UH Energy
UNIVERSITY OF HOUSTON

SOUTH TEXAS SECTION OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

# 16th STS-AIChE
# Southwest Process Technology Conference

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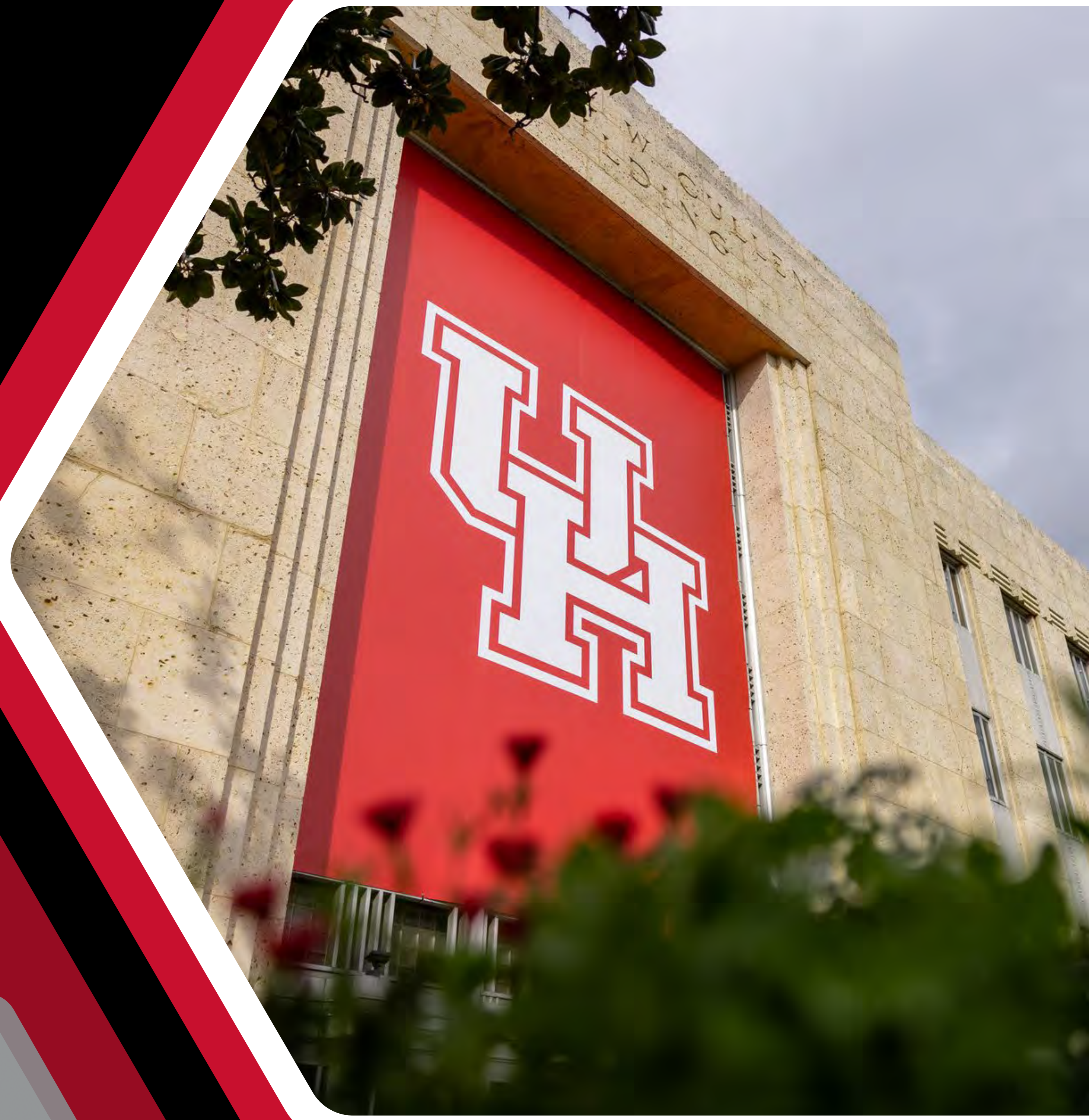
University of Houston





- Addressing PFAS in Water Supplies: Regulatory Landscape, Treatment Technologies, and Industry Response


- Corey Smith, PE, BCEE, CWO & Ramanathan Ganesan, MS (Chem.)
- Civitas Engineering Group, Inc.



# Agenda

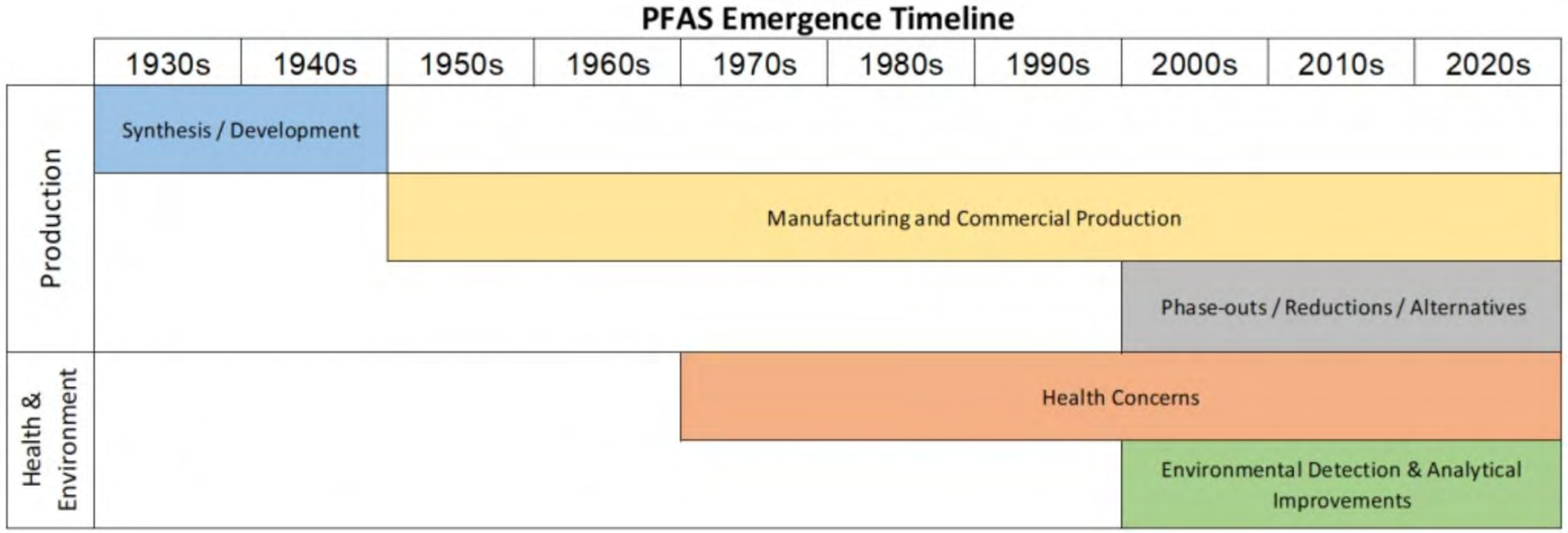
- Section 1: PFAS Overview
- Section 2: Available Technologies
- Section 3: Funding Options
- Section 4: Emerging Technologies
- Section 5: EPA Regulations for Wastewater
- Civitas Engineering Group, Inc.

# Section 1: PFAS Overview



# What are PFAS (and why they're hard to manage)

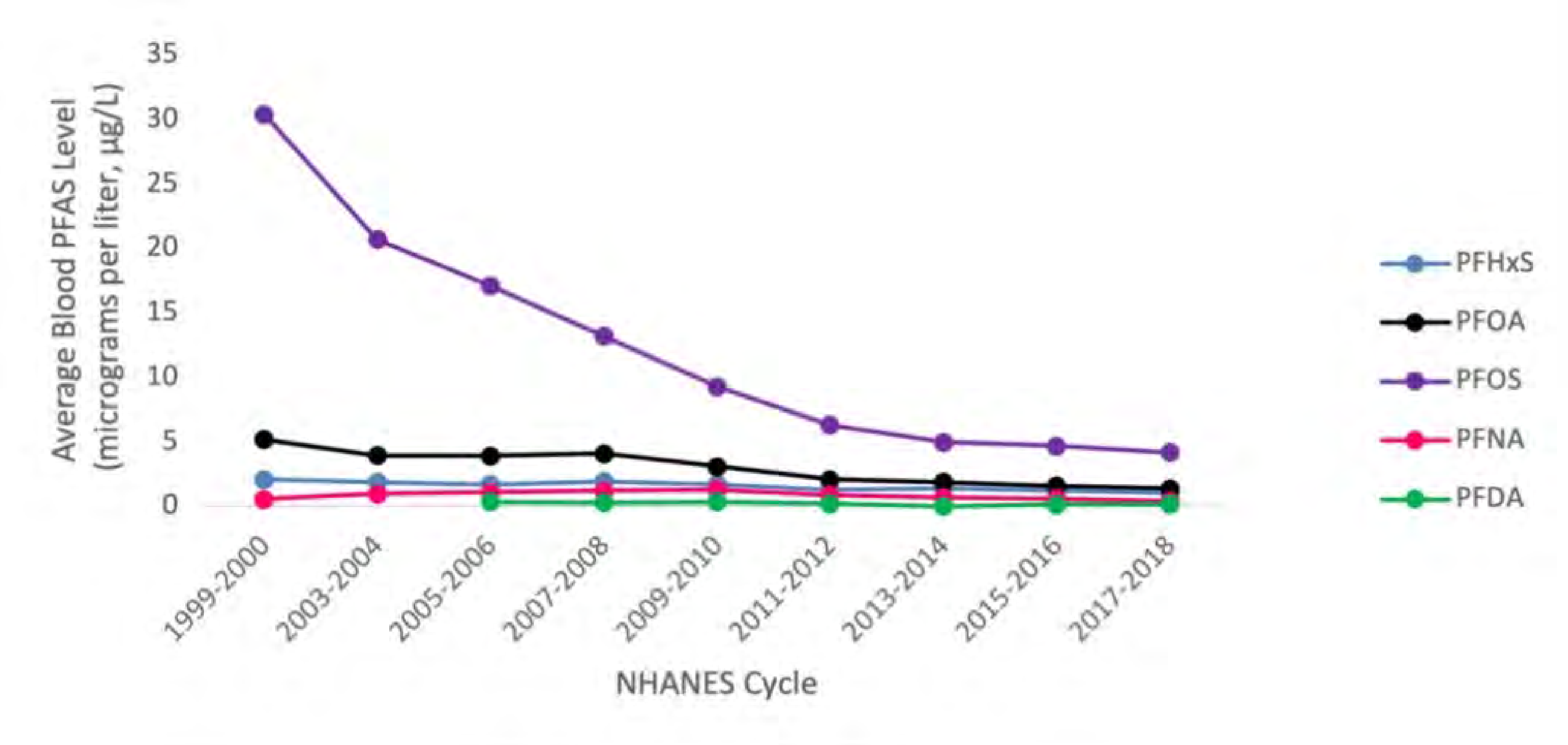
- Family of 12,000+ synthetic chemicals (introduced beginning in 1940s)
- Used in firefighting foams, textiles, packaging, plating
- Persistent, bio-accumulative, mobile
- Regulatory definitions vary (EPA, OECD, EU)




