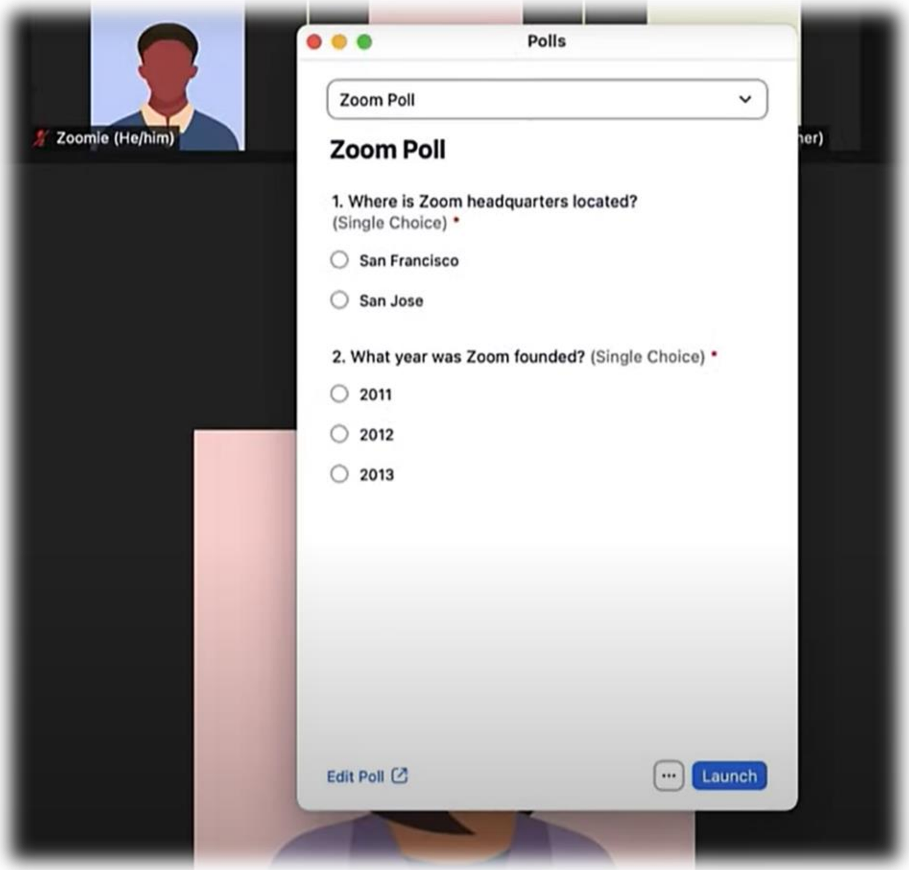
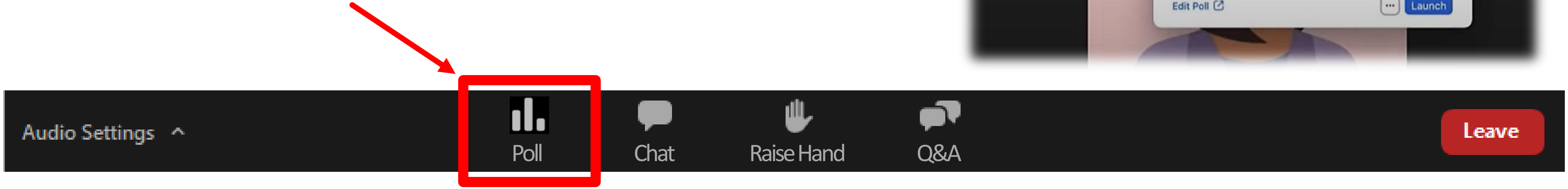




Messages From the Organizers

Messages, links to information, and attachments will be added to the Chat box throughout the presentation.

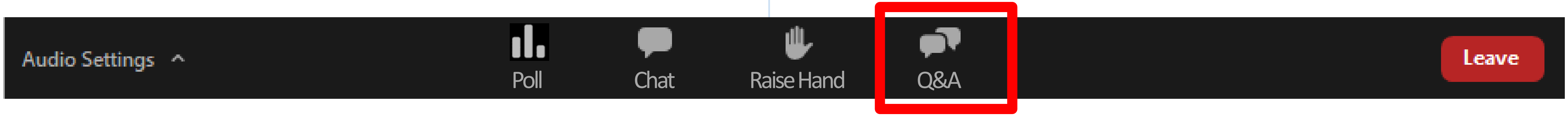
Only organizers and presenters can send information in the Chat box.

To Ask a Question

1. Select the **Q&A** icon at the bottom of your screen.

2. Type your question in the compose box, and then select **send.** You have the option to submit questions anonymously.

If you lose access to Zoom and are not able to communicate in the Q&A box, send an email to EPA-Webinar-SDWS@icf.com



Submitted questions can only be seen by the organizers and presenters.

To Receive a Certificate of Attendance

1. You must have registered with your name and email or be in a room with someone who did.
2. Attend the webinar for at least 60 minutes.
3. If you are attending with someone registered and viewing on the same computer, the person logged in must send the full names and emails of the additional participants to EPA-Webinar-SDWS@icf.com.

Note

Acceptance of certificates is contingent on organization requirements—EPA cannot guarantee acceptance. Closed-captioned recordings of the webinars are provided below for later viewing and as a training resource; certificates cannot be provided for viewing webinar recordings.

Small Drinking Water Systems Webinar Series

Technical Assistance for Lead

May 21, 2024 from 2 to 3:30 p.m. ET

Registration and additional information coming soon!

EPA hosts webinar series dedicated to delivering the latest information and training on our cutting-edge research addressing environmental and public health issues.

Webinar dates and topics are subject to change.

Presentation 1

Overview of EPA's Final PFAS National Primary Drinking Water Regulation

This presentation provides an overview of the final PFAS National Primary Drinking Water Regulation, including the key regulatory requirements and timing for water systems and drinking water primacy agencies to comply with these requirements, background on the regulation development, and funding information to support rule implementation.

Ashley Greene, EPA Office of Water | PFASNPDWR@epa.gov

Ashley has over 15 years of experience as a physical scientist in EPA's Office of Water. She currently works in OW's Office of Ground Water and Drinking Water on the development and review of drinking water rules and regulations under the Safe Drinking Water Act, including the PFAS drinking water rule.

Final PFAS National Primary Drinking Water Regulation

“ Every American deserves to be able to turn on their water tap or faucet and be able to drink clean water.

- **Joseph Biden**, President of the United States

Overview

“PFAS pollution in drinking water has plagued communities across this country for too long. Today, I am proud to finalize this critical piece of that Roadmap, and in doing so, save thousands of lives and help ensure our children grow up healthier.

- EPA Administrator **Michael Regan**

Key Messages

- PFAS exposure over a long period of time can cause cancer and other illnesses that decrease quality of life or result in death.
- PFAS exposure during critical life stages such as pregnancy or early childhood can also result in adverse health impacts.
- PFAS pollution can have disproportionate impacts on small, disadvantaged, and rural communities already facing environmental contamination.
- As the lead federal agency responsible to protect drinking water, EPA is using the best available science on PFAS to set national standards.

Key Messages

- The Biden-Harris Administration has finalized the first-ever national drinking water standard for per- and polyfluoroalkyl substances (PFAS).
- EPA is issuing this rule after reviewing extensive research and science on how PFAS affects public health, while engaging with the water sector and with state regulators to ensure effective implementation.
- EPA also considered 120,000 comments on the proposed rule from a wide variety of stakeholders.
- The final rule will reduce PFAS exposure for approximately 100 million people, prevent thousands of deaths, and reduce tens of thousands of serious illnesses.

Summary of Final Rule

“EPA is taking a signature step to protect public health by establishing legally enforceable levels for several PFAS known to occur individually and as a mixture in drinking water.

- **Jennifer McLain,** Director
Office of Ground Water and Drinking Water

Regulatory Levels: Maximum Contaminant Level Goals

- EPA is taking a signature step to protect public health by establishing levels for several PFAS known to occur individually and/or in a mixture in drinking water.

- For PFOA and PFOS, EPA is setting a non-enforceable health-based goal of **zero**. This is called a Maximum Contaminant Level Goal (MCLG).
  - This reflects the latest science showing that there is no level of exposure to these two PFAS without risk of health impacts.

- For PFNA, PFHxS, and HFPO-DA (GenX Chemicals), EPA is setting MCLGs of **10 parts per trillion**.

Regulatory Levels: Maximum Contaminant Levels

- EPA is setting enforceable Maximum Contaminant Levels (MCLs) at **4.0 parts per trillion** for PFOA and PFOS, individually.
  - This standard will reduce exposure from these PFAS in our drinking water to the lowest levels that are feasible for effective implementation.
- For PFNA, PFHxS, and HFPO-DA (GenX Chemicals), EPA is setting MCLs of **10 parts per trillion.**

Regulatory Levels: Hazard Index

- EPA is also regulating, through a Hazard Index (HI), mixtures of four PFAS: **PFHxS, PFNA, HFPO-DA,** and **PFBS**.
- Decades of research show some chemicals, including some PFAS, can combine in mixtures and have additive health effects, even if the individual chemicals are each present at lower levels.
- PFAS can often be found together and in varying combinations as mixtures.

Regulatory Levels: Hazard Index

- The Hazard Index is a long-established approach that the EPA regularly uses, for example in the Superfund program, to determine the health concerns associated with exposure to chemical mixtures.

- The Hazard Index is calculated by adding the ratio of the water sample concentration to a Health-Based Water Concentrations.

$$HI\ MCL = \left(\frac{[HFPO{-}DA_{water}]}{[10\ ppt]}\right) + \left(\frac{[PFBS_{water}]}{[2000\ ppt]}\right) + \left(\frac{[PFNA_{water}]}{[10\ ppt]}\right) + \left(\frac{[PFHxS_{water}]}{[10\ ppt]}\right) = 1$$

- Details are provided in EPA Hazard Index Fact Sheet.

Hazard Index MCL Calculation Examples

	HFPO-DA		PFBS		PFNA		PFHxS		Hazard Index	
• **Example 1**	$\left(\frac{[0\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[200\ ppt]}{[2000\ ppt]}\right)$	+	$\left(\frac{[4\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[4\ ppt]}{[10\ ppt]}\right)$	=	0.9	No exceedance of final Hazard Index MCL
• **Example 2**	$\left(\frac{[5\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[200\ ppt]}{[2000\ ppt]}\right)$	+	$\left(\frac{[6\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[15\ ppt]}{[10\ ppt]}\right)$	=	3 (2.7 rounds to 3)	Exceedance of final Hazard Index MCL (and exceedance of PFHxS MCL)
• **Example 3**	$\left(\frac{[14\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[0\ ppt]}{[2000\ ppt]}\right)$	+	$\left(\frac{[0\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[0\ ppt]}{[10\ ppt]}\right)$	=	1 (1.4 rounds to 1)	No exceedance of final Hazard Index MCL (only one PFAS present)
• **Example 4**	$\left(\frac{[9\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[100\ ppt]}{[2000\ ppt]}\right)$	+	$\left(\frac{[4\ ppt]}{[10\ ppt]}\right)$	+	$\left(\frac{[3\ ppt]}{[10\ ppt]}\right)$	=	2 (1.65 rounds to 2)	Exceedance of final Hazard Index MCL (no individual MCL exceedances)

*MCL compliance is determined by running annual averages at the sampling point

Regulatory Levels: Summary

Chemical	Maximum Contaminant Level Goal (MCLG)	Maximum Contaminant Level (MCL)
PFOA	0	4.0 ppt
PFOS	0	4.0 ppt
PFHxS	10 ppt	10 ppt
HFPO-DA (GenX chemicals)	10 ppt	10 ppt
PFNA	10 ppt	10 ppt
Mixture of two or more: PFHxS, PFNA, HFPO-DA, and PFBS	Hazard Index of 1 (unitless)	Hazard Index of 1 (unitless)

*Compliance is determined by running annual averages at the sampling point

Implementation

“ Our responsibility through the Safe Drinking Water Act is to protect people’s drinking water, and we are taking action to reduce the threat of PFAS contamination.

- **Eric Burneson,** Director
Standards and Risk Management Division
Office of Ground Water and Drinking Water

Implementation

Under the rule requirements, public water systems must

- conduct initial and ongoing compliance monitoring for the regulated PFAS,
- implement solutions to reduce regulated PFAS in their drinking water if levels violate the MCLs, and
- inform the public of the levels of regulated PFAS measured in their drinking water and if an MCL is exceeded.

Implementation: Initial Monitoring Requirements

- Final rule requirements for community water systems and non-transient, non-community water systems for initial monitoring of regulated PFAS concentrations include
  - two or four samples collected at each entry point to the distribution system over a period of one year, dependent on system size and type; and/or
  - use of recent, previously acquired PFAS drinking water data from the fifth Unregulated Contaminant Monitoring Rule (UCMR 5) or state-level drinking water occurrence data or other appropriate collection program.
- Initial monitoring results will determine initial compliance monitoring schedule for each individual entry point within the system.
- Initial monitoring (or demonstration of previously acquired data) must be completed in the three years following rule promulgation.

Implementation: Compliance Monitoring Requirements

Requirements for compliance monitoring of regulated PFAS are based on the Standardized Monitoring Framework and include the following:

- Reduced triennial monitoring for sampling locations with all sample results below the rule trigger levels based on initial monitoring results.
- Default quarterly monitoring for sampling locations with any initial monitoring sample results that are at or exceed the rule trigger levels.
  - Rule trigger level: 1/2 of MCLs for regulated PFAS (i.e., 2.0 ppt for PFOA and PFOS, 5 ppt for PFHxS, PFNA, and HFPO-DA, and 0.5 (unitless) for Hazard Index)
- Following one year of quarterly monitoring, annual compliance monitoring for sampling locations with four consecutive quarterly samples determined by the primacy agency to all be reliably and consistently below the MCLs.
- If sampling location results remains reliably and consistently below the MCLs (even if at or above trigger levels), can continue monitoring annually and possibly reduce further to triennial monitoring if all sample results are consistently below trigger levels.
- Sampling frequency is the same for all regulated PFAS.

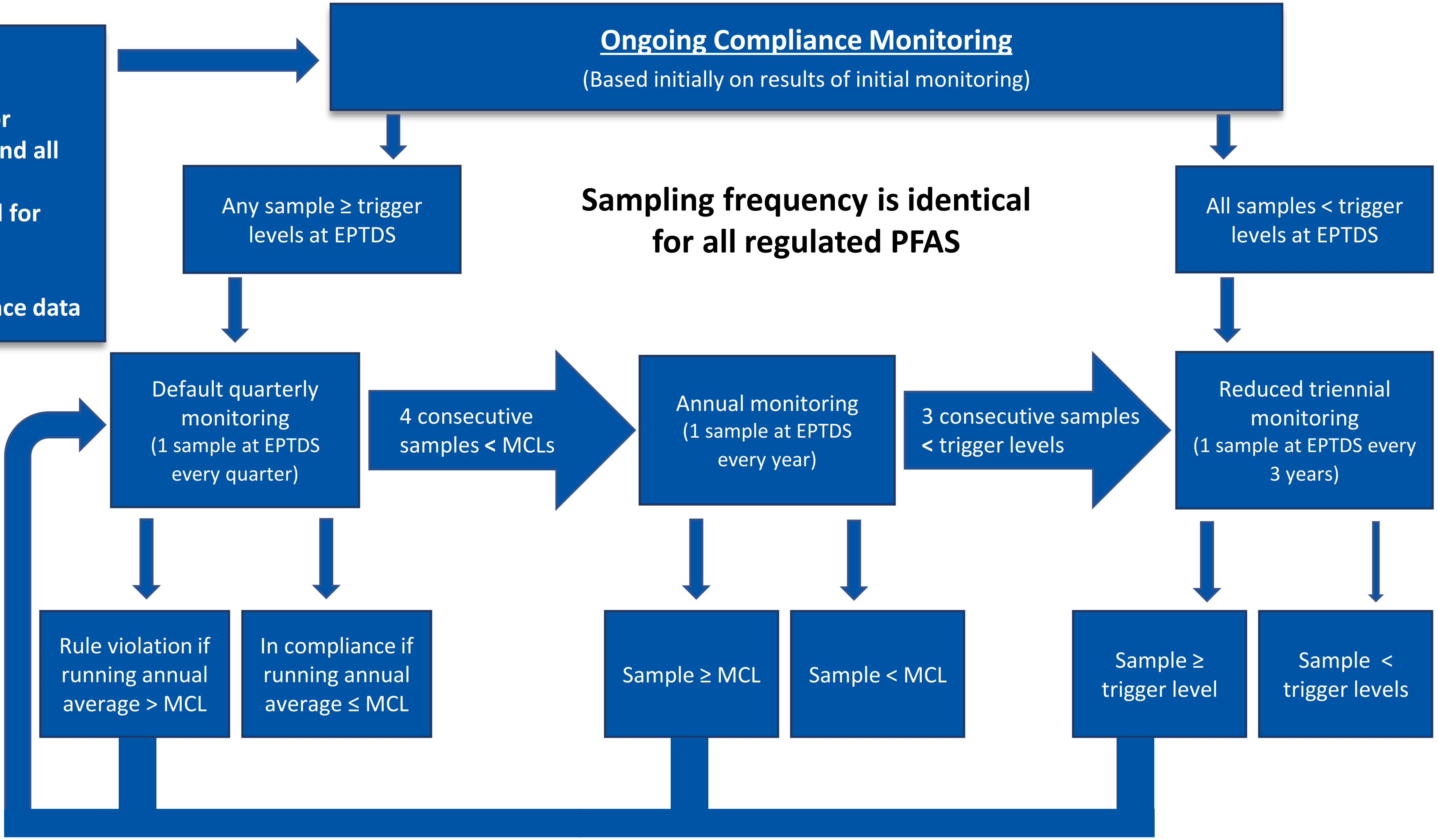
Implementation: Monitoring Requirements Summary

<u>**Initial Monitoring**</u>

- **Four quarterly samples within a 12-month period for ground water systems serving greater than 10,000 and all surface water systems**
- **Two semi-annual samples within a 12-month period for ground water systems serving 10,000 or fewer**

OR

- **Use of recent, existing PFAS drinking water occurrence data**



Rule Trigger Levels (1/2 MCLs)

- **PFOA and PFOS = 2.0 ppt**
- **PFHxS, HFPO-DA, and PFNA = 5 ppt**
- **Hazard Index = 0.5 (unitless)**

*** EPTDS = Entry point to the distribution system**

Implementation: MCL Compliance Determination

- The compliance determination is done through a running annual average (RAA) calculation for systems conducting quarterly monitoring.
- Systems are out of compliance with an NPDWR if the RAA of quarterly samples at a sampling point exceeds a respective MCL (PFOA, PFOS, PFHxS, PFNA, HFPO-DA, and/or Hazard Index).
- PQLs are factored into the compliance calculation. If a sample result is less than the PQL for the monitored PFAS, zero will be used to calculate the RAA.
  - For example, if a system quarterly sampling results for PFOA that are 2.0, 2.0, 5.0, and 2.5 ppt for their last four quarters at a sample location, the values used to calculate the RAA for that sample location would be 0, 0, 5.0, and 0 ppt with a resulting PFOA RAA of 1.3 ppt [i.e., (0+0+5.0+0) / 4 = 1.25 ppt (rounded to 1.3 ppt)].
- A system will not be considered in violation of an MCL until it has completed one year of quarterly sampling, unless a sampling result will cause the RAA to exceed an MCL regardless of any future monitoring (e.g., the analytical result is greater than four times the MCL).

Implementation: Communication with the Public

- PWSs will be required to issue public notification to customers if PFAS levels in drinking water violate an MCL.
- For all PFAS MCL violations, the final rule will require public notification to be provided within 30 days of an MCL violation.
- The final rule requires annual public notification for violations of monitoring and testing procedures.
- Community water systems are also required to include PFAS information in the Consumer Confidence Report distributed to their customers, including the following:
  - The level of PFAS that is measured in the drinking water.
  - The potential health effects of any PFAS detected in violation of an EPA MCL.

Implementation: Timeframes

Within **three years** of rule promulgation (2024 – 2027): Initial monitoring must be complete

Starting **three years** following rule promulgation (starting 2027 – 2029):

- Results of initial monitoring must be included in Consumer Confidence Reports
- Regular monitoring for compliance must begin, and results of compliance monitoring must be included in Consumer Confidence Reports
- Public notification for monitoring and testing violations

Starting **five years** following rule promulgation (starting 2029):

- Comply with all MCLs
- Public notification for MCL violations

Implementation: Reducing PFAS in Drinking Water

- EPA's final rule does not dictate how water systems remove these contaminants. The rule is flexible, allowing systems to determine the best solutions for their community.
- Drinking water utilities can choose from multiple proven treatment options.
- Water treatment technologies exist to remove PFAS chemicals from drinking water including granular activated carbon, reverse osmosis, and ion exchange systems.
- In some cases, systems can close contaminated wells or obtain new uncontaminated source of drinking water.

Implementation: Treatment Residuals and Disposal

- Treatment technologies that remove PFAS from drinking water produce PFAS containing materials that eventually must be disposed of when they are exhausted or are not reactivated or regenerated.
- The current practice for many PFAS drinking water treatment systems is to dispose of treatment residuals as non-hazardous waste. Typically, GAC is reactivated, anion exchange media is landfilled or incinerated, and reverse osmosis/nanofiltration brine is treated prior discharge to surface water or sanitary sewers in accordance with pretreatment or permit requirements.
- Concurrent with this drinking water rule, EPA released an updated version of the *PFAS Destruction and Disposal Guidance* to include new information about disposal of residuals.
- EPA recently announced a final rule to designated PFOA and PFOS as hazardous substances under CERCLA. This designation of PFOA and PFOS as CERCLA hazardous substances does not require waste to be treated in any particular fashion, nor disposed of at any specific type of landfill. The designation also does not restrict, change, or recommend any specific activity or type of waste at landfills.
- EPA has prioritized research on PFAS disposal options in different environmental media and best management practices.

Costs and Benefits

"On a personal level, every life saved and every life that's improved as a result of this Rule is priceless.

- **Bruno Pigott**, EPA Acting Assistant Administrator for Water

Costs and Benefits

- By reducing exposure to PFAS, this final rule will
  - save **thousands of lives**;
  - prevent **tens of thousands of serious illnesses**, including cancers, liver disease, heart attacks, and strokes; and
  - reduce immune system impacts and developmental impacts to pregnant people and babies.
- The benefits are quantified by considering the costs of illness such as lost wages, medical bills, and the value of every life lost.
- The quantifiable health benefits of this rule are estimated to be **$1.5 billion** annually.
- There are also many other health impacts that will be avoided which EPA does not have data to quantify.

Costs and Benefits

- EPA estimates that between about 6% and 10% of the 66,000 public drinking water systems subject to this rule may have to take action to reduce PFAS to meet these new standards.
- Compliance with this rule is estimated to cost approximately $1.5 billion annually.
- These costs include water system monitoring, communicating with customers, and if necessary, obtaining new or additional sources of water or installing and maintaining treatment technologies to reduce levels of the six PFAS in drinking water.
- EPA considered all available information and analyses for costs and benefits, quantifiable and non-quantifiable, of this rule and determined that the **benefits justify the costs**.

Costs and Benefits (see fact sheet for details)

	How Much?	What From?	The Potential Impact
Costs	$1.5 Billion per year	Monitoring, communicating with customers, and if necessary, obtaining new or additional sources of water or installing and maintaining treatment technologies.	States, Tribes, and territories with primacy will have increased oversight and administrative costs. **66,000 regulated water systems** will have to conduct monitoring and notifications. **4,100 – 6,700 water systems** may have to take action to reduce levels of PFAS.
	Non-quantified*	Costs for some systems to comply with the Hazard Index, HFPO-DA, and PFNA MCLs.	
Benefits	$1.5 Billion per year	The rule results in fewer cancers, lower incidence of heart attacks and strokes, and fewer birth weight-related deaths. Actions taken to implement the rule may also lead to associated health benefits from reductions in other PFAS and unregulated disinfection byproducts. Benefits will prevent over **9,600 deaths and reduce approximately 30,000 serious illnesses.**	**83 – 105 million people** will have improved drinking water as a result of lower levels of PFAS
	Non-quantified*	Increased ability to fight disease, reductions in thyroid disease and impacts to human hormone systems, reductions in liver disease, and reductions in negative reproductive effects such as decreased fertility.	

***Non-quantified benefits and costs are those that EPA could not assign a specific dollar value to as part of its national level quantified analysis, but it doesn't mean their benefits or costs are less important than those with numerical values.**

Funding & Technical Assistance

“ We know that PFAS pollution can have a disproportionate impact on small, disadvantaged, and rural communities, and there is federal funding available specifically for these water systems.

- **Yu-Ting Guilaran,** Deputy Office Director, Office of Ground Water and Drinking Water

PFAS Funding and Technical Assistance

- PFAS contamination can have a disproportionate impact on small, disadvantaged, and rural communities, and there is federal funding available specifically for these water systems.
- The Bipartisan Infrastructure Law (BIL) dedicates $9 billion specifically to invest in communities with drinking water impacted by PFAS and other emerging contaminants. $1B of these funds can be used to help private well owners.
- An additional $12 billion in BIL funding is available for general drinking water improvements.

For more: epa.gov/water-infrastructure

PFAS Funding and Technical Assistance

- EPA collaborates with state, Tribes, territories, community partners, and other key stakeholders to implement Water Technical Assistance (WaterTA) efforts and the end result is more communities with applications for federal funding, quality water infrastructure, and reliable water services.
- EPA's water technical assistance program is ensuring that disadvantaged communities can access federal funding.
- EPA's free WaterTA supports communities to identify water challenges, develop plans, build technical, managerial and financial capacity, and develop application materials to access water infrastructure funding.

For more: epa.gov/water-infrastructure/water-technical-assistance-programs

PFAS Strategic Roadmap

“ The Biden-Harris Administration is committed to utilizing science and holding polluters accountable to address and prevent PFAS contamination.

- **White House Fact Sheet:** Biden-Harris Administration Takes New Action to Protect Communities from PFAS Pollution.

EPA's Commitment to Address PFAS Contamination

- The Agency released its PFAS Strategic Roadmap in October 2021 and established the Agency's three overarching goals:
  - Restricting PFAS from entering the environment in the first place.
  - Remediating—or cleaning up—PFAS contamination where it is found.
  - Researching PFAS to strategically address public health and environmental risks.
- Since 2021, the Agency has taken many actions to strengthen public health protections and address PFAS in the environment.
- The Agency's final PFAS drinking water regulation is a cornerstone of this holistic approach.

Resources

“ EPA is working to help protect communities from PFAS contamination.