*Source 1

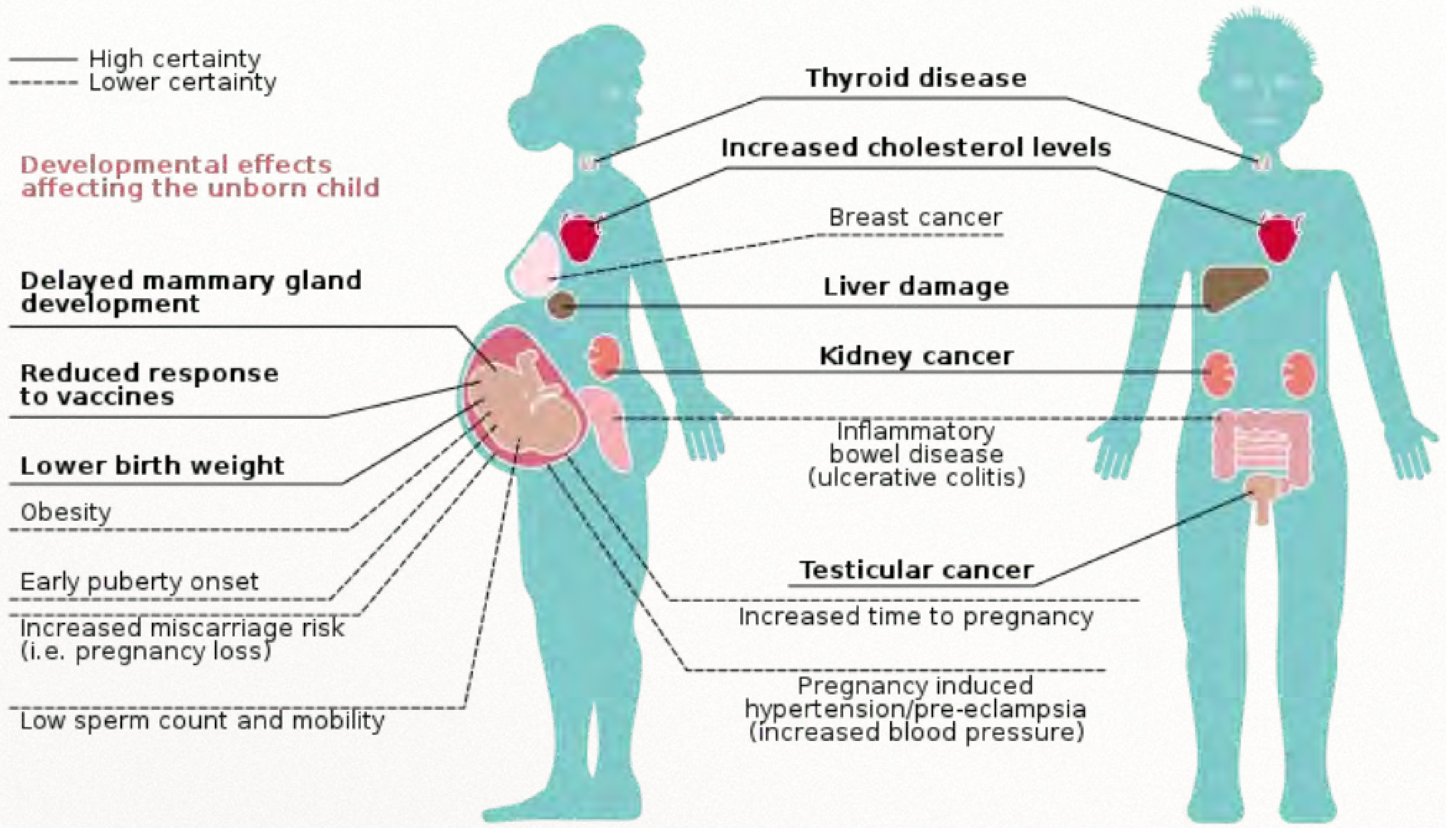
General Timeline of PFAS Emergence and Awareness

# Emerging Health & Environmental Concerns




*Source 1

PFAS level in Human Blood over the years




*Source 1

PFAS Effects in Human Body

# PFAS Awareness Timeline

| Categories | Activities, Milestones, and Developments in 2000s |
|---|---|
| Scientific Progress & Health Advisories | • 2002 – PFAS drinking water investigation commences in Minnesota<br>• 2009 – USEPA issues provisional short-term health advisories for PFOA and PFOS<br>• 2009 – C8 Science Panel begins publication of studies<br>• 2012 – USEPA investigates GenX in Cape Fear River, NC<br>• 2013 – UCMR3 testing of six PFAS in public water systems initiated<br>• 2016 – USEPA issues lifetime health advisory levels for PFOS and PFOA<br>• 2018 – ATSDR 3rd draft toxicological profile for perfluoroalkyls for public review<br>• 2018 – USEPA issues Fact Sheet: Draft Toxicity Assessments for GenX Chemicals and PFBS |
| Regulatory Actions | • 2002 – USEPA issues first PFAS-related consent order, requiring a PFAS manufacturer to provide alternate drinking water (USEPA, 2002)<br>• 2002 & 2007 – USEPA finalizes Significant New Use Rules (SNURs) under TSCA<br>• 2006 to 2015 – 2010/2015 PFOA Stewardship Program<br>• 2013 & 2015 – USEPA publishes and proposes additional SNURs<br>• 2018 – USEPA hosts National PFAS Summit and community engagement meetings<br>• 2019 – USEPA issues PFAS Action Plan |
| Legal Actions | • 2010 – MN files lawsuit against 3M alleging environmental and drinking water exposures<br>• 2017 – DuPont and Chemours settle 3,550 lawsuits in OH and WV associated with Parkersburg, WV facility<br>• 2017 – Class action lawsuit filed against DuPont and Chemours related to GenX in NC<br>• 2018 – Lawsuit between MN and 3M settles; MI and NY pursue lawsuits against industry<br>• 2018 – Class action lawsuit against 3M, DuPont, and Chemours filed on behalf of everyone in the United States who has been exposed to PFAS |

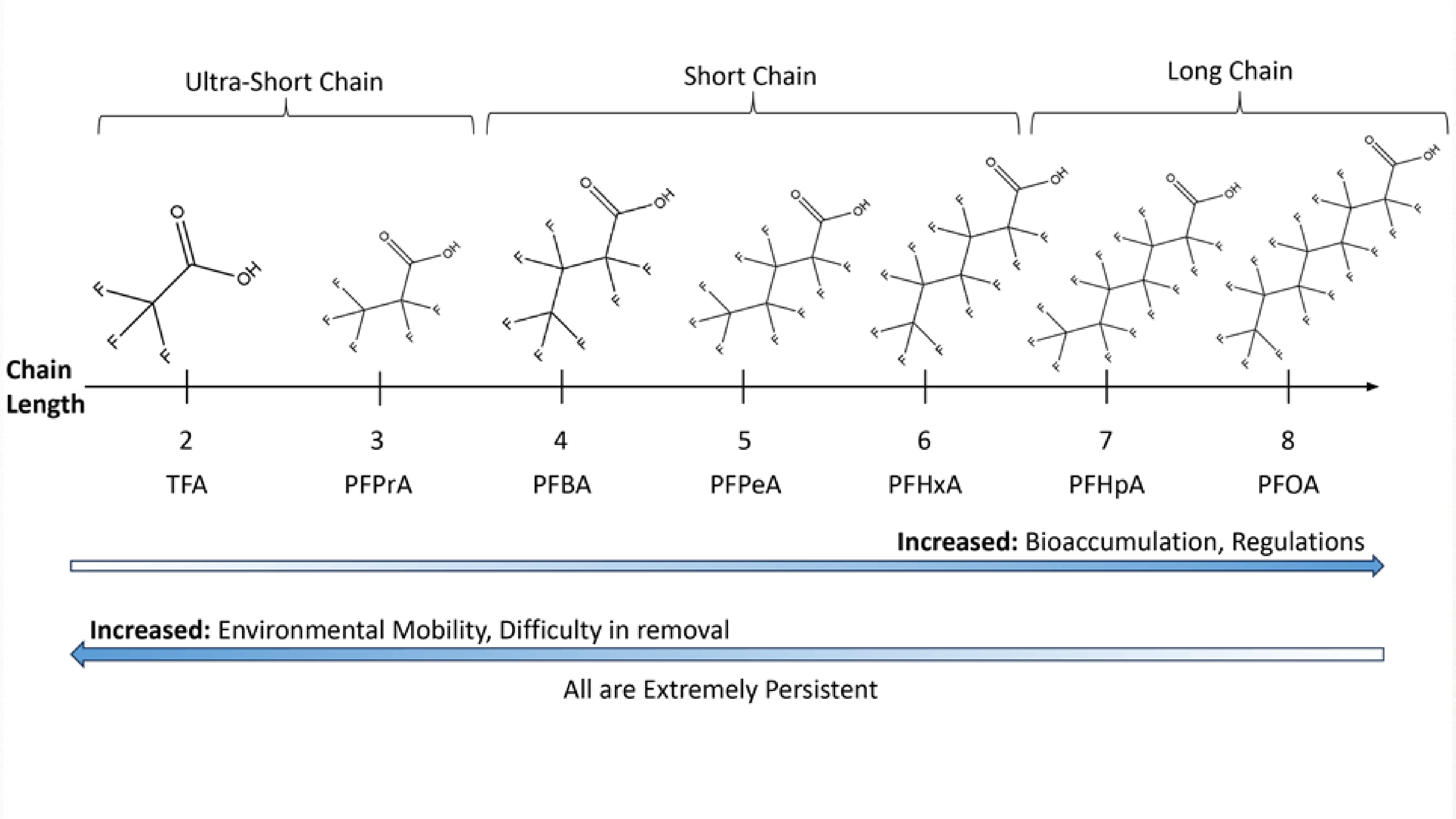
Select examples provided as indicators of societal awareness and response to PFAS since 2000; not an exhaustive list.

*Source 1

PFAS Growing Awareness and Concerns

# PFAS Chemistry: Long vs Short Chain

- Long-chain: PFCAs with ≥7 fluorinated carbons (e.g., PFOA C8), PFSAs with ≥6 (e.g., PFOS C8).
- Short-chain: PFCAs <7, PFSAs <6 (e.g., PFBS C4).
- Short-chain are generally more mobile and harder to adsorb than long-chain—this drives technology choice and media life




*Source 2

PFAS Short Chain & Long Chain Compounds

# PFAS Sources & Pathways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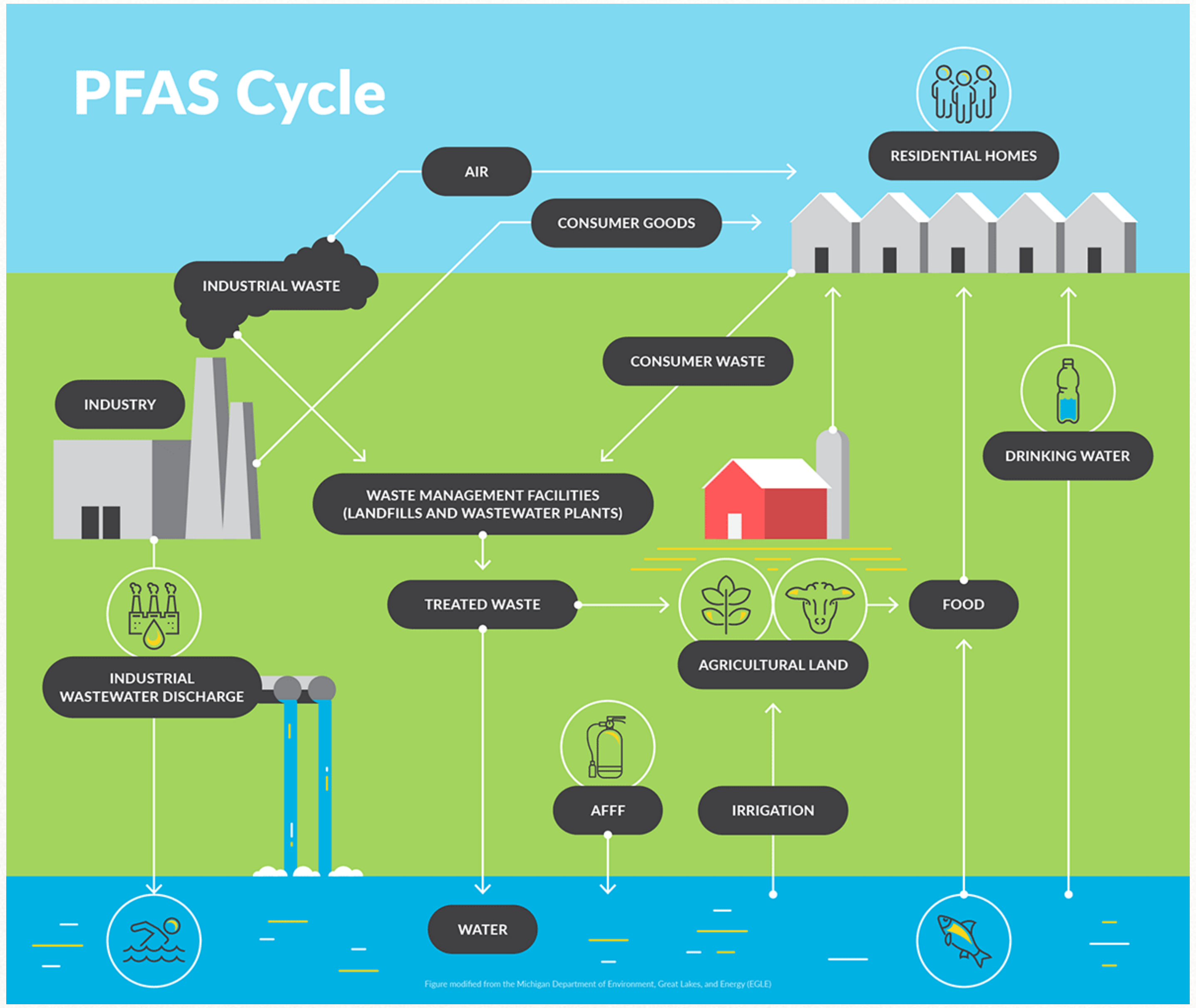
PFAS Sources

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PFAS Human Exposure Routes

# How PFAS Precursors Turn into Terminal PFAS

## Biological Transformation in WWTPs

- Activated sludge processes or aerobic/anaerobic digestion, polyfluoroalkyl substances (precursors) can biodegrade into perfluoroalkyl acids (PFAAs)
- FTS → PFHxA
  FTOH (fluorotelomer alcohol) → PFOA

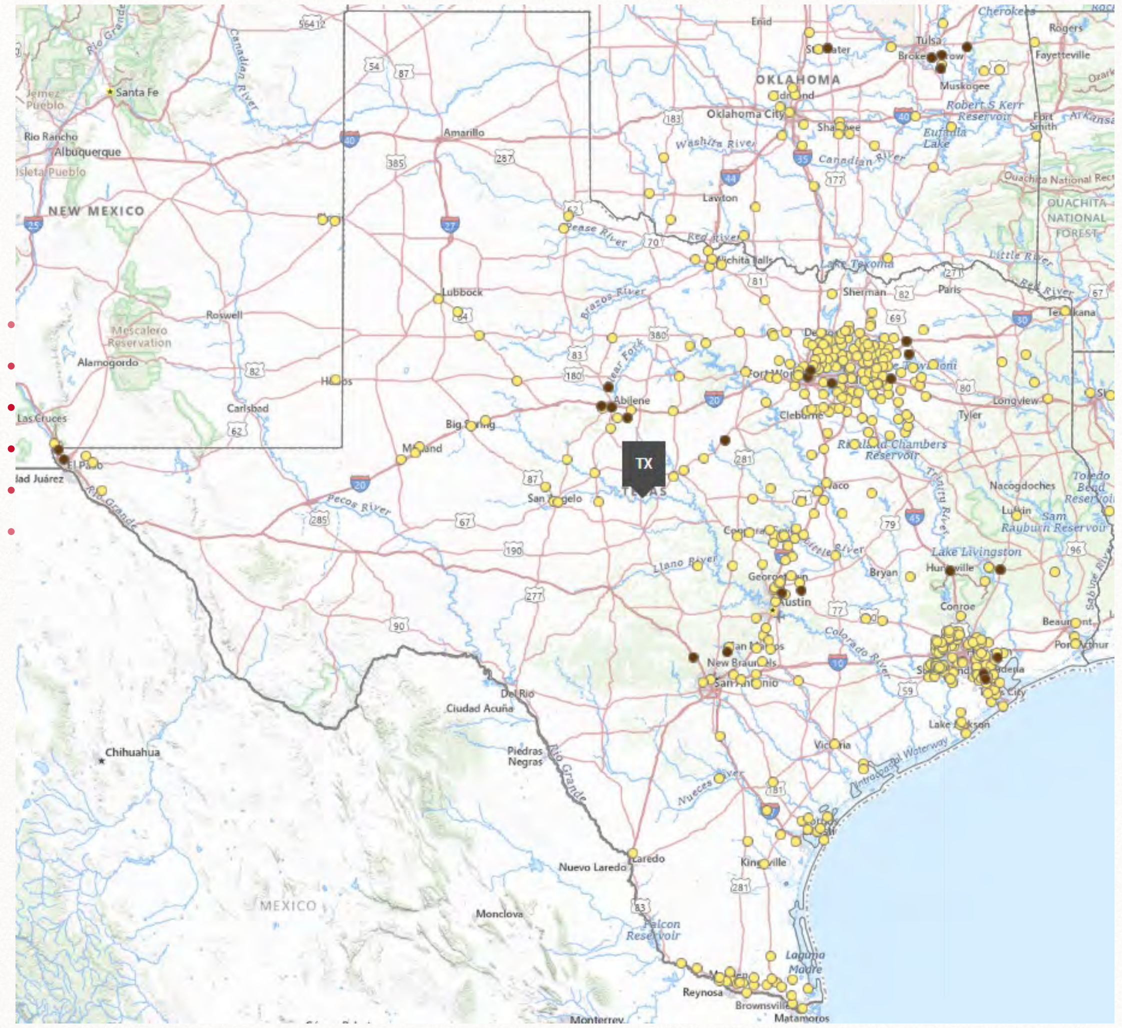
## Oxidative Transformation in Natural Waters

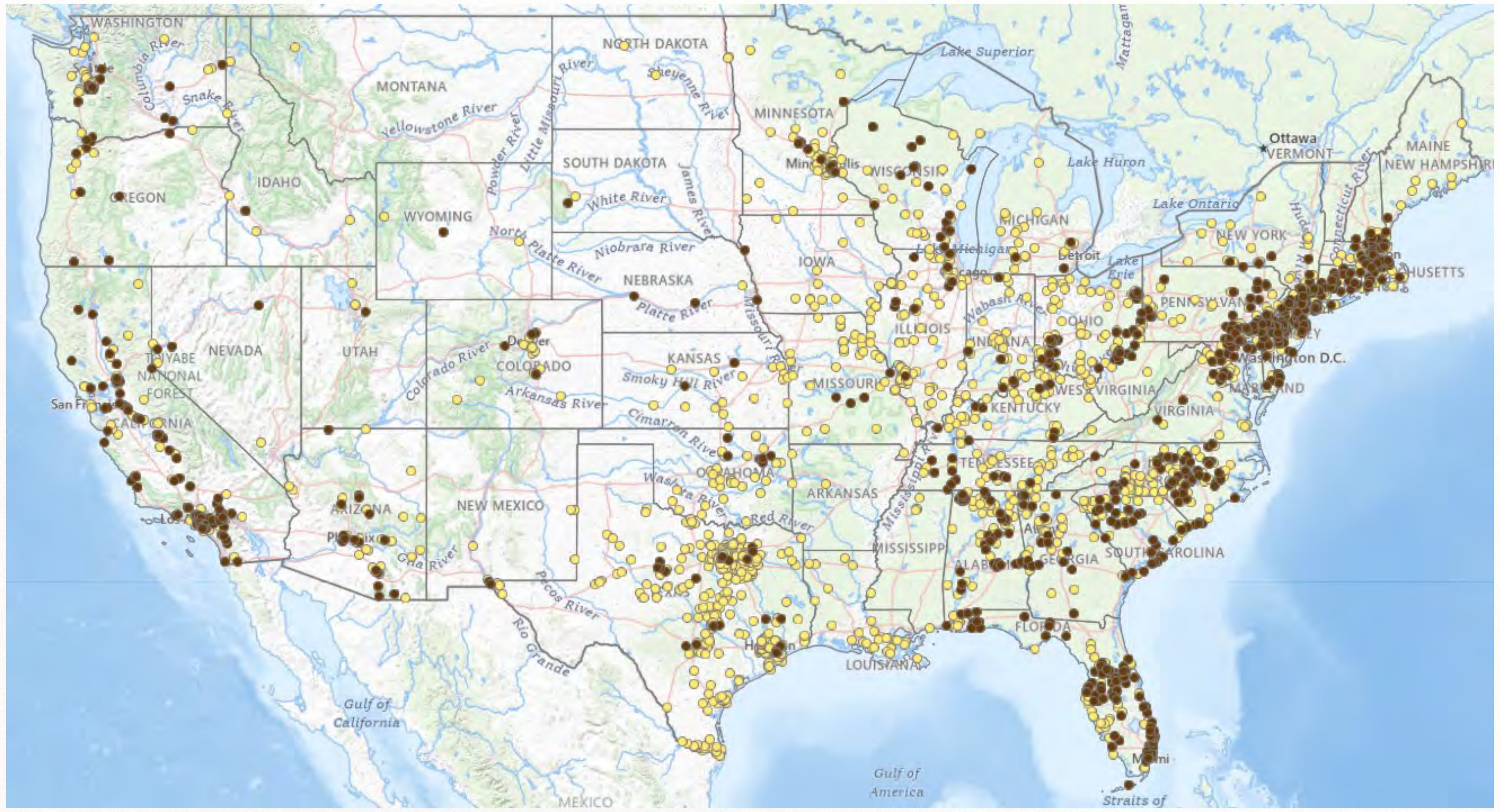
- Ozone ($O_3$)
  Sunlight (UV)
  Hydroxyl Radicals (•OH)
- diPAP (di-phosphate precursor) → PFOA over time via environmental oxidation

## Chlorination in Drinking Water Treatment

- Chlorine disinfection can trigger the Oxidation of Precursors into Terminal PFAS
- Chlorinated Water + Time = increased PFHxA or PFOS concentrations

# PFAS Occurrence in Drinking Water

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**Drinking Water - UCMR and State Data:**

- [x] UCMR PWSs with:
  - ● Result(s) Above Maximum Contaminant Level (MCL)
  - ● Result(s) At or Above UCMR MRL
  - ○ No Results At or Above UCMR MRL



# US EPA – Latest Regulatory Landscape

- May 2025 Update to National Primary Drinking Water Regulation
  - PFOA MCL - 4 ppt (MCLG = 0)
  - PFOS MCL - 4 ppt (MCLG = 0)
- Initial monitoring generally due by 2027; compliance extended to 2031.
- Reconsider the other compounds, including the Hazard Index
- Sept - Motion filed for above. Intent for revision in Spring 2026

| Compound | Final MCLG | Final MCL (enforceable levels) |
|---|---|---|
| PFOA | Zero | 4.0 parts per trillion (ppt) (also expressed as ng/L) |
| PFOS | Zero | 4.0 ppt |
| PFHxS | 10 ppt | 10 ppt |
| PFNA | 10 ppt | 10 ppt |
| HFPO-DA (commonly known as GenX Chemicals) | 10 ppt | 10 ppt |
| Mixtures Containing two or more PFHxS, PFNA, HFPO-DA, and PFBS | 1 (unitless) Hazard Index | 1 (unitless) Hazard Index |

# Sampling (Drinking Water & Surface Water Nuance)

- **SAP = Sampling & Analysis Plan** → defines **what, where, and how** samples are collected & analyzed.
- **Why needed** → ensures data quality, consistency, and regulatory defensibility.
- **Purpose** → characterize PFAS & key water quality factors to support PFAS pilot study design.
- **Scope** → sampling at multiple WTP unit processes (water & sludge), with defined approach & QA/QC

| Field QC Samples | | |
|---|---|---|
| QC Sample | Description | Minimum Frequency |
| Field Reagent Blank (FRB) | Reagent water provided by the lab that is poured into an empty sample bottle or a bottle that only contains preservative. | Two FRBs per sampling day. One per PFAS water method. |
| Field Duplicate | Sample collected at the same time and location under same circumstances and treated the same all the way through laboratory and field procedures. | One duplicate per sampling day. |
| Equipment Blank | If needed, equipment blanks are prepared by pouring PFAS-free laboratory grade water through non-disposable or non-dedicated sampling equipment such as tubing. | Collected once for the sludge sampling beaker. Analyzed by EPA method 1633 |

# Sampling Equipment

| ACCEPTED SAMPLING EQUIPMENT | |
|---|---|
| USES | Example Materials |
| Sampling Equipment | HDPE, Polypropylene, Silicone, Stainless Steel, PVC, Acetate, Cotton, LDPE bags (e.g, Ziploc), LDPE |
| Items used to secure sampling bottles | Natural Rubber, Nylon, Uncoated Metal springs, polyethylene |

LDPE may be used if an equipment blank has confirmed it to be PFAS-free. LDPE does not contain PFAS in the raw material but may contain PFAS cross-contamination from the manufacturing process.