- **Ryan Albert, Branch Chief**
Risk Reduction Branch, Office of Ground Water and Drinking Water

Resources (Materials)

- Webinar Presentations and Recordings
- General Q&As
- PFAS NDPWR Fact Sheet
- Fact Sheet: Water Filters
- Fact Sheet: What are the Benefits and Costs of the Rule?
- Fact Sheet: Understanding the Hazard Index
- Fact Sheet: Small Drinking Water Systems
- Fact Sheet: PFAS Drinking Water Treatment Technologies
- Fact Sheet PFAS NPDWR Monitoring Requirements
- Fact Sheet: Comparison of Between EPA"s Proposed and Final PFAS NPDWR
- Detailed Q&As for Primacy Agencies and Water Systems
- PFAS Communications Toolkit (videos, social media, infographics)

Materials available at

epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

EPA's PFAS NPDWR website:
epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

For questions regarding the PFAS NPDWR, please send to PFASNPDWR@epa.gov

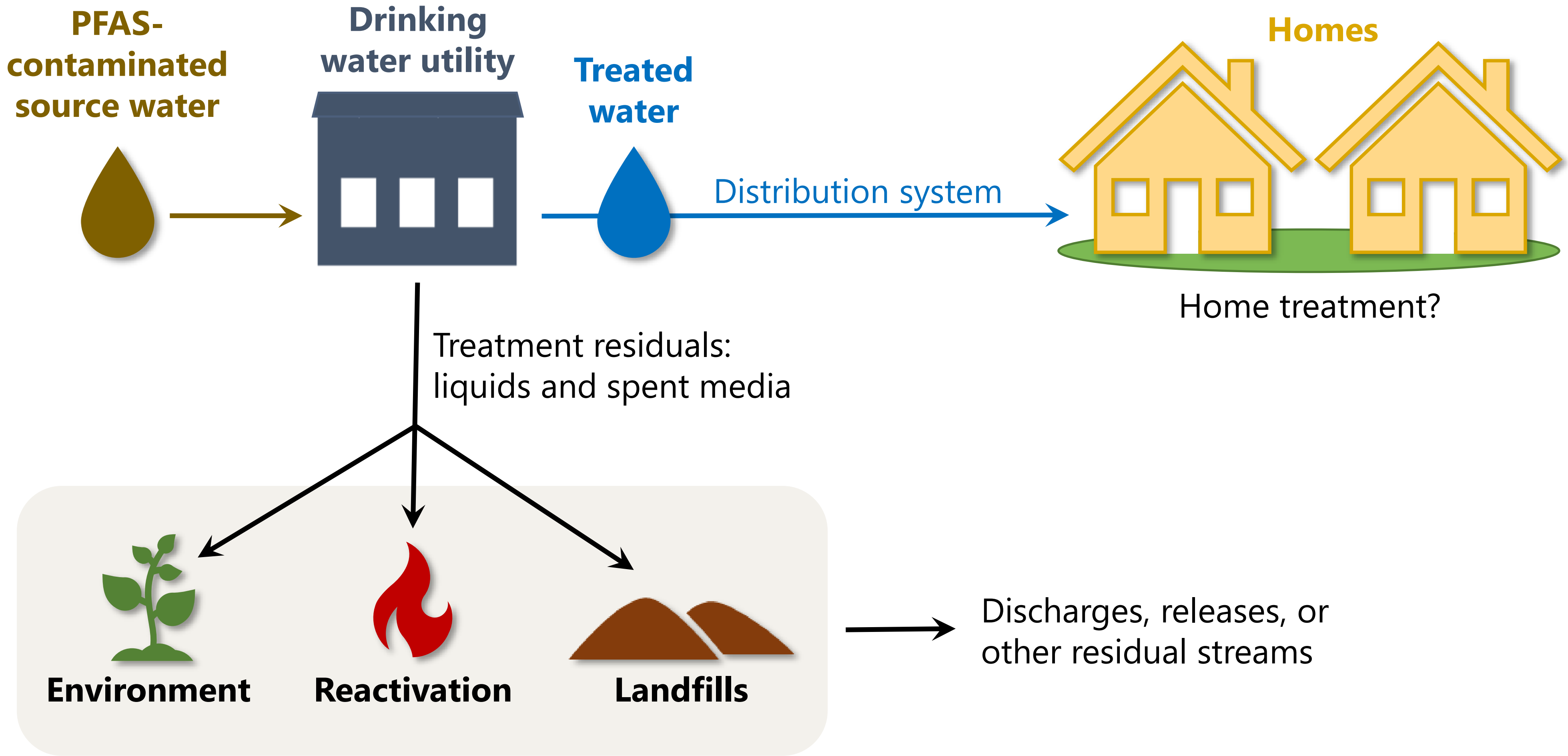
Removal of PFAS Compounds from Drinking Water: Fundamentals and Applications

This presentation focuses on the three treatment processes designated as best available technologies for PFAS removal from drinking water: granular activated carbon (GAC), ion exchange (IX), and membranes (NF/RO). There will be a brief discussion on the fundamentals of each process followed by basic considerations of process selection, process design, and costing.

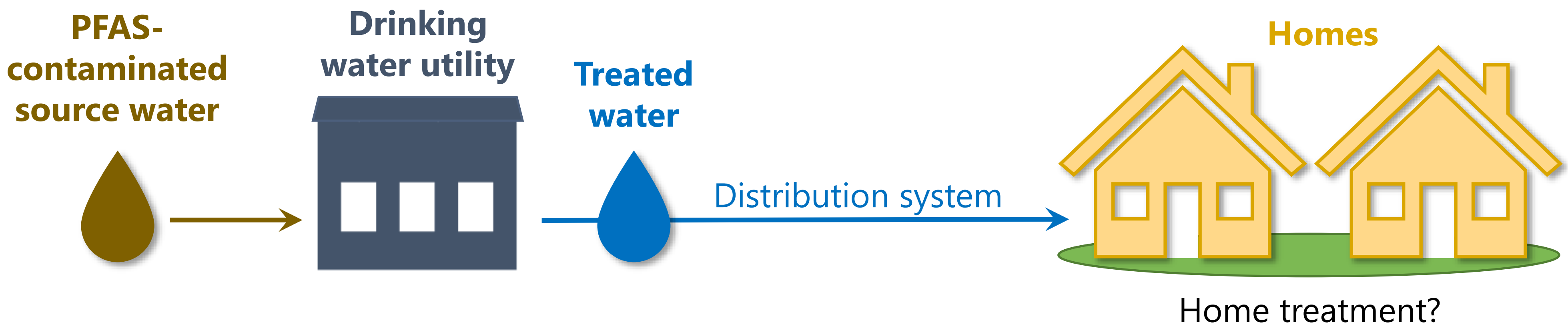
Nicholas Dugan, P.E., EPA Office of Research and Development | dugan.nicholas@epa.gov

Nick is an environmental engineer in EPA's Office of Research and Development, Center for Environmental Solutions and Emergency Response. He has over 25 years of experience conducting research in the removal of microbial and chemical contaminants from drinking water, and is currently helping to lead the nationwide implementation of a technical support project for the removal of PFAS and other emerging contaminants from drinking water.

How Do We Remove PFAS From Drinking Water?



How Do We Remove PFAS From Drinking Water?



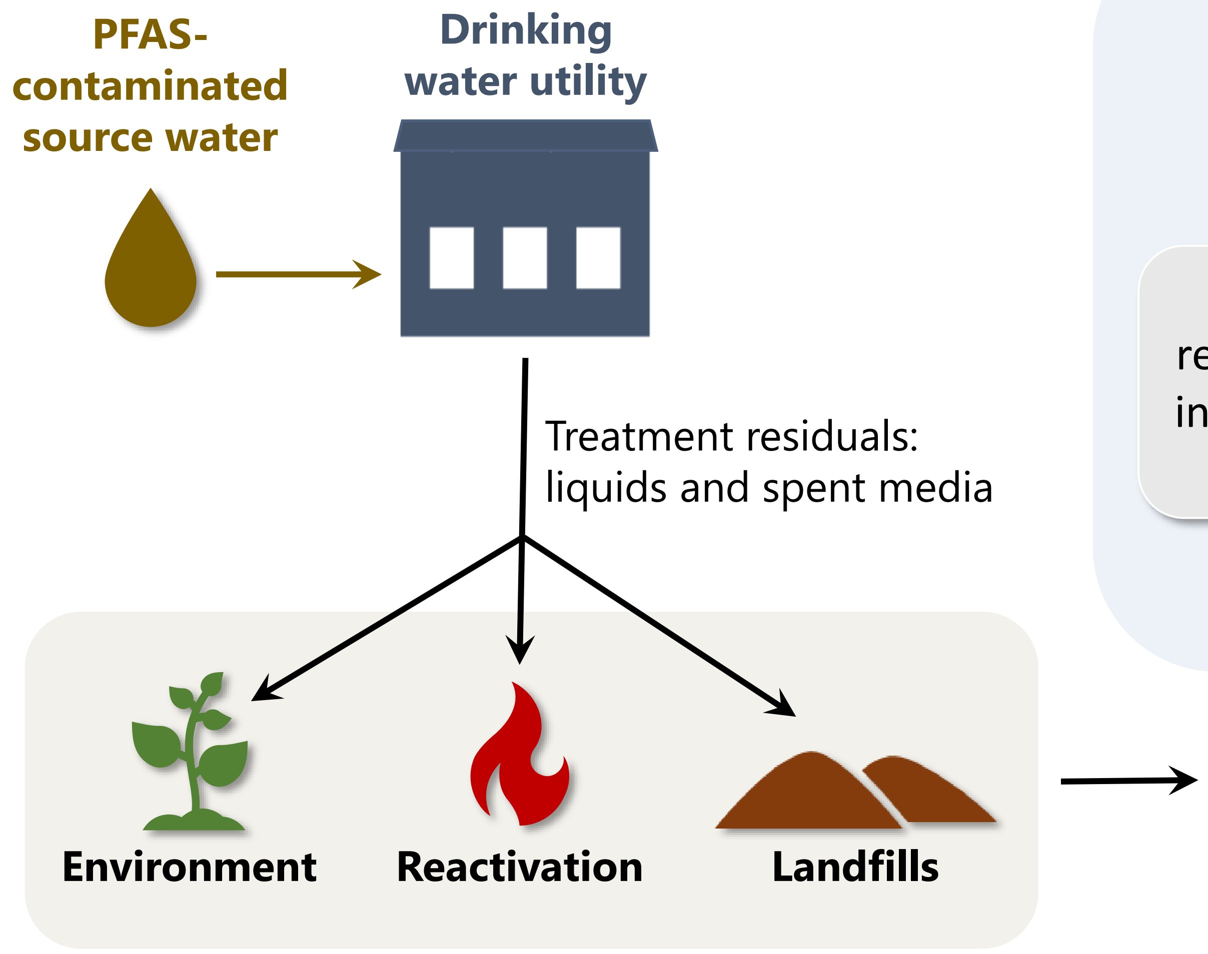
Effective Treatment Technologies for PFAS

Anion exchange resin, granular activated carbon (GAC), and membrane separation (RO) are generally effective at removal.

More effective for long-chain than short-chain PFAS.

Removal efficiencies and cost depend on source water characteristics and water system characteristics.

How Do We Remove PFAS From Drinking Water?