| PROHIBITED SAMPLING EQUIPMENT | | |
|---|---|---|
| PFAS-Based Fluoropolymers | Trademark | Example Materials |
| Polytetrafluoroethylene (PTFE) | Teflon® and Hostaflon® | Ball check-valves on certain bailers, lining of some hoses and tubing, wiring, certain kinds of gears, lubricant, and some objects that require the sliding action or parts |
| Polyvinylidene-fluoride (PVDF) | Kynar® | Tubing, films/coatings on aluminum, galvanized or aluminized steel, wire insulators, and lithium-ion batteries |
| Polychlorotrifluoroethylene (PCTFE) | Neoflon® | Valves, seals, gaskets, and food packaging |
| Ethylene-tetrafluoro-ethylene (ETFE) | Tefzel® | Wire and cable insulation and covers, films for roofing and siding, liners in pipes, and some cable ties |
| Fluorinated-ethylene propylene (FEP) | Teflon® FEP and Hostaflon® FEP, and may also include Neoflon® | Wire and cable insulation and covers, pipe linings, and some labware |
| Perfluoroalkoxy polymer (FAP) | - | Known to be used in the food packaging industry |
| Perfluoropolyethers (PFPE) | - | Used as a surface treatment for natural stone, metal, glass, plastic, textiles, leather, and paper and paperboard treatment for food-contact applications. |



# Sampling Equipment

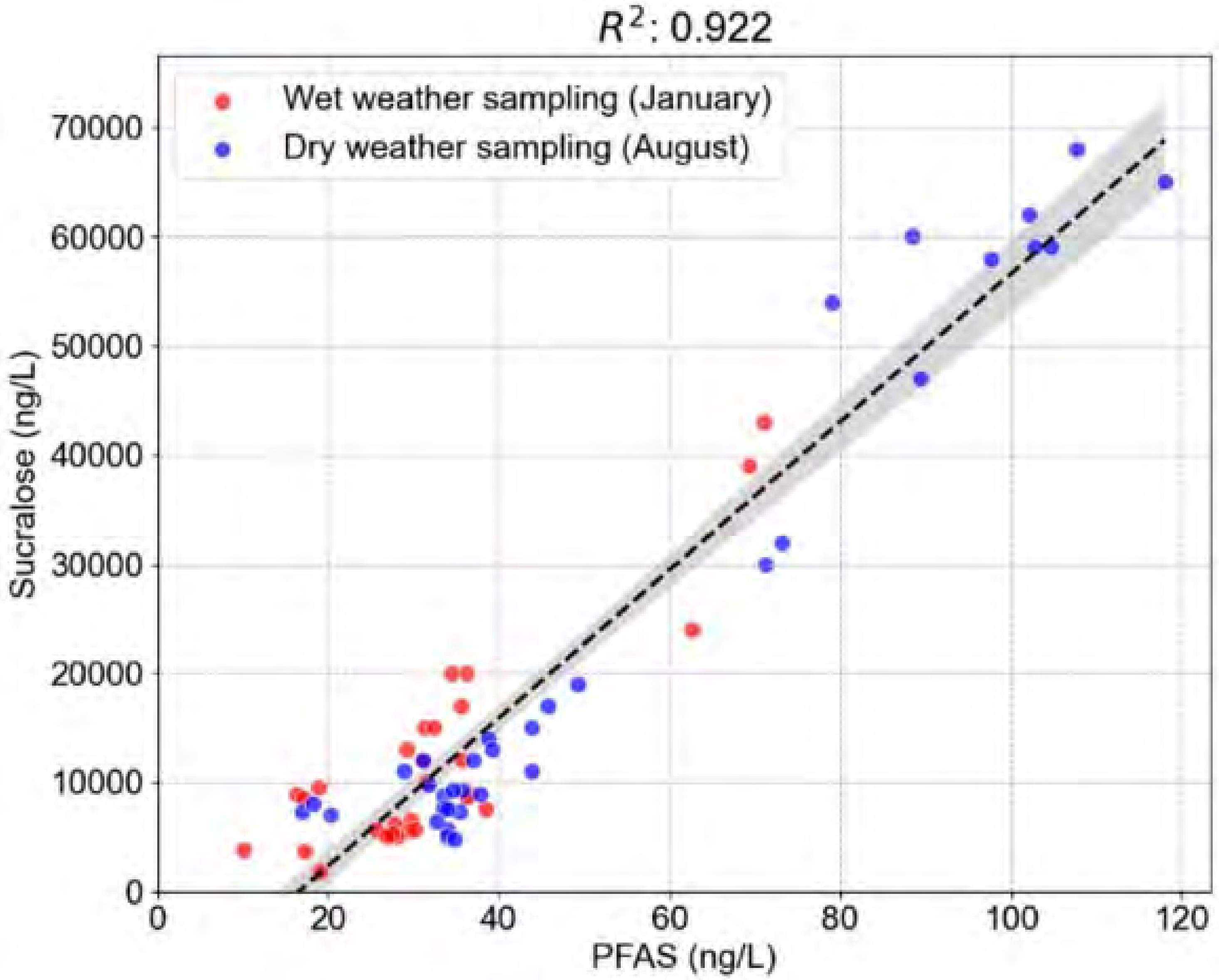
| PROHIBITED AND ALLOWABLW PERSONAL PROTECTION EQUIPMENT (PPE) | | |
|---|---|---|
| PPE Category | Prohibited | Allowable |
| Gloves | • Latex Gloves | • Powderless Nitrile Gloves |
| Apparel | • Polyethylene fiber suits<br>• Clothing washed with fabric softener<br>• Washed with water, dirt, and/or stain resistant chemicals<br>• Tyvek suits and water-resistant synthetics suits<br><br><u>Prohibited trademark products:</u><br>• Gore-Tex<br>• Tyvek<br>• Any Teflon® branded product and fabric protector<br>• GreenShield® NK Guard S Series<br>• Repellan KFC®<br>• Any RUCO® branded product<br>• Lurotex Protector RL ECO®<br>• Repellant KFC®<br>• UnidyneTM<br>• Resist Spills™<br>• Scotchgard™ Fabric Protector | • Safety boots made from polyurethane and/or Polyvinyl chloride (PVC)<br>• Synthetic and natural fibers (e.g., cotton) that are well laundered (more than six times with no fabric softener)<br>• PVC or wax-coated fabrics<br>• Neoprene |
| Personal Care Products<br>(e.g., cosmetics,<br>moisturizers, hand cream, dental floss, sunscreen, chap stick) | • Any product not listed in the adjacent column or without PFAS free verification | • Sunscreens: Banana Boat Sport Performance, Meijer Sunscreen Lotion, Neutrogena Ultra-Sheer Dry-Touch, Alba Organics Natural, Yes to Cucumbers, Aubrey Organics, Jason Natural Sun Block, Kiss My Face, Coppertone Ultra Guard Broad Spectrum, Coppertone Sport AccuSpray<br>• Insect Repellents: OFF Deep Woods, Sawyer Permethrin, Jason Natural Quit Bugging Me, Repel Lemon Eucalyptus, Herbal Armor, California Baby Natural Bug Spray, BabyGanics |

# WRF Study No. 5082

- Study included investigation of Trinity River Watershed


# WRF Study No. 5082

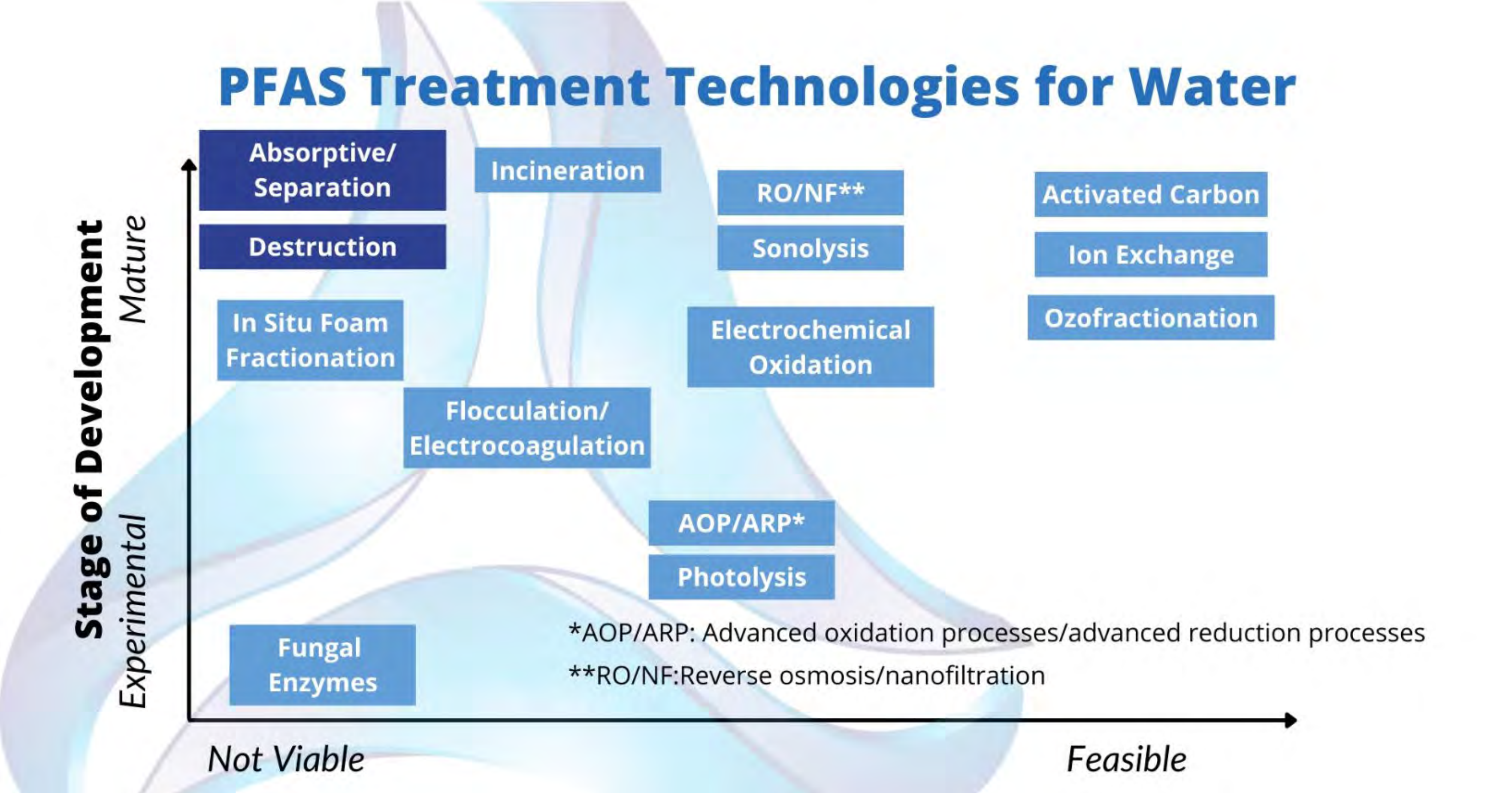
- Strong correlation between sucralose and PFAS concentrations
- Concluded that municipal WWTPs are dominant PFAS loading pathway
- Data suggest background non-WWTP source contributes ~19 ng/L
- Summer PFAS concentrations generally higher due to higher WWTP flow proportion



# Section 2: Available Treatment Technologies

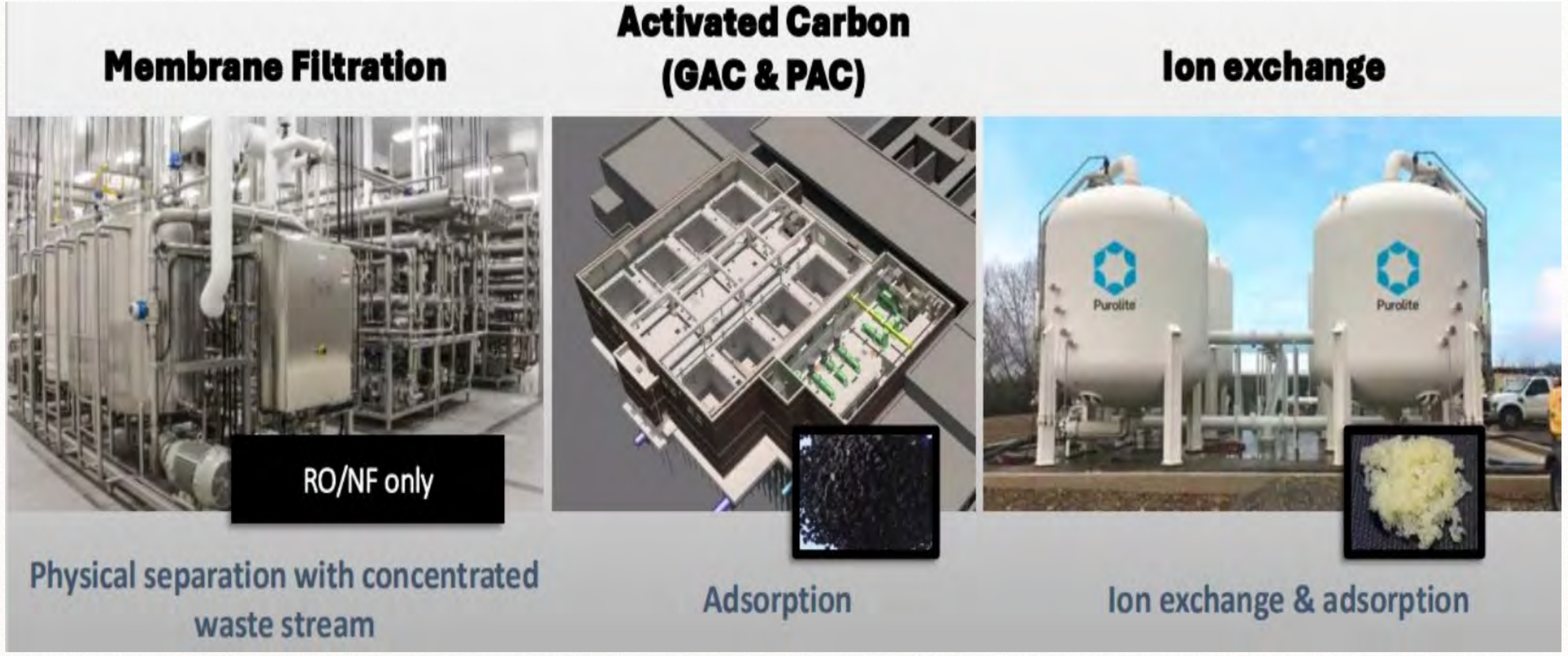
# Treatment Technologies

- Reverse Osmosis / Nanofiltration (RO/NF): high rejection across PFAS, but brine disposal challenges
- Ion Exchange (IX): effective for both long/short-chain, faster kinetics, EBCT ~2–4 minutes
- Granular Activated Carbon (GAC): effective for long-chain, EBCT ~10–15 minutes




*Source 6

PFAS Treatment Technology for Water

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Popular PFAS Treatment Technology

# Reverse Osmosis/Nanofiltration

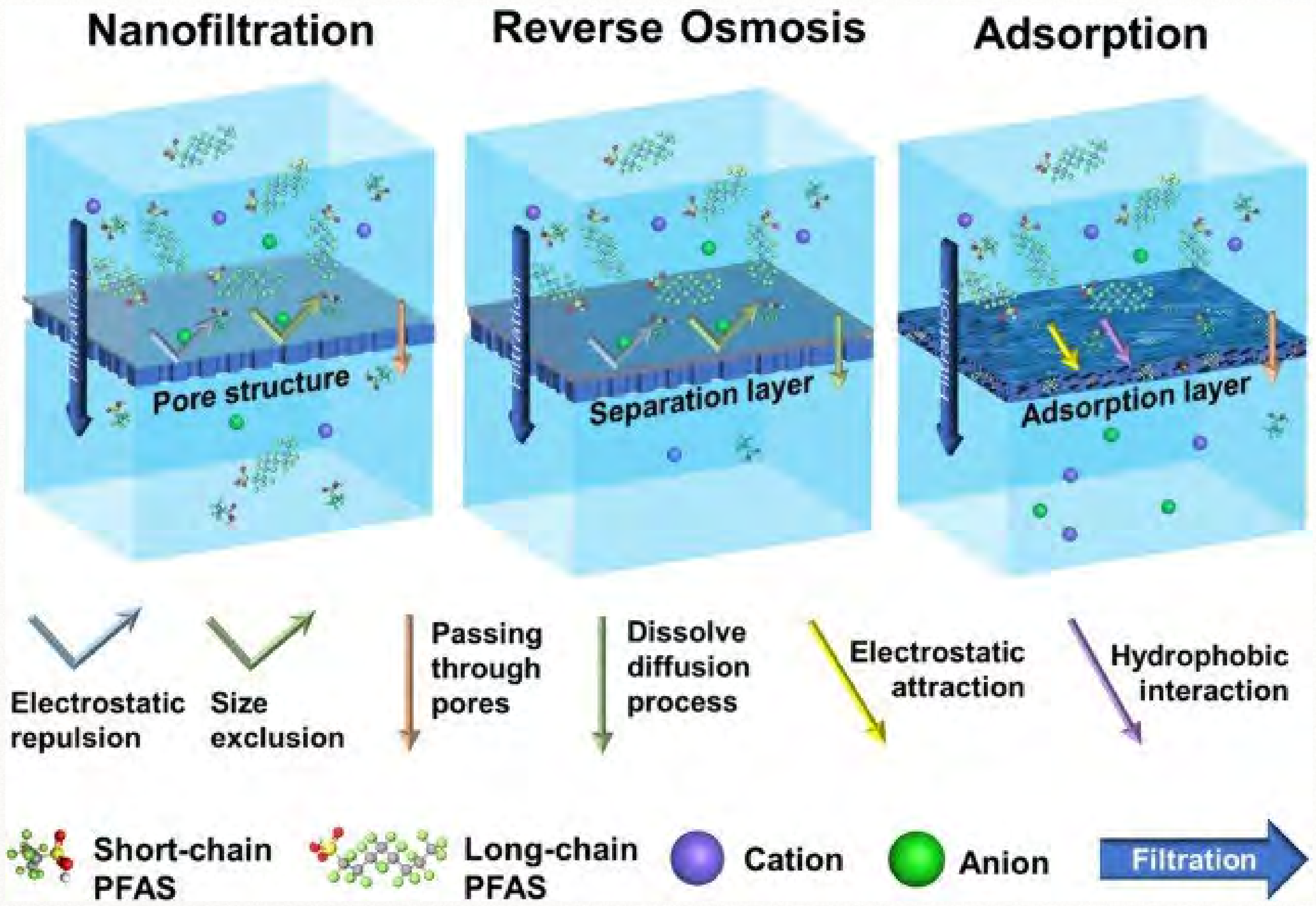
- Pretreatment required
- Post-treatment required for corrosivity
- Complex operation
- High capital & operating cost

Pros

- o Excellent PFAS removal (short & long chain)
- o Broad co-contaminant removal
- o Suitable for groundwater systems

Cons

- o Reject water requires treatment
- o High energy / cost
- o Membrane fouling risk




*Source 8

RO/Nanofiltration

| Potential Removal | Costs |
|---|---|
| PFOA: 47-99%<br>PFOS: 93-99% | $$$ |

# Ion Exhange(IX)

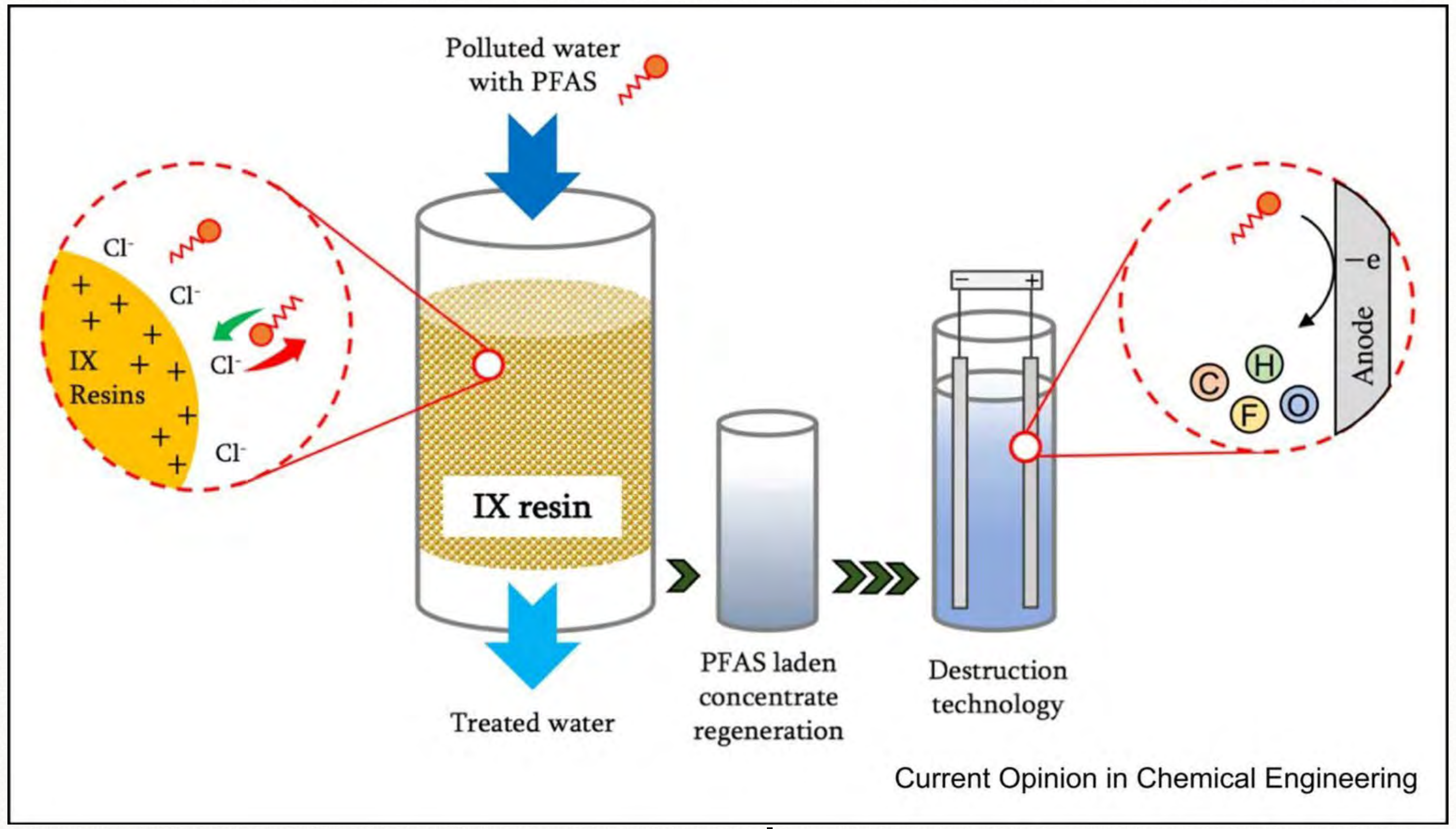
- Works via ion exchange + adsorption
- PFAS-selective, but not chlorine tolerant
- Often single-use, resins incinerated after service
- Example: Purofine PFA694E, CalRes 2301, Amberlite PSR2 Plus

Pros

- Resins can be specialized for specific PFAS
- Effective for both long & short-chain PFAS
- Faster sorption rates (depending on resin/porosity)

Cons

- Performance influenced by PFAS, ionic strength, resin type
- Variable efficacy across PFAS types
- Surface waters may need clarification/filtration before IX