Discharges, releases, or other residual streams

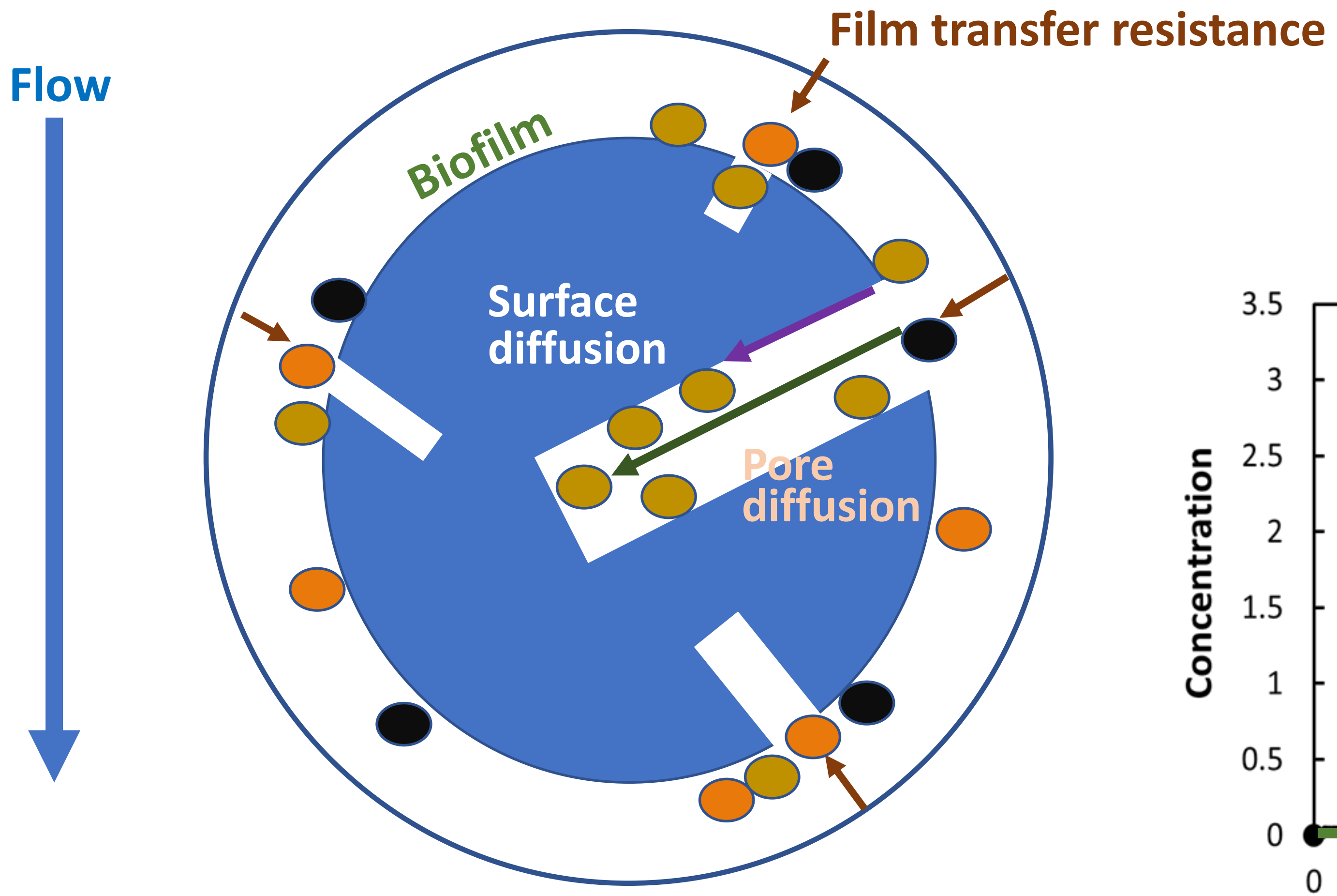
Treatment Residuals

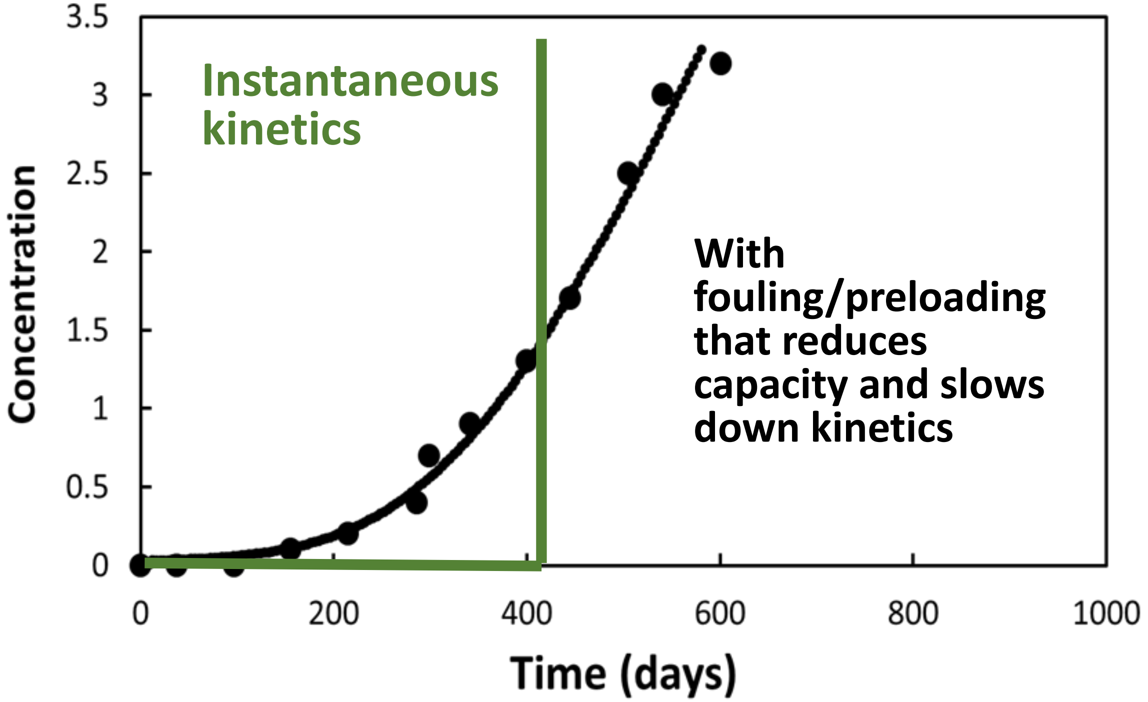
PFAS found in spent GAC and spent resin.

Spent media can be regenerated, landfilled, or incinerated with unknown releases of PFAS.

There are no known commercial treatments (mineralization) for RO concentrate streams or regenerant solutions.

Adsorption Mechanisms (with preloading)





Adsorption Mechanisms (continued)

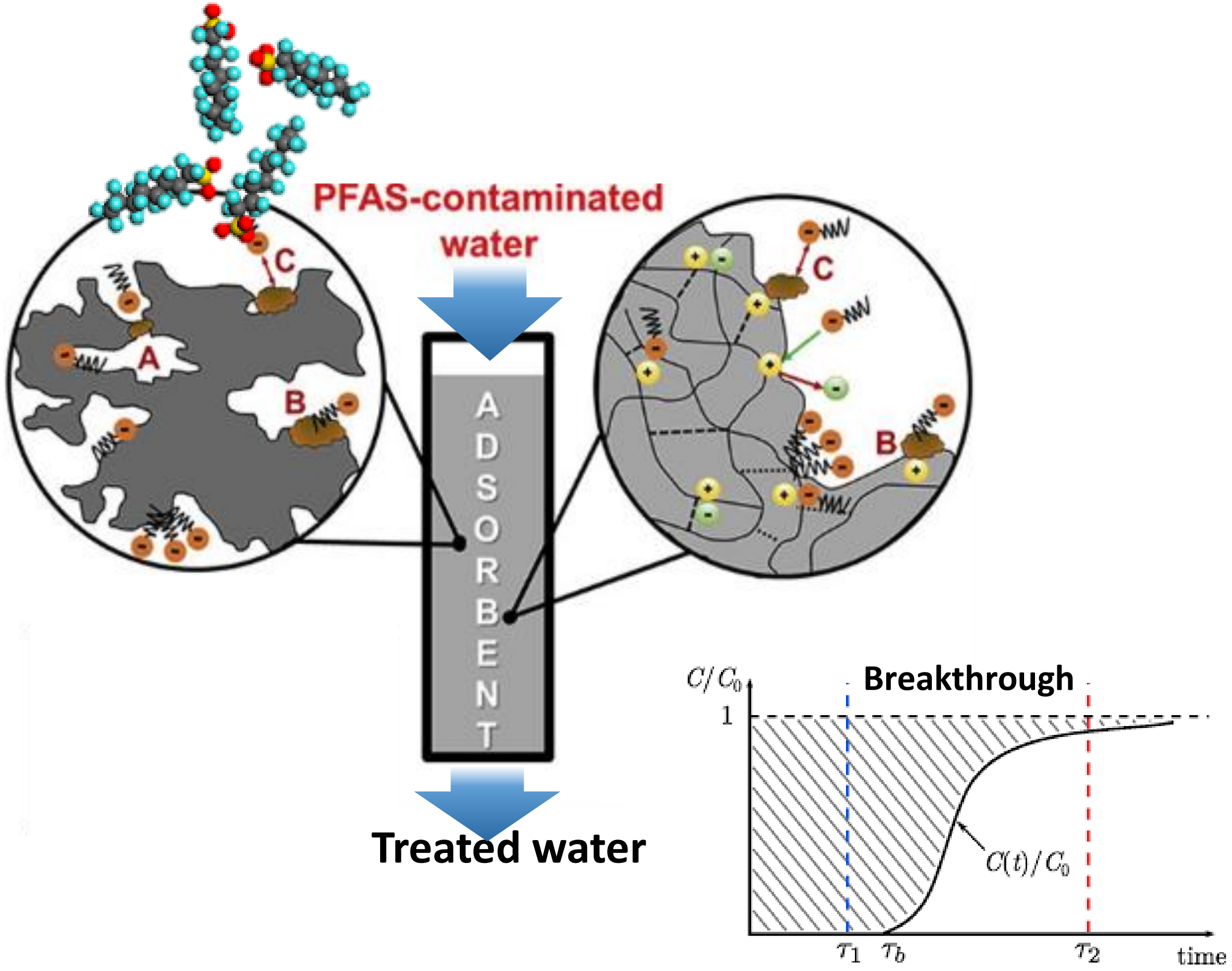


Image: *Water Research, Volume 171*

The affinity of adsorbent varies depending on chemical structures and properties causing early breakthrough for certain PFAS chemicals.

Intro to Ion Exchange

- Positively-charged active sites
- Initially loaded with chloride anions (negative charge)
- Other anions exchange onto active sites (e.g., PFAS, nitrate, sulfate, bicarbonate, natural organic matter)
- Chloride is released
- PFAS-selective resins

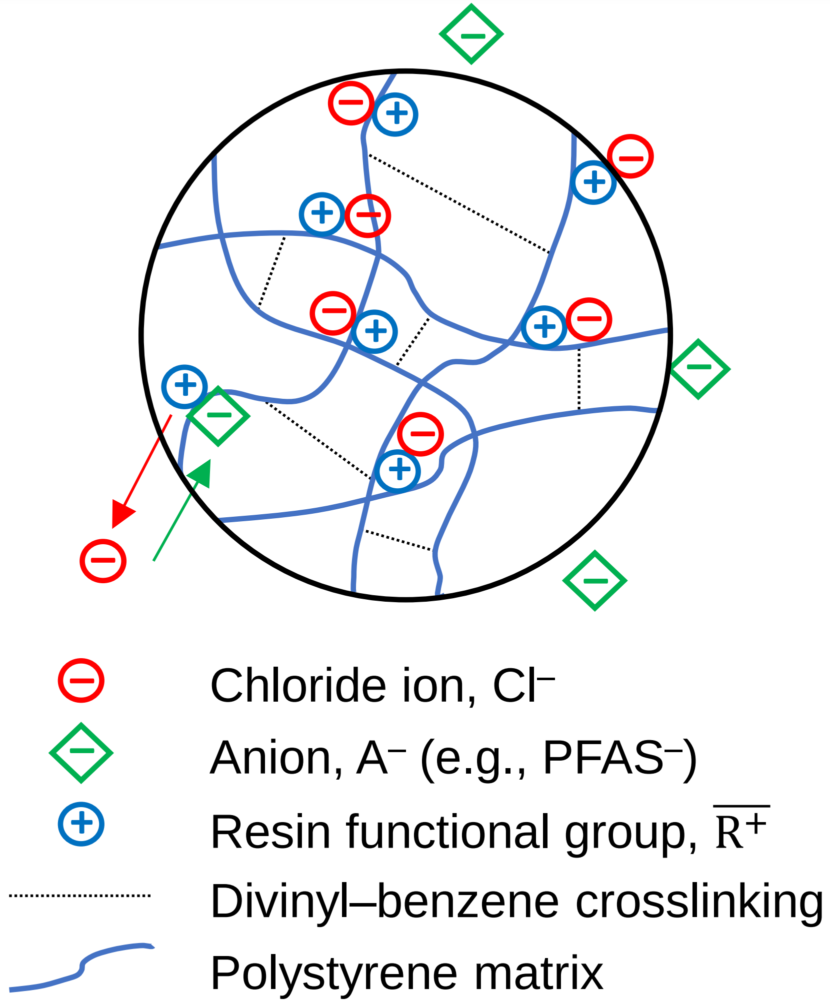
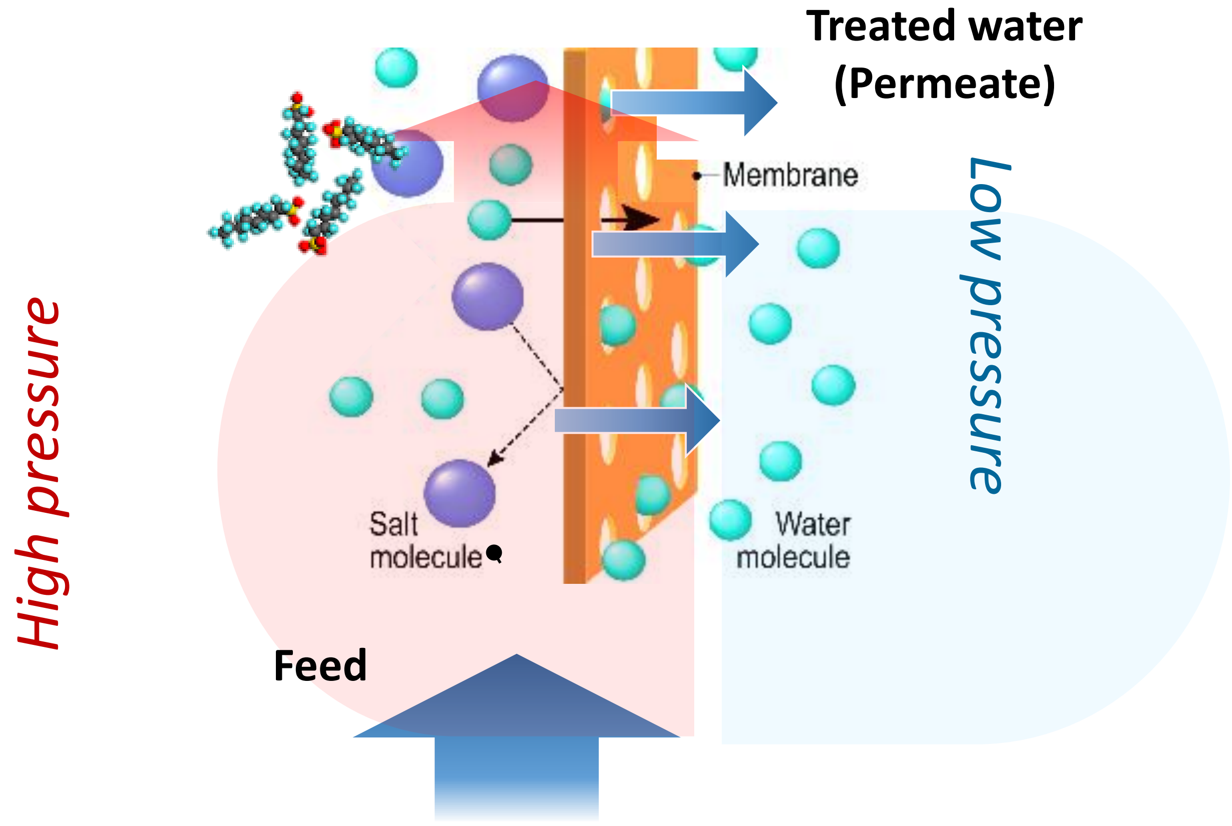