*Source 10

Ion Exchange

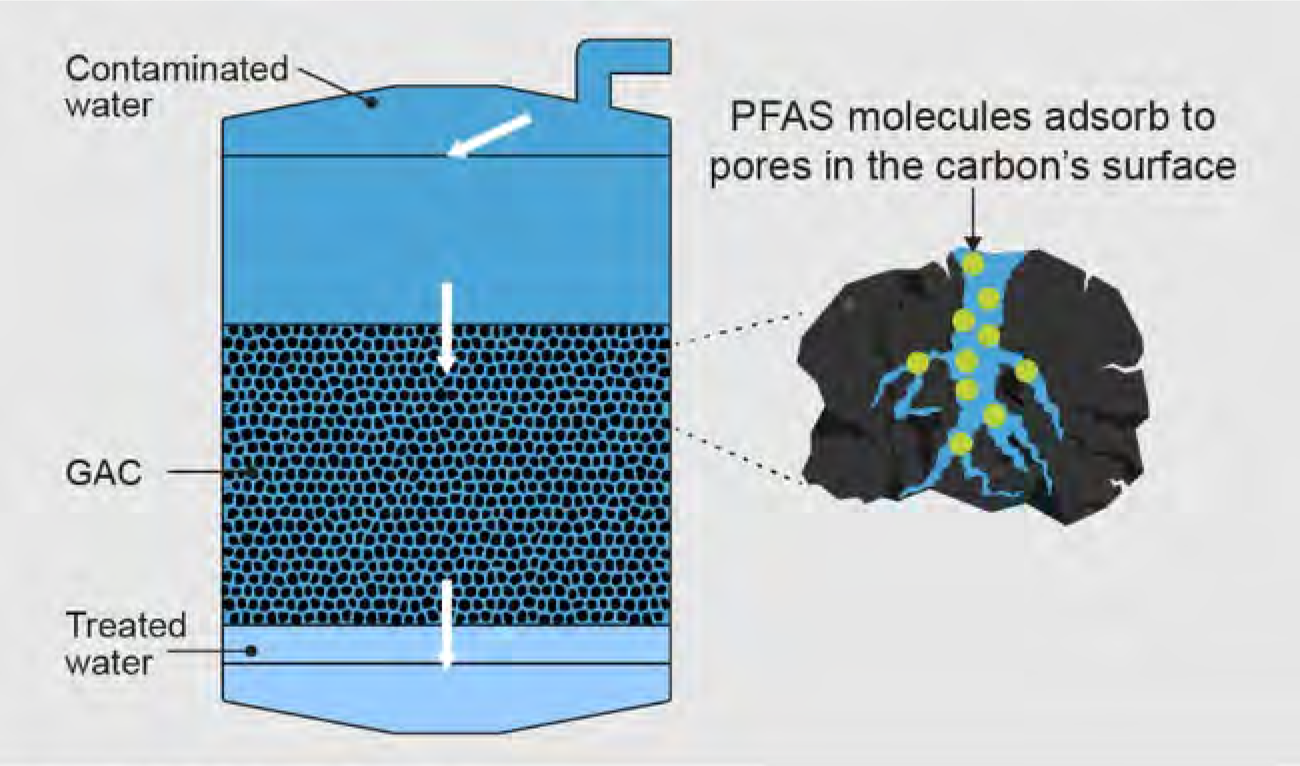
| Potential Removal | Costs |
|---|---|
| PFOA: 77-99%<br>PFOS: 90-99% | $$ |

# Granular & Powdered Activated Carbon (GAC / PAC)

- Removes PFAS via adsorption
- Many full-scale installations (drinking water & wastewater)
- Spent GAC is reactivated or incinerated
- Example: Calgon F400, Norit GAC400

Pros
- o Widely used for PFAS removal
- o High removal rate possible (esp. long-chain)
- o Flexible application for surface water or groundwater

Cons
- o Lower efficiency for short-chain PFAS removal
- o GAC requires long mass transfer and higher EBCT needed
- o Residual management required
- o TOC presence in influent reduces efficiency




Source: GAO. | GAO-23-106970

*Source 9

GAC Column

| Potential Removal | Costs |
| --- | --- |
| PFOA: 40-99%<br>PFOS: 18-99% | $$ |

# GAC Quality Parameters

## Density

### Apparent Density (AD)

- Density value on a dry basis
- Simple and repeatable
- Good QC parameters
  - Indicator of Pore Structure
  - Indicator of Spent Carbon Loading

Backwashed & Drained Density (BW&D)

- 15% less than apparent density
- BW&D = 0.85 x AD

## Iodine Number

Measures the loading of iodine in mg/g

- Indicator of total pore volume
- High MW/loading applications

Limitations

- Represents bulk loading
- Over 100% loading
- Static test
- Wetting

| Iodine number (mg/g) | Quality |
|---|---|
| >1000 | High Capacity |



# GAC Quality Parameters

## Empty Bed Contact Time (EBCT)

### Definition

- Time required to cycle a volume of water equal to the volume occupied by the media in a vessel
- This is not the hydraulic residence time

### Equation

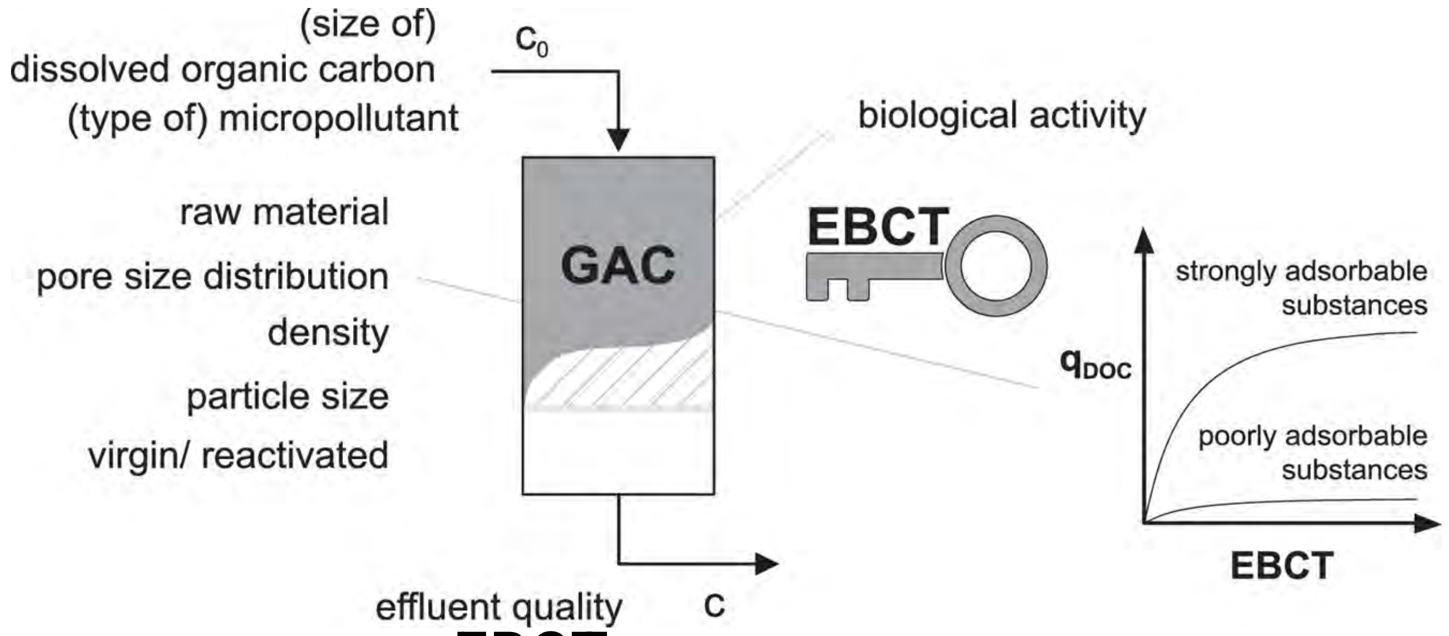
- EBCT(min) = Volume of media in filter (gal)/flowrate through filter (gpm)

### Adsorption is not instantaneous

- Need sufficient contact time to achieve desired treatment objectives
- Lead/Lag recommended for certain application(i.e., PFAS)

### Potential issues of Undersized EBCTs

- Reduced service life
- Premature breakthrough
- Diminished media utilization




*Source 11

EBCT

| GAC Vessel EBCT Targets | |
|---|---|
| | EBCT (min) |
| TOC | 7-15 |
| PFAS | 10 - 20 |
| VOCs | 6-10 |
| T&O | 5-10 |

# GAC System Design Parameters

## Hydraulic Loading Rate (HLR)

### Definition

- Volumetric flow of velocity expressed typically as flow per area (eg. gpm/ft$^2$)

### Equation

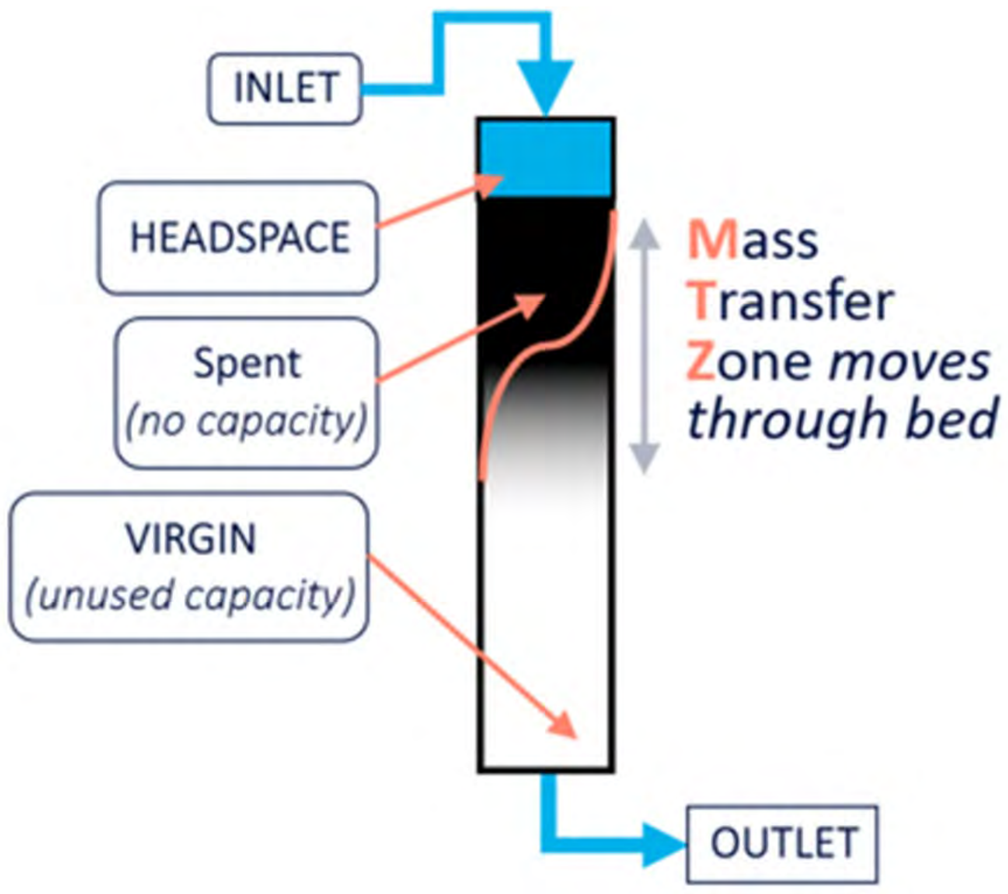
- HLR (gpm/ft$^2$) = flowrate through filter (gpm)/ surface area of filter (ft$^2$)

### The HLR controls the mass transfer zones (MTZ)

- Allows for even adsorption/Carbon use
- Recommended HLR range = 6-10 gpm/ft$^2$ for GAC

### Potential issues if outside recommended target

- Too low -> flow channeling
- Too high or low -> poor media utilization
- Too high -> excessive head loss
- Too high -> mechanical failures

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# Importance of Testing

## Motivation and Type of Testing

### Why

- Extremely difficult to quantify performance without testing
- Many Factors influence the effective service life ot GAC:
  - Water quality
  - EBCT & HLR
  - Target contamination concentration
  - Co-contaminants

### Goals

- Feasibility Assessment
- Product Comparison
- Service Life Estimation

### Types

- Bench Scale
  - Isotherm
  - Rapid Small Scale Column Testing (RSSCT)
- In-Process
  - Pilot Column
  - Full-Scale Filter

# Rapid Small Scale of Column Testing (RSSCT)

## Main Takeaways

- Assess ability to remove target contaminants
- Quick performance comparison of different GACs
- Very rough estimate of bed life

## Limitations

- Fluctuations in influent quality not modeled
- No bio activity assessment possible
- No accurate assessment of turbidity removal

*Source 12

RSSCT process for PFAS

# Pilot Column Test

## Main Takeaways

- Assess ability to remove target contaminants
- Investigates performance comparison of different media
- More accurate estimate of bed life

## Limitations

- Fluctuations in influent quality
- Bio activity assessment possible
- Turbidity removal assessment possible
- Ability to test various bed depths
- Ability to test various hydraulic loading rates