Figure adapted from Lee et al. (2018) ***doi.org/10.3390/ma11040560.***

High Pressure Membranes

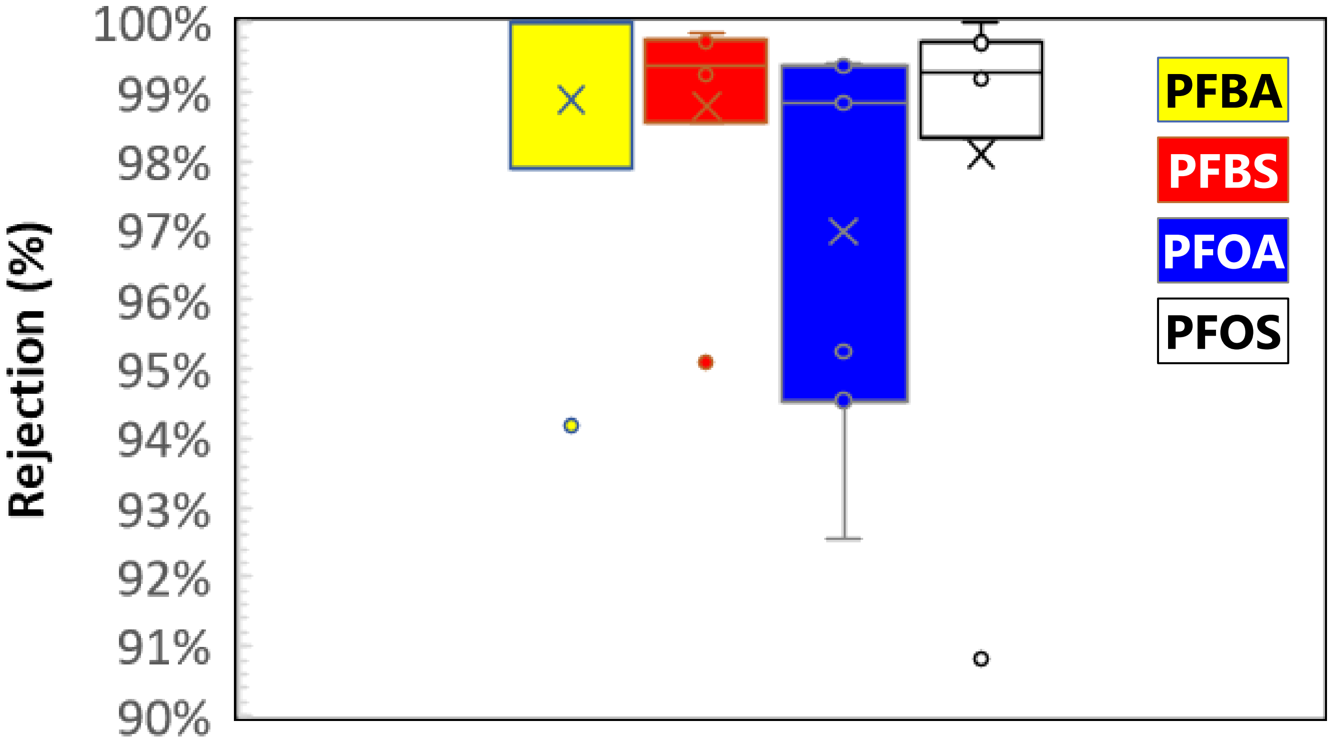
Permeate water flux (Jv) :

$$J_v = L_p(\Delta P - \sigma \cdot \Delta\pi)$$



RO shows highest removal efficiencies for a wide range of PFAS chemicals.

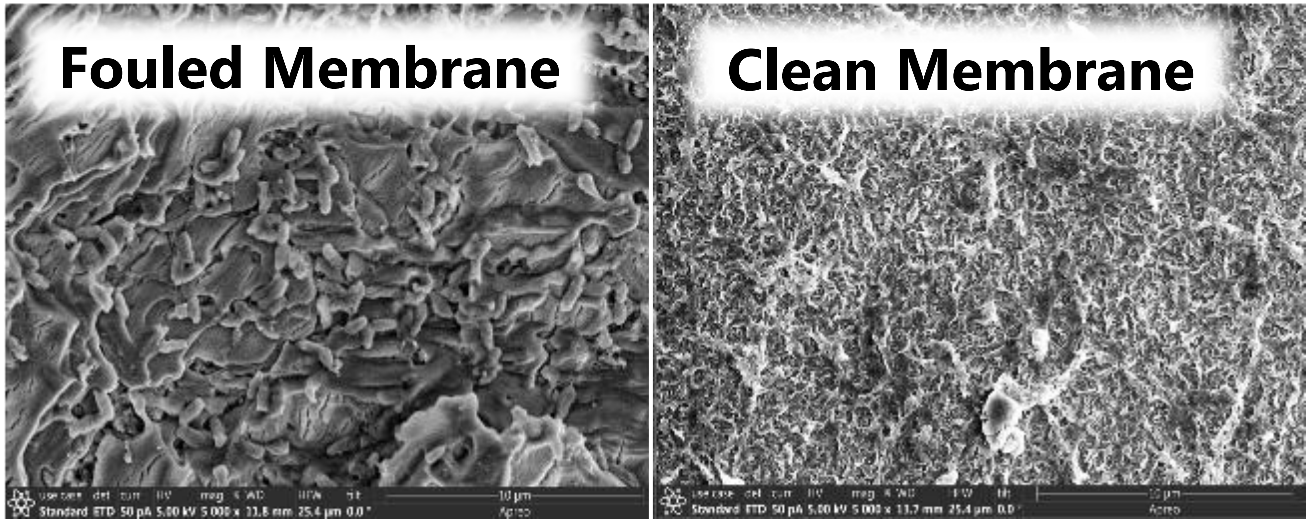
High Pressure Membranes (continued)



PFAS rejections are high

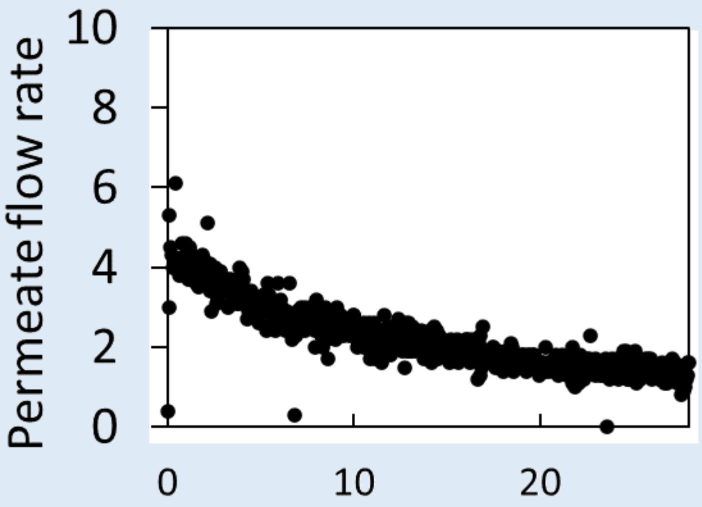
- For reverse osmosis and nanofiltration membranes
- Poor rejections for low-pressure membranes (ultrafiltration and microfiltration)

High Pressure Membranes (continued)



Membranes will foul

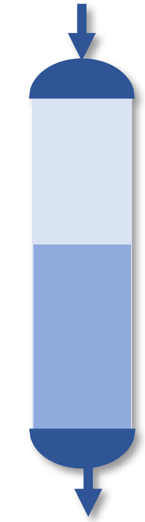
- Require anti-scalants
- Need periodic cleaning
- Surface waters foul to a much greater degree than groundwater



Ineffective Drinking Water Treatment for PFOS

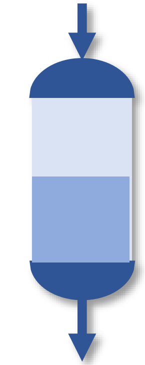
- Conventional Treatment
- Low Pressure Membranes
- Biological Treatment (including slow sand filtration)
- Disinfection
- Oxidation
- Advanced Oxidation

GAC Versus IEX



Granular Activated Carbon (GAC)

- EBCT typically range from 5 to 20 minutes
- Hydraulic Loading: Typically 4 gpm/ft^2 (10 m/hr) – ranges from 2 to 6 gpm/ft^2



Anion Exchange Resins (IEX)

- EBCT typically range from 2 to 7 minutes
- Hydraulic loading is typically 8 gpm/ft^2 (20 m/hr) – ranges from 6 to 12 gpm/ft^2

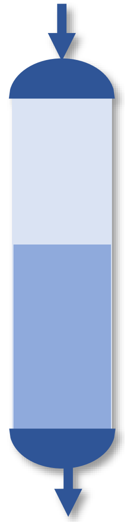
Definitions

Empty Bed Contact Time (EBCT): Time (min) for the flow rate to fill up the volume of the bed – without the media being present. Does not include volume above or below the active media.

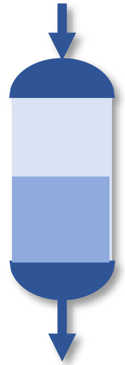
Loading Rate: Flow rate per cross sectional area of the bed (gpm/ft^2 or m/hr).

Bed Volumes Fed (BVF): Number of bed volumes (cross sectional area times depth of media) fed to achieve a certain effluent concentration.

GAC Versus IEX (continued)



Granular Activated Carbon (GAC)



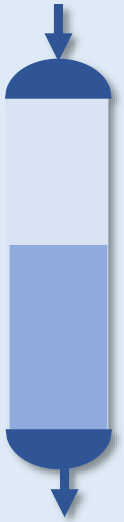
Anion Exchange Resins (IEX)

Be cautious of claims that one should choose between the two due to higher capacity, smaller EBCT, shorter beds, smaller footprint/higher hydraulic loading, or BVF between change outs.

It will come down to cost to achieve a treatment goal and other secondary factors.

Select Treatments: Advantages and Considerations

Treatment Advantages



Granular Activated Carbon (GAC)

- Most studied technology
- Will remove 100% of the contaminants, for a time
- Good capacity for some PFAS

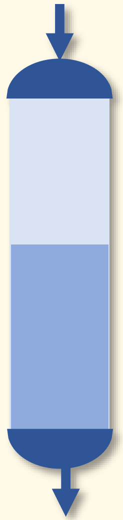
☑ Will remove a significant number of disinfection byproduct precursors

☑ Will help with maintaining disinfectant residuals

☑ Will remove many co-contaminants

☑ Likely positive impact on corrosion (lead, copper, iron)

Treatment Issues to Consider



Granular Activated Carbon (GAC)

- Reactivation/replacement frequency can be short in some instances
- Potential overshoot of poor adsorbing PFAS, if not designed correctly

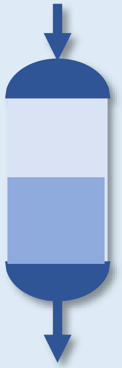
- Initial flushing needed (backwashing?)
- Backwashing should not be an issue
- Disposal or reactivation of spent carbon

Construction/Operation Issues

Granular Activated Carbon (GAC)

- Adsorbent choice and size
- Design type (pressure or gravity)
- Materials of construction
- Empty bed contact time/flow rate/loading rate/total flow
- Number of contactors (parallel, series, lead lag)
- Number of redundant vessels
- Bed depth and contactor dimensions (accounting for carbon expansion during backwash)
- Pretreatment (e.g., iron, manganese, natural organic matter, particulates)
- Carbon life (regulatory/water quality goal)
- GAC rinsing (avoiding potential arsenic release)
- Backwash interval (backwash loading rate, expansion duration, carbon loss rate)
- Residuals management options (reactivation, nonhazardous landfill, hazardous landfill)
- Backwash pumping design, storage, and backwash residuals management)
- *Over 300 additional design parameters*

Treatment Advantages



Anion Exchange Resins
(PFAS selective)

- Will remove 100% of the contaminants, for a time
- High capacity for some PFAS
- Smaller beds/footprint compared to GAC

☑ Can remove select co-contaminants

Treatment Issues to Consider

Anion Exchange Resins
(PFAS selective)

- Replacement frequency can be short in some instances
- Media is more expensive than GAC
- Potential overshoot of poor adsorbing PFAS, if not designed correctly

- Initial flushing needed or buffered resin (backwashing?)
- Unclear secondary benefits
- Disposal of resin

Construction/Operation Issues

Anion Exchange Resins
(PFAS selective)

- Resin choice
- Materials of construction
- Empty bed contact time/flow rate/loading rate/total flow
- Number of contactors (parallel, series, lead lag)
- Number of redundant vessels
- Bed depth and contactor dimensions
- Pretreatment (e.g., iron, manganese, anions, natural organic matter, particulates)
- Resin life (regulatory/water quality goal)
- Flushing on startup (chloride release)
- Residuals management options (incineration, nonhazardous landfill, hazardous landfill)
- Over 300 additional design parameters

Treatment Advantages

High Pressure Membranes

(Reverse Osmosis or Nanofiltration)

High PFAS rejection

- ☑ Will remove many co-contaminants
- ☑ Will remove a significant number of disinfection byproduct precursors
- ☑ Will help with maintaining disinfectant residuals

Treatment Issues to Consider

High Pressure Membranes
(Reverse Osmosis or Nanofiltration)

High PFAS rejection

- Corrosion control (bypass treatment?)
- Lack of options for concentrate stream treatment or disposal

Construction/Operation Issues

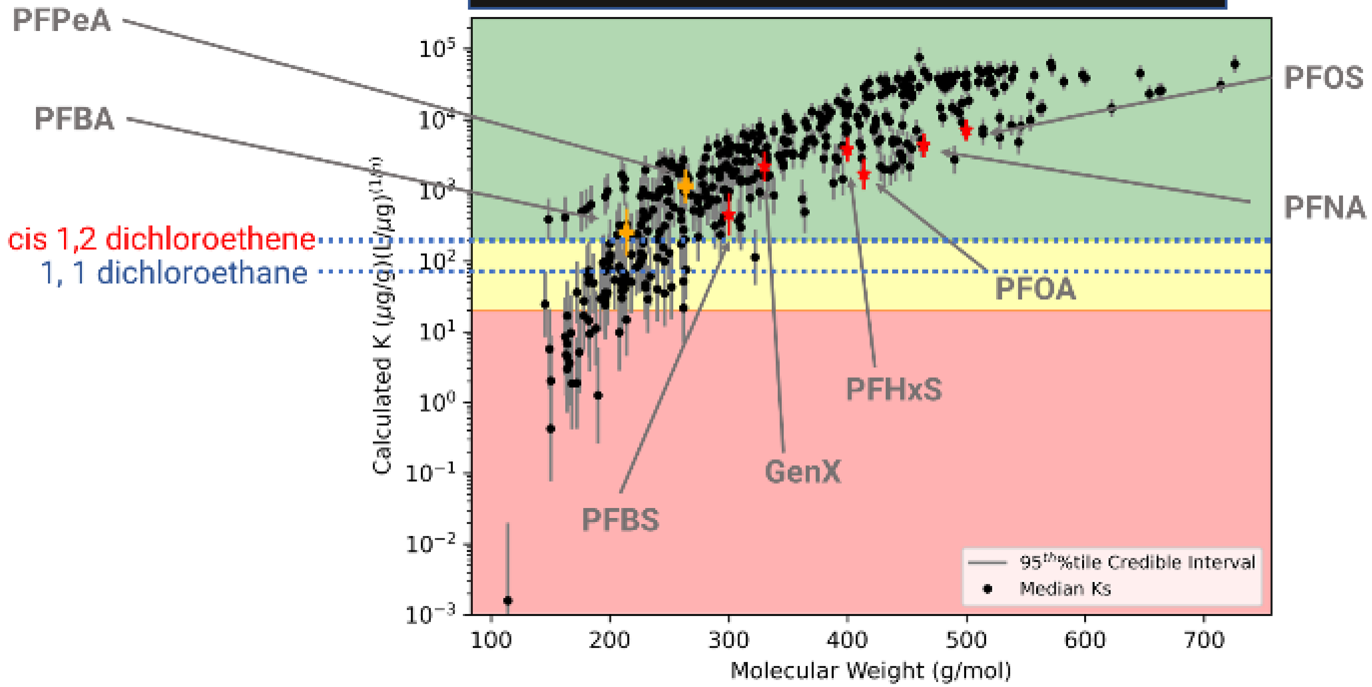
High Pressure Membrane Systems

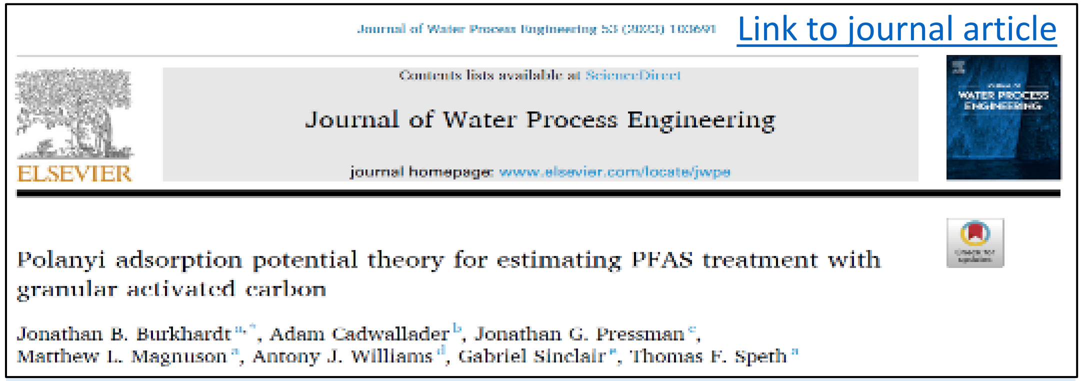
- Membrane choice (regulatory/water quality goal)
- Water quality (major ions, TDS, SDI)
- Materials of construction
- Number of elements/array design
- Target recovery rate
- Design flux/cross flow velocity
- Number of redundant vessels
- Pressure range
- Pretreatment (e.g., iron, manganese, natural organic matter, hardness, particulates)
- Anti-scalant choice and dose
- Time in between chemical cleanings (based on flux decline)
- Membrane life (five years)
- Residuals management options (discharge to sewer, waterway, ZLD)
- Over 300 additional design parameters

Predicting PFAS Treatment

Very limited rule of thumb:
"Longer chain PFAS adsorb better to GAC"

Green: Likely adsorbable
Yellow: Possibly adsorbable (site specific)
Red: Likely not economically adsorbable




Journal of Water Process Engineering 53 (2023) 103691
[Link to journal article]
Contents lists available at ScienceDirect
Journal of Water Process Engineering
journal homepage: www.elsevier.com/locate/jwpe
ELSEVIER

Polanyi adsorption potential theory for estimating PFAS treatment with granular activated carbon

Jonathan B. Burkhardt[a,*], Adam Cadwallader[b], Jonathan G. Pressman[c], Matthew L. Magnuson[a], Antony J. Williams[d], Gabriel Sinclair[a], Thomas F. Speth[a]

Recent Publication

428 PFAS evaluated

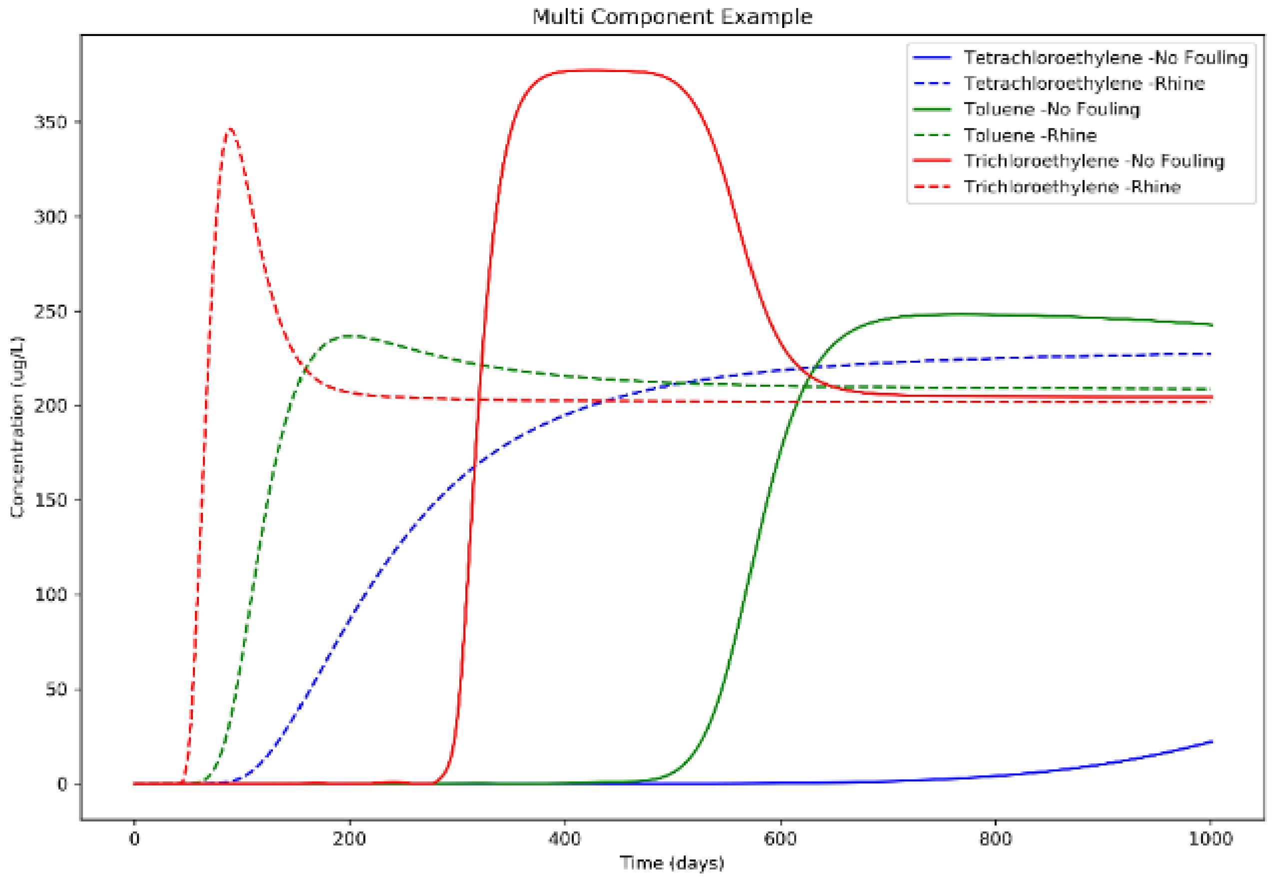
- Vast majority (400+) had no granular activated carbon (GAC) treatment information available.
- Suggests 76-87% of the PFAS could be cost-effectively removed by GAC – 30 of 31 PFAS analyzed by EPA Methods 533 and 537.1.
- Additional PFAS can be added.

Multicomponent Adsorption

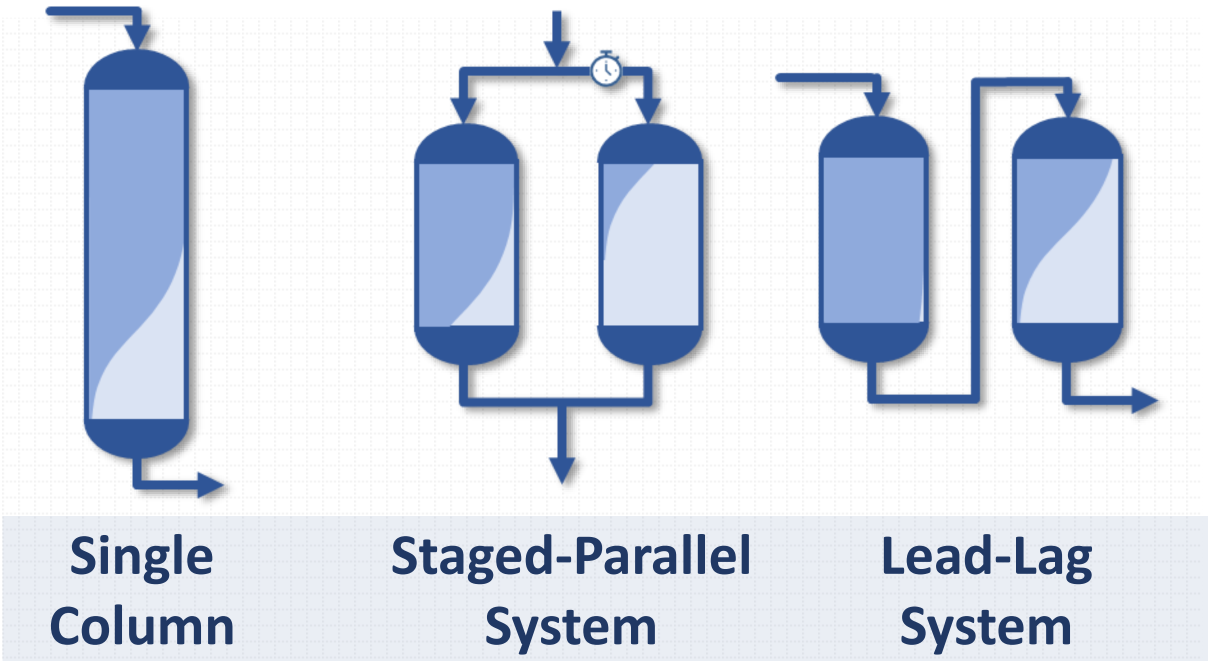
Chromatographic Behavior

Similar to other competitive adsorption situations

- Weaker adsorbing contaminants break through earlier.
- Competition will reduce capacities for all contaminants, but it is a complex function.
- Stronger adsorbing contaminants can chromatographically push weaker adsorbing contaminants through – potentially creating effluent concentrations higher than influent concentrations (overshoot).



Column Configurations



- Single column system typically discards some potential sorption capacity on changeout.
- Media use efficiency can be improved at the cost of system complexity.
- When some breakthrough is acceptable, parallel systems can run media past exhaustion.
- Lead-Lag system increases media efficiency when breakthrough threshold is low and can provide increased margin of safety.