Pilot Column Test for PFAS

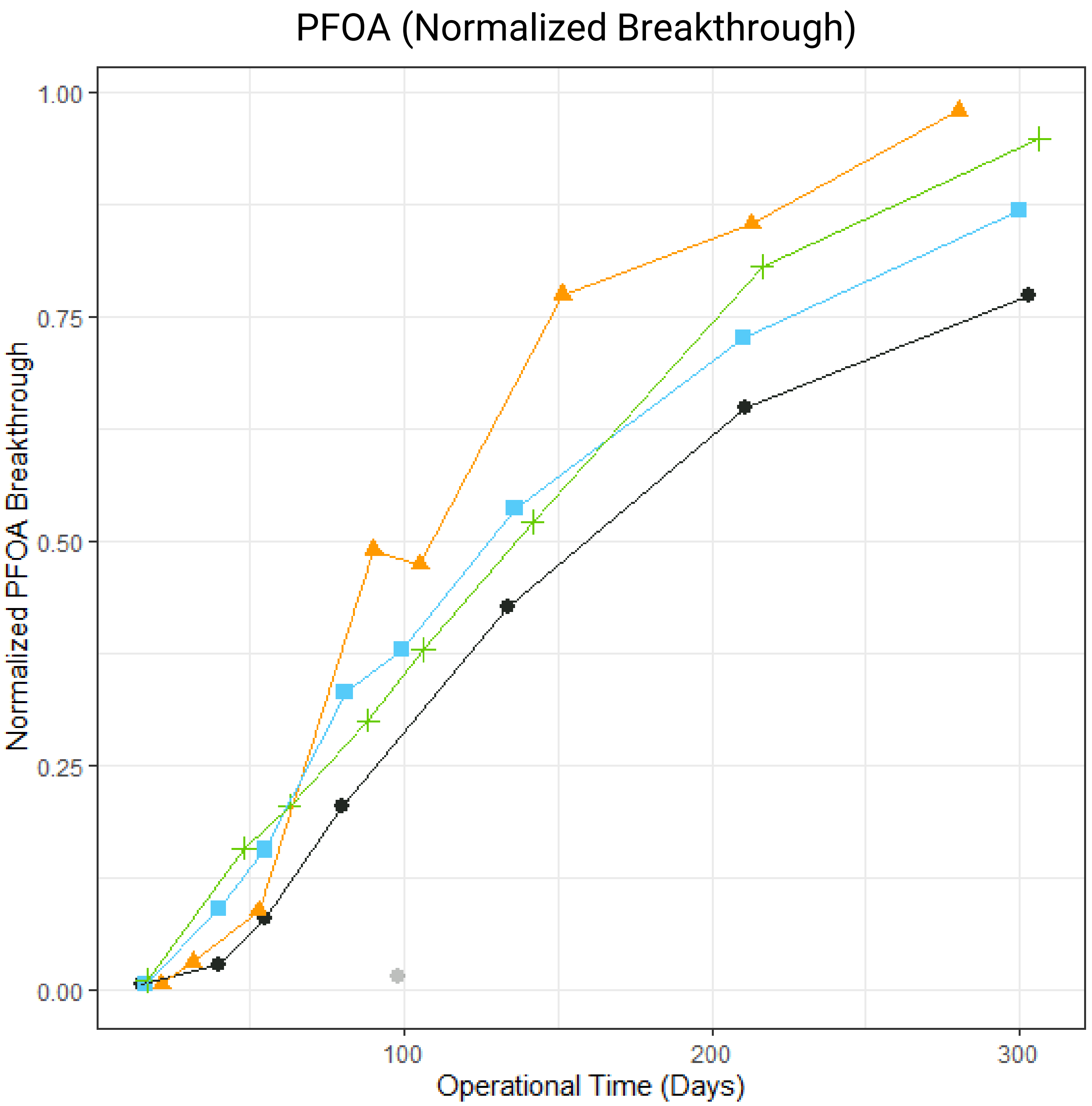
# GAC Media Conditioning

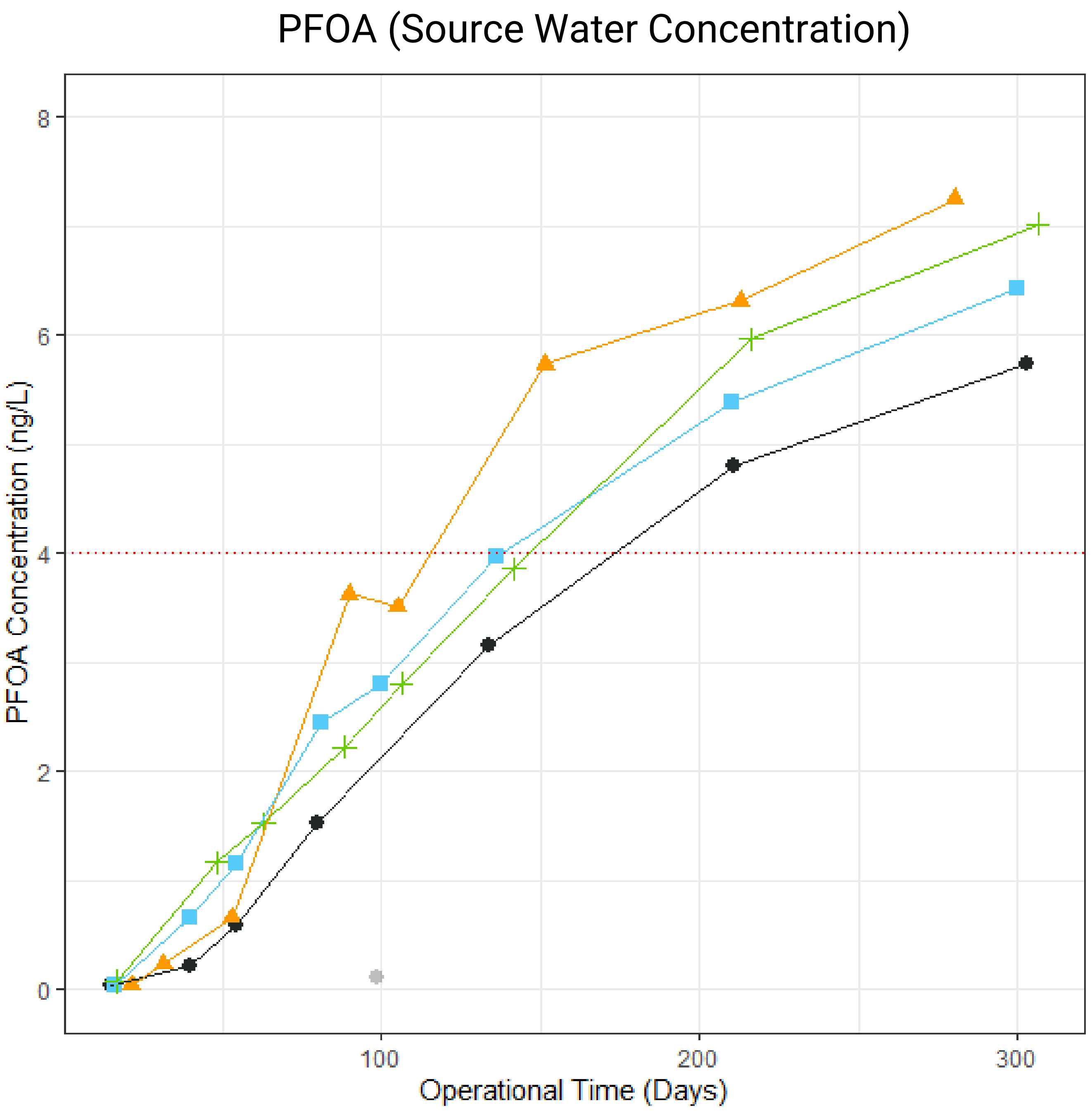
## Pilot Column Test

- On startup, virgin GAC may cause pH rise and arsenic release.
- Natural variability in coal vein → product/batch differences.
- Standard recommendation: flush to waste before service.
- Arsenic spike typically shorter than pH spike; utilities vary in acceptance (MCL vs non-detect).
- Up to 500 BV flushing may be required to stabilize pH.
- Evaluate effluent blending and temporary caustic adjustment to manage spikes.
- Conditioning process may take several days per contactor.