Treatment Costs

Drinking Water Cost Models

[Drinking Water Treatment Unit Cost Models and Overview of Technology webpage]

(or search "EPA WBS" in web browser)

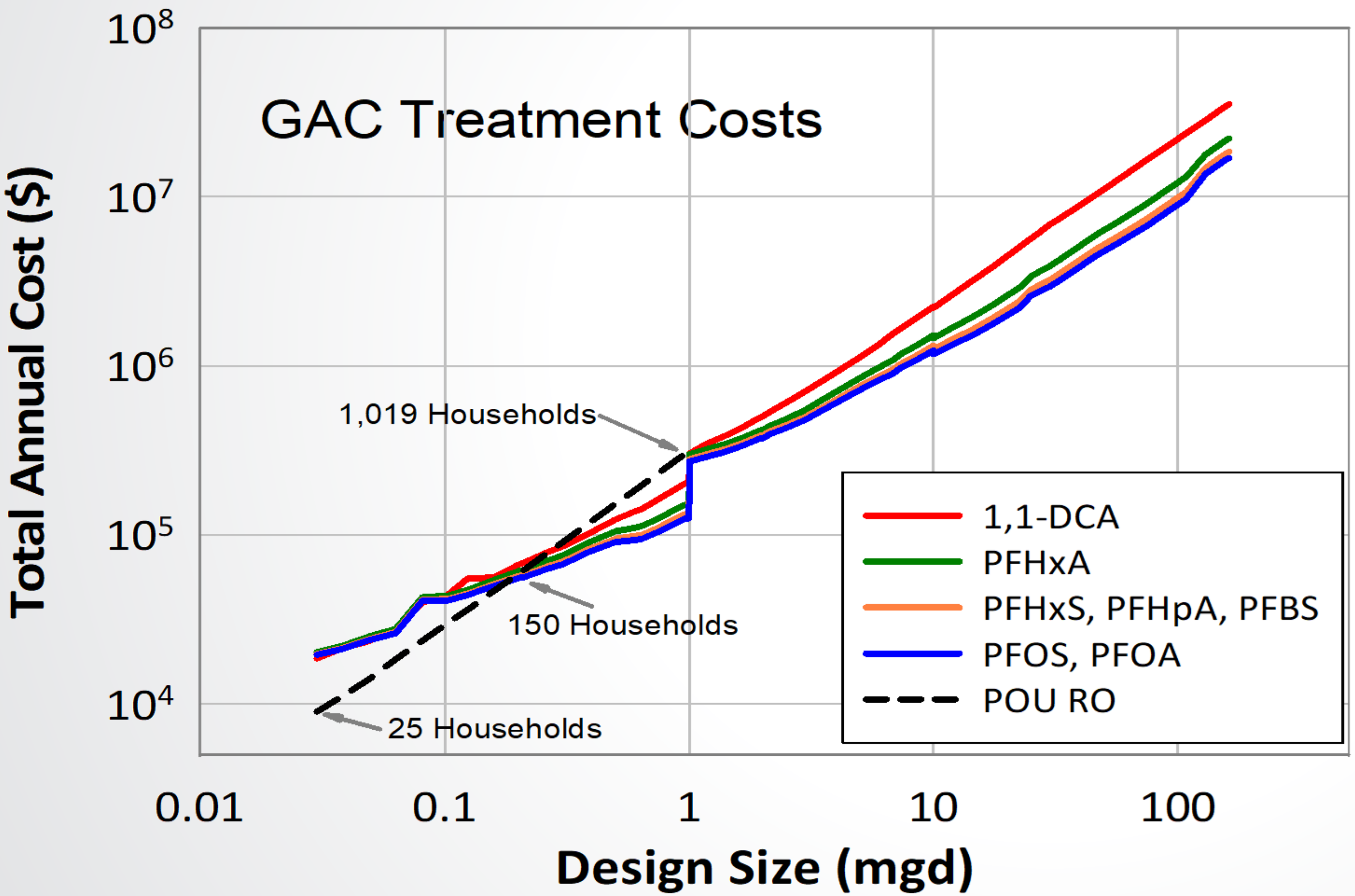
Small Systems Considerations

Specific Design Modifications for Smaller Systems within the Cost Model

(Flows under 1 MGD)

- Construction issues (building)
- Residual handling flexibility
- Reduced spacing between vessels
- Smaller and no redundant vessels
- Reduced instrumentation
- No booster pumps
- No backwash pumps
- Reduced concrete pad thickness
- Reduced indirect costs

Costs for PFAS Treatment: GAC Example



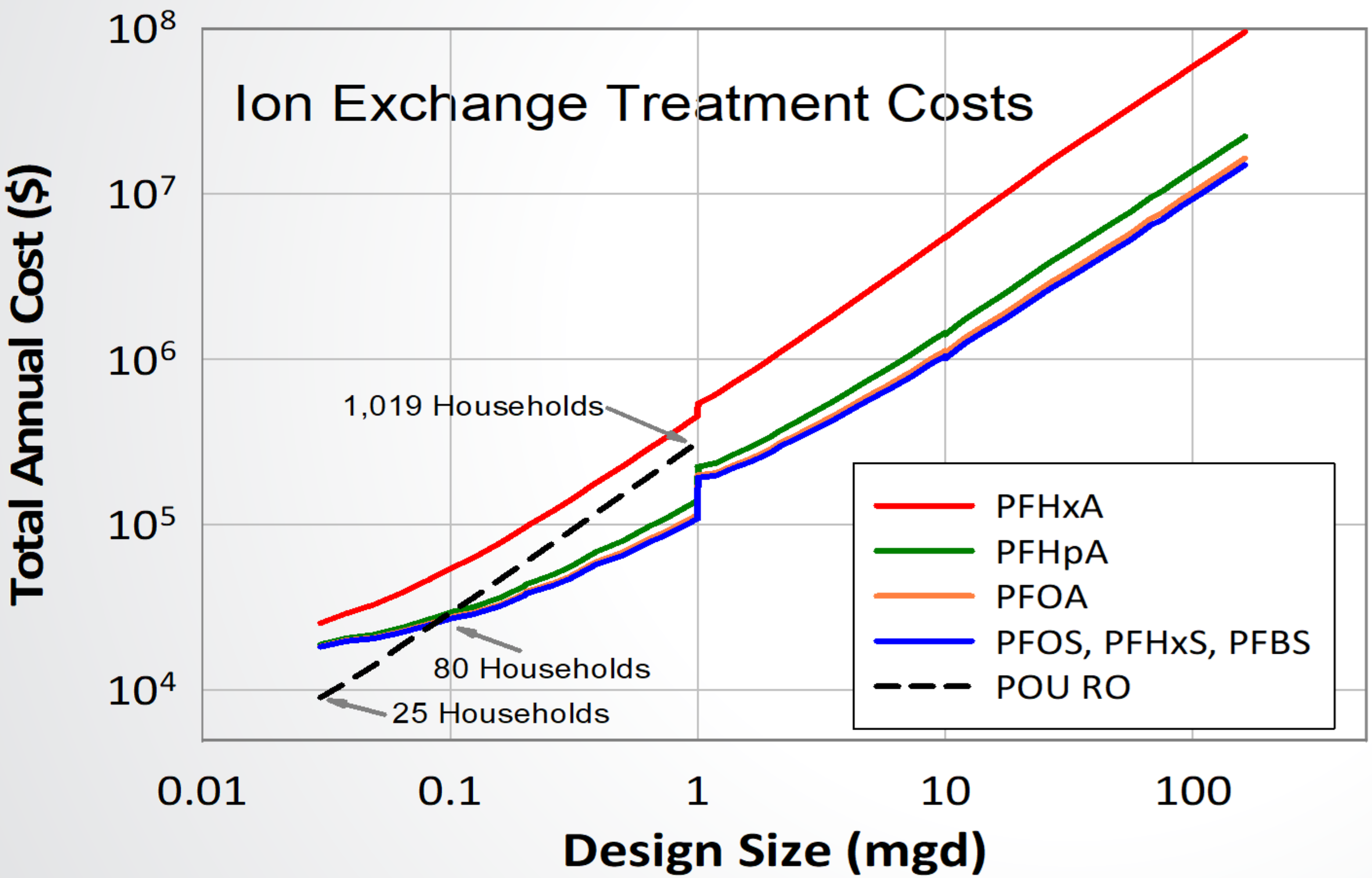
Primary Assumptions:

- Two vessels in series
- 20 min Empty Bed Contact Time (EBCT) Total
- Bed Volumes Fed
  - 1,1-DCA = 5,560 (7.5 min EBCT)
  - PFHxA = 20,000
  - PFHxS, PFHpA, PFBS = 35,000
  - PFOA, PFAS = 50,000
- 7% Discount rate
- Mid-level cost
- Non-hazardous GAC Reactivation
- 2021 dollars

Other scenarios will result in different costs

https://www.epa.gov/system/files/documents/2024-04/2024-pfas-tech-cost_final-508.pdf

Costs for PFAS Treatment: IEX Example



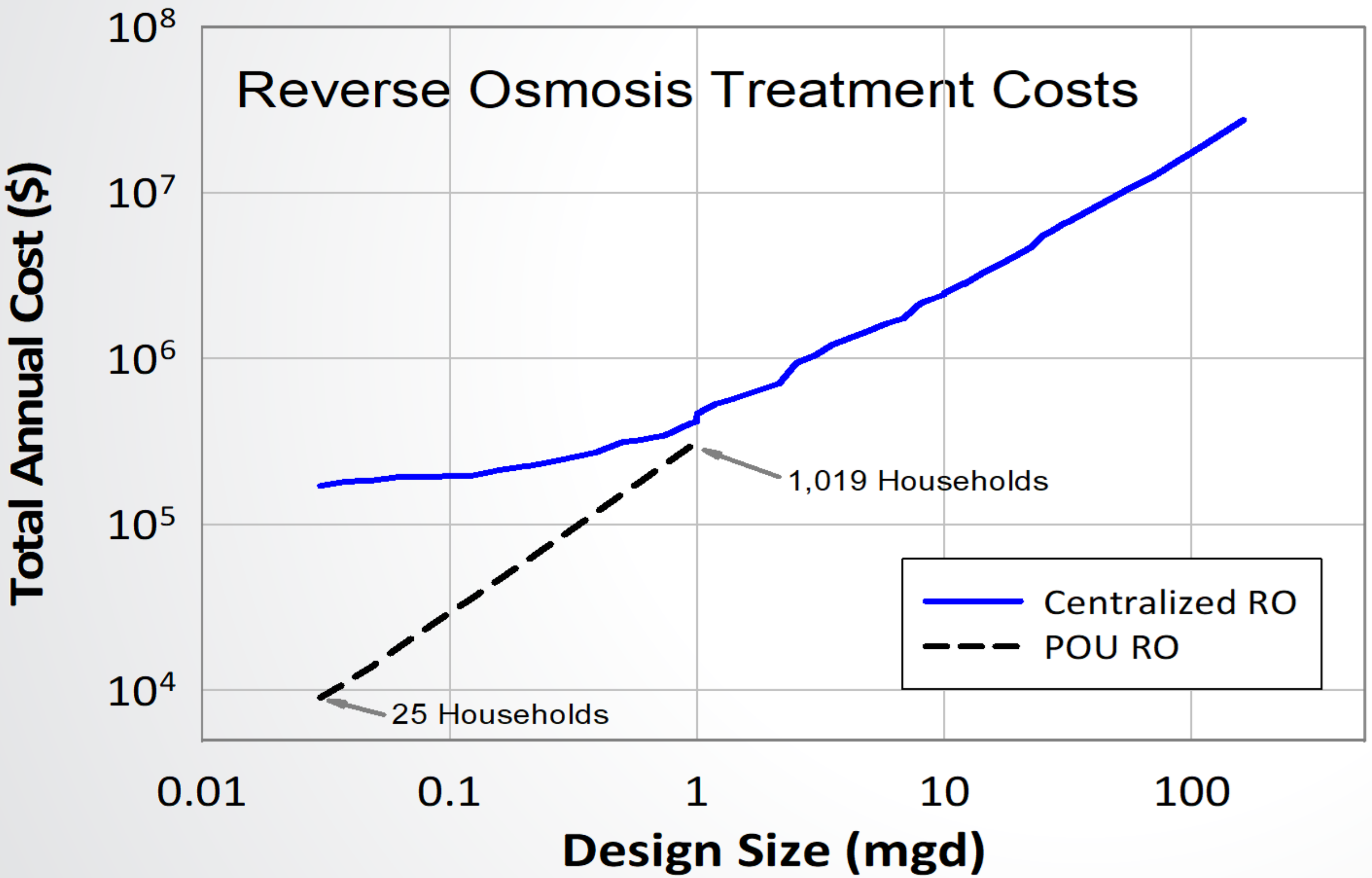
Primary Assumptions:

- Two vessels in series
- 6 min EBCT Total
- Bed Volumes Fed:
  - PFHxA = 20,000
  - PFHpA = 120,000
  - PFOA = 200,000
  - PFOS = 240,000
- 7% Discount rate
- Mid-level cost
- Incineration of spent resin
- 2021 dollars

Other scenarios will result in different costs

https://www.epa.gov/system/files/documents/2024-04/2024-pfas-tech-cost_final-508.pdf

Costs for PFAS Treatment: RO Example



Primary Assumptions:

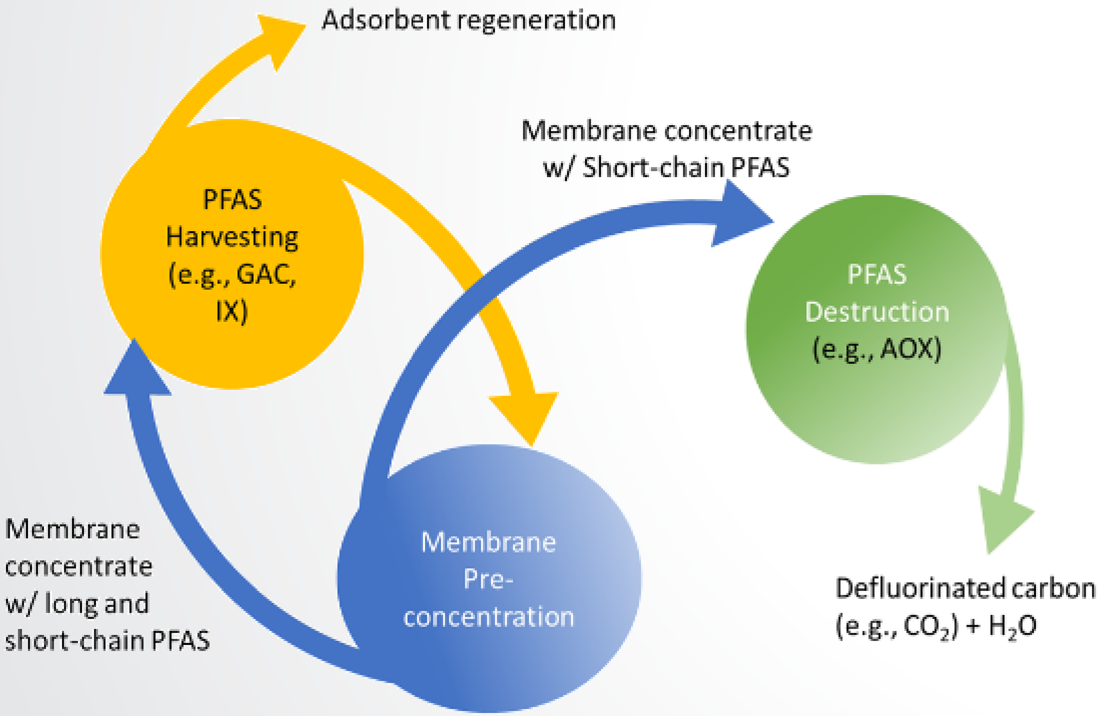
- Potable water, TDS 500 mg/L
- Loose RO membranes
- Flux rate = 19 gfd
- Recovery = 70-80 %
- pH adjustment
- Basic Antiscalant
- Cleaning interval = 16 mths
- Direct discharge of concentrate
- Membrane life = 5 years
- 7 % discount rate
- Mid-level cost
- 2021 dollars

Other scenarios will result in different costs

https://www.epa.gov/system/files/documents/2024-04/2024-pfas-tech-cost_final-508.pdf

Combined Processes?

Residual treatment will be very expensive

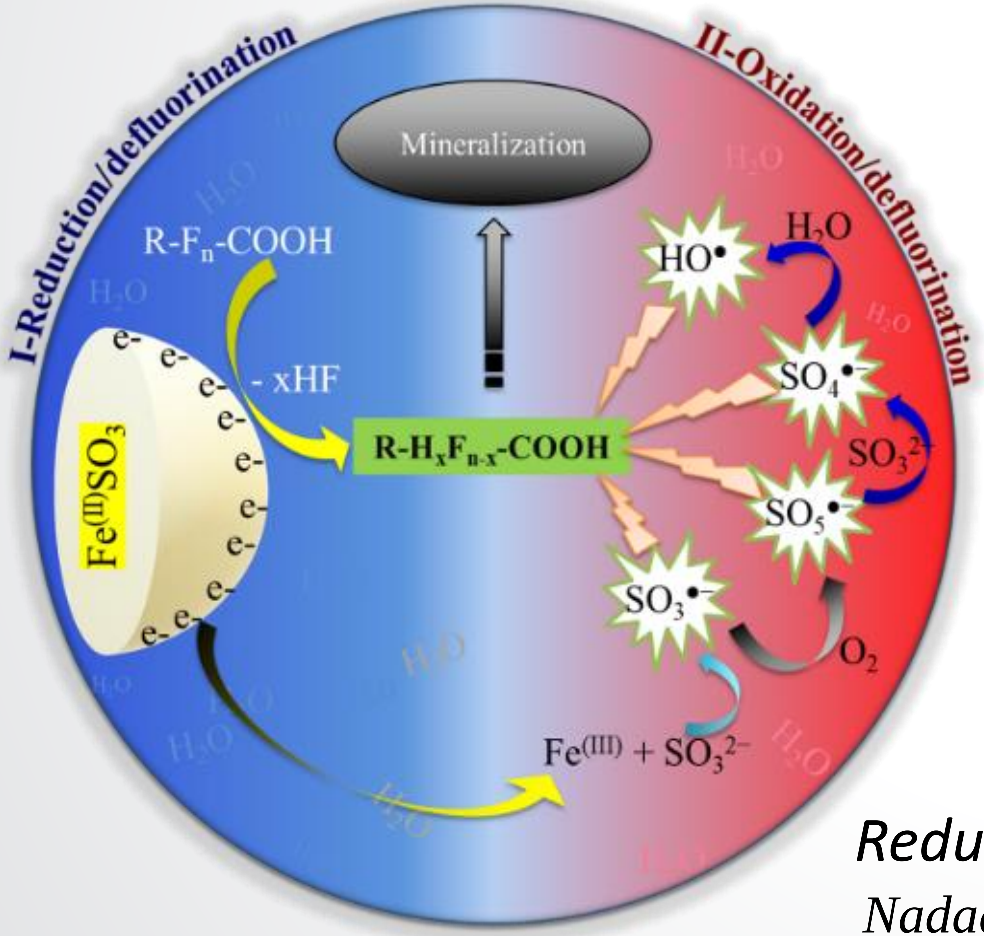


Further investigations are necessary for destruction or containment to prevent reintroduction of PFAS into the environment

- *Incineration (limited liquid sources)*
- *Pyrolysis (limited liquid sources)*
- *Supercritical water oxidation*
- *Hydrothermal liquefaction*
- *Hydrothermal oxidation*
- *Sub-critical water oxidation*
- *Sono-chemical oxidation*
- *Zero-valent iron*
- *Electron beam*
- *Solvated electrons*
- *Advanced oxidation*
- *Photocatalysis*
- *Ultraviolet irradiation*
- *Activated persulfate*
- *Plasma*
- *Biological*

Combined Processes?

Residual treatment will be very expensive



Further investigations are necessary for destruction or containment to prevent reintroduction of PFAS into the environment

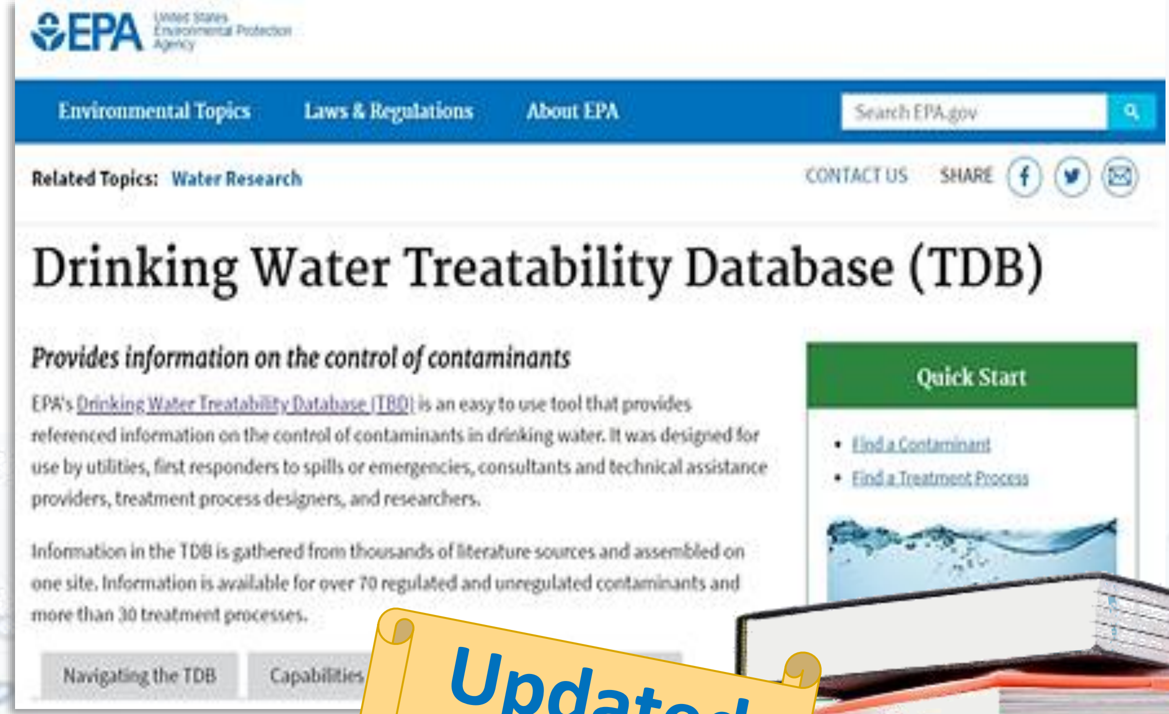
Reductive-oxidative using iron-based catalyst (Cat-Redox)

Nadagouda et al. US EPA, US Patent US20200179909A1

Treatment Information and Technical Support

Drinking Water Treatability Database

- Interactive literature review database with thousands of sources
- 160 regulated and unregulated contaminants
- 35 treatment processes commonly employed or known to be effective
- Treatment information to be used in performance or cost models



Currently available:

☑ 68 different PFAS
☑ Over 200 PFAS references

Access EPA's Drinking Water Treatability Database
(or search "EPA TDB" in your browser)

Environmental Technologies Design Option Tool

- Suite of software models
- Evaluate and design systems that use granular activated carbon or anion exchange resins for the removal of contaminants, including PFAS, from drinking water and wastewater.

Access ETDOT
(or search "EPA ETDOT" in your browser)

Drinking Water State Revolving Fund Technical Support: Emerging Contaminants/PFAS

Objectives

1. Identify sustainable and cost-effective EC/PFAS treatment strategies, with a particular focus on small and disadvantaged drinking water systems.
2. Develop tools and approaches for determining effective treatment for EC/PFAS.
3. Disseminate results nationally.

Drinking Water State Revolving Fund Technical Support: Emerging Contaminants/PFAS

Specific Tasks

Technology Demonstration and Evaluation

- Conduct water sampling and analysis over extended periods (>6 months) for full-scale and pilot systems, where appropriate.
- Evaluate and optimize the PFAS treatment scheme.
- Evaluate management strategies for residual streams (spent GAC and IEX, RO concentrate).

App/Model/Tool/Website Development

- Develop tools (performance and cost models) and approaches (best practice guides).
- Link data, materials, and tools to EPA's Drinking Water Treatability Database and other outlets to facilitate use.

Drinking Water State Revolving Fund Technical Support: Emerging Contaminants/PFAS

Benefits to the System/Community

- EPA-funded in-depth evaluation of the performance and operation of EC/PFAS treatment systems (6 months to multiple years).
- Access to new tools, apps, and informational guides on the design, performance, operation, and cost of EC/PFAS treatment technologies trained with the utility's data.

Data collected with be made available to help local decision making on optimization of both the new technology and entire treatment scheme.

Direct access to EPA's technical experts.

- Potential use of EC/PFAS data for use as regulatory sampling (state dependent).
- An opportunity to collaborate with the EPA on presentations, publications, and other materials especially for the local community.

Points of Contact

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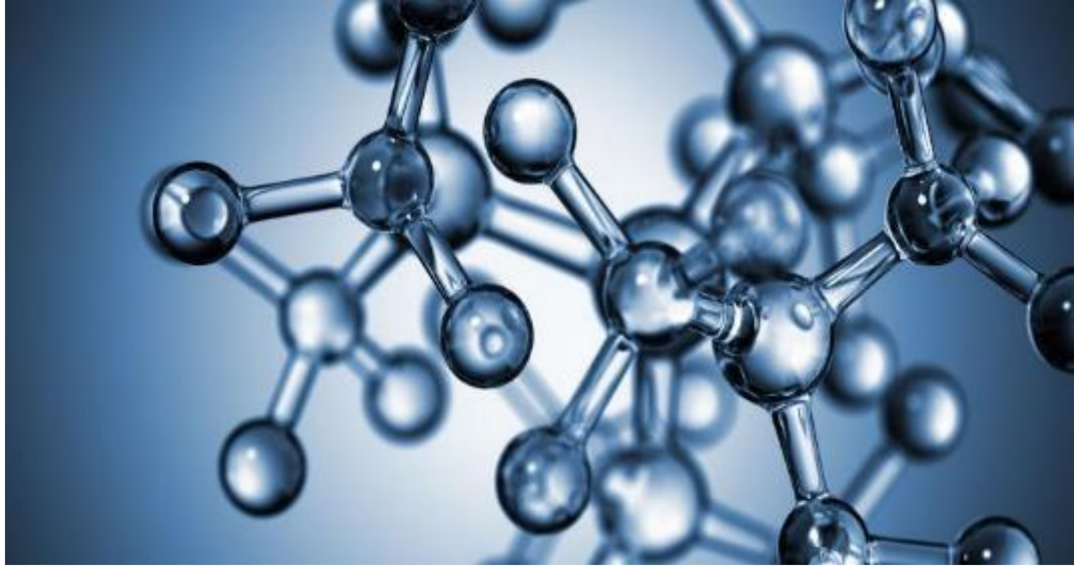

EPA PFAS Activities: epa.gov/pfas

PFAS Research and Development: epa.gov/chemical-research/research-and-polyfluoroalkyl-substances-pfas

What Affects PFAS Removal?

Contaminant and Design Choices

Parameter/Choice	Impact (capacity and/or kinetics)
Contaminant	Capacity and kinetics (external and internal)
Contaminant concentration	Capacity and kinetics (external and internal)
Adsorbent choice	Capacity and kinetics (external and internal)
Adsorbent particle size	Kinetics (external, internal)
Adsorbent shape	Kinetics (external)
Hydraulic loading rate	Kinetics (external)
Column size / replacement frequency	Capacity (when replaced)
System operation (parallel, series, lead lag)	Capacity (when replaced)

What Affects PFAS Removal? (continued)

Background Water Quality

Parameter/Choice	Impact (capacity and/or kinetics)
Inorganics (e.g., nitrate, sulfate, bicarbonate)	Capacity
Other organic contaminants	Capacity
Natural organic matter (NOM)	**Direct competition:** Capacity **Preloading:** Capacity and kinetics (internal)
Biofilm growth	Capacity and kinetics (external and internal)
Temperature	Capacity and kinetics (external and internal)
Inorganic precipitation (Fe, Mn)	Capacity and kinetics (external)

Effective Drinking Water Treatment for PFOS

Treatment Type	Percent Removal	Effectiveness
☑ Anion Exchange Resin (AEX) →	90 to 99 →	Effective
☑ High Pressure Membranes →	93 to 99 →	Effective
☑ Granular Activated Carbon (GAC)		
☑ Designed for PFAS Removal →	>89 to >98 →	Effective
⃠ *Extended Run Time* →	*0 to 26* →	*Ineffective*
△ Powdered Activated Carbon (PAC) →	10 to 97 →	Effective for only select applications

PAC dose to achieve

50% Removal: 16 mg/L,
90% Removal: >50 mg/L
(Dudley et al., 2015)

Q&A Session

Learn more about drinking water:
epa.gov/ground-water-and-drinking-water

Get feature articles about EPA research:
epa.gov/sciencematters