# GAC Media Comparison

- Cabot
- Xylem
- Norit
- Calgon

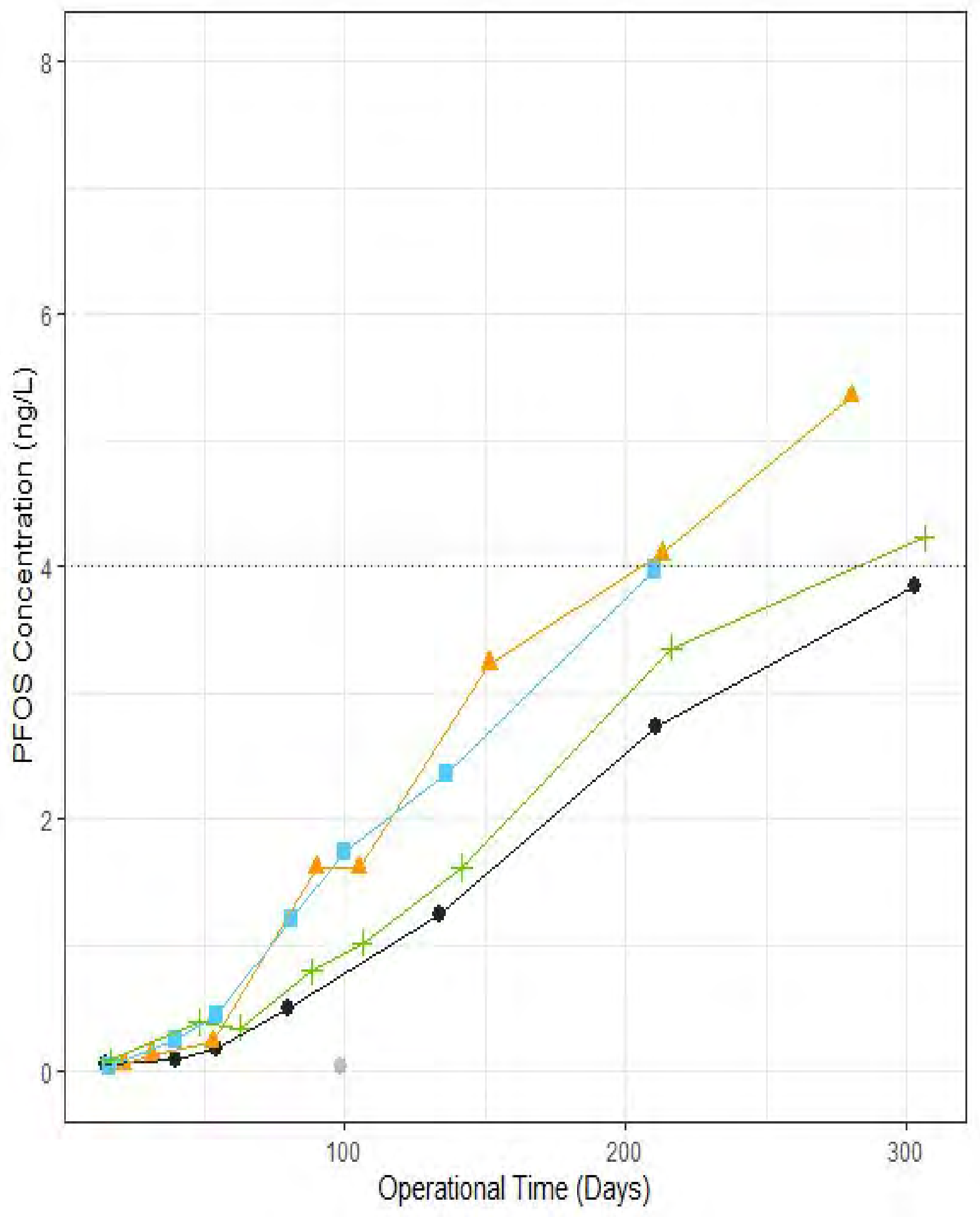


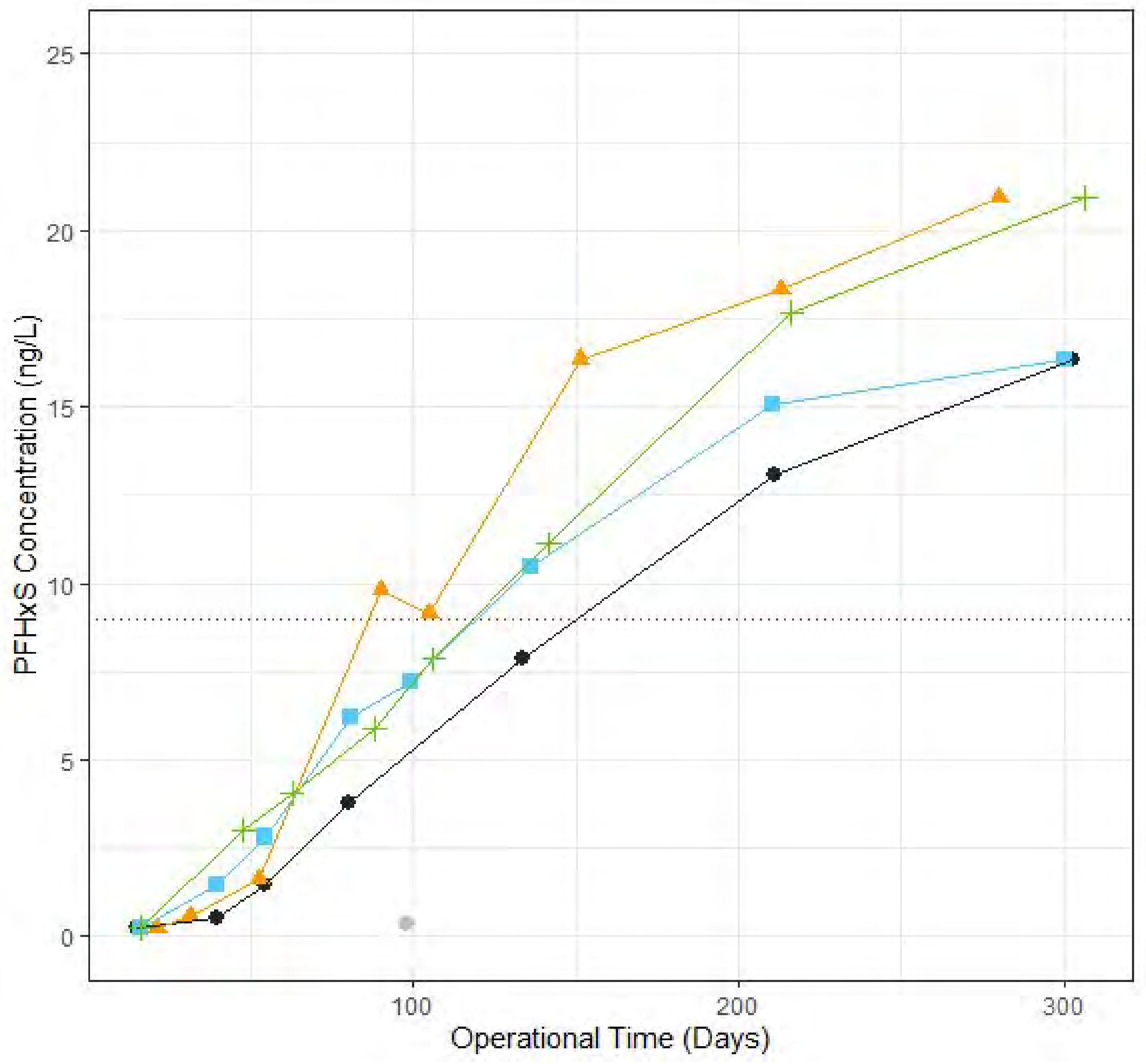
# GAC Media Comparison

- Cabot
- Xylem
- Norit
- Calgon

PFOS (Source Water Concentration)




PFHXS (Source Water Concentration)





# Section 3: Funding Options

# Federal PFAS Funding - Key Programs

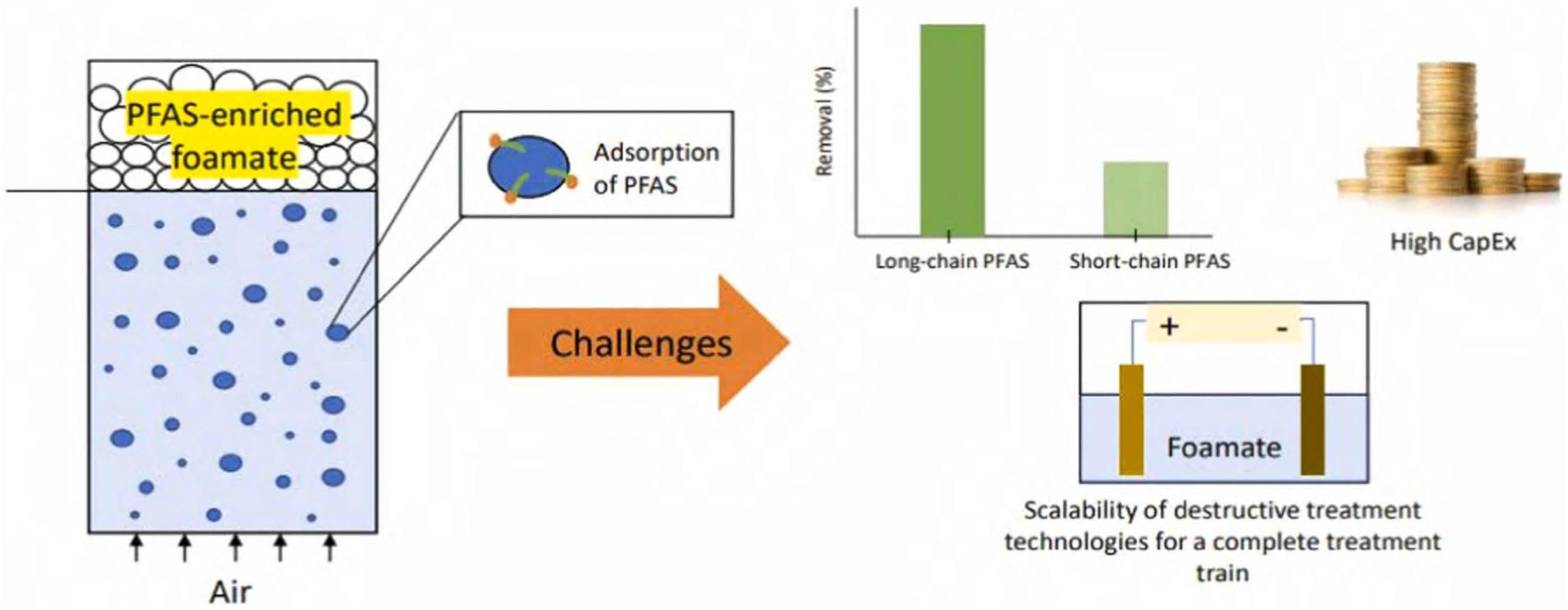
- SRF & IIJA (Bipartisan Infrastructure Law) – FY2025 overview: National ~$4.5B total (DWSRF base $1.1B, General Supplemental $2.6B, Emerging Contaminants $0.8B).
- IIJA Emerging Contaminants set-aside: $1B/year for 5 years (2022–2026, $5B total) – covers PFAS and other ECs.
- WIFIA low-interest loans – typical for large projects:
  - Minimum size: $20M (large systems) / $5M (small systems)
  - Can finance up to 49% of eligible project costs; federal requirements apply (NEPA, Davis-Bacon, BABA, etc.).
- DoD – Defense Environmental Restoration Program (DERP): ongoing funding to address legacy contamination on military installations (no fixed program cap; appropriated annually).
- EPA PFAS/EC in Small or Disadvantaged Communities: grants that can cover up to 100% of eligible costs for qualifying systems.
- USDA Rural Development (RD) Water/Wastewater: grants/loans with typical grant share up to ~75% for rural systems.
- DOE ARPA-E and related research grants: cost-share models typically up to ~80% of eligible costs (project dependent).

# Texas PFAS Funding - Key Programs

- EPA EC-Small/Disadvantaged communities grants (Texas share): $114.7M total for qualifying communities
- FY 2025 Texas SRF context (drinking water) : DWRSF base ~$87M; IIJA General Supplement ~$199M; IIJA EC~$61M
- DWRSF – Emerging Contaminants (EC): ~$61M available
  - Prioritizes disadvantaged communities and systems serving <25,000 population.
  - Eligible: PFAS planning, design, and construction projects.
- CWSRF – EC (Wastewater/Stormwater):~$9.7M available (FY 2024~$$9.7M) via grants/loan forgiveness.
  - Supports PFAS mitigation in wastewater, runoff, and sludge handling.

# Section 4: Emerging Technologies

# Surface Active Foam Fractionation (SAFF)

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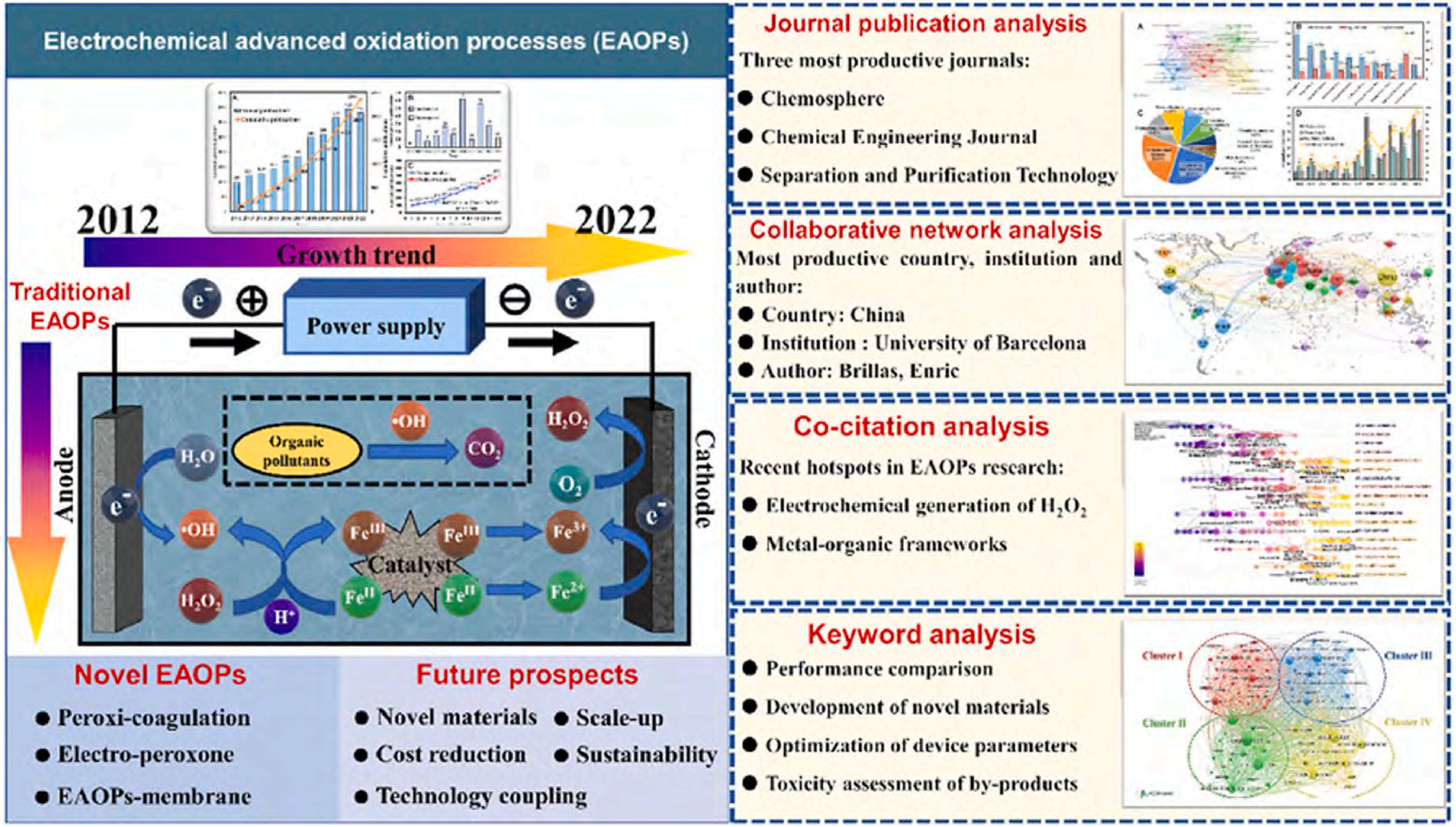
# Electrochemical Advanced Oxidation Processes (eAOPs)

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# Section 5: EPA Regulations for Wastewater

# EPA Actions on PFAS in Sewage Sludge & Wastewater

## National Sewage Sludge Survey (NSSS)

- Planned in collaboration with the POTW Influent PFAS Study.
- Will generate national occurrence and concentration data for PFAS in sewage sludge.
- Data will inform risk assessments and future risk management actions.

## Effluent Limitations Guidelines (ELGs)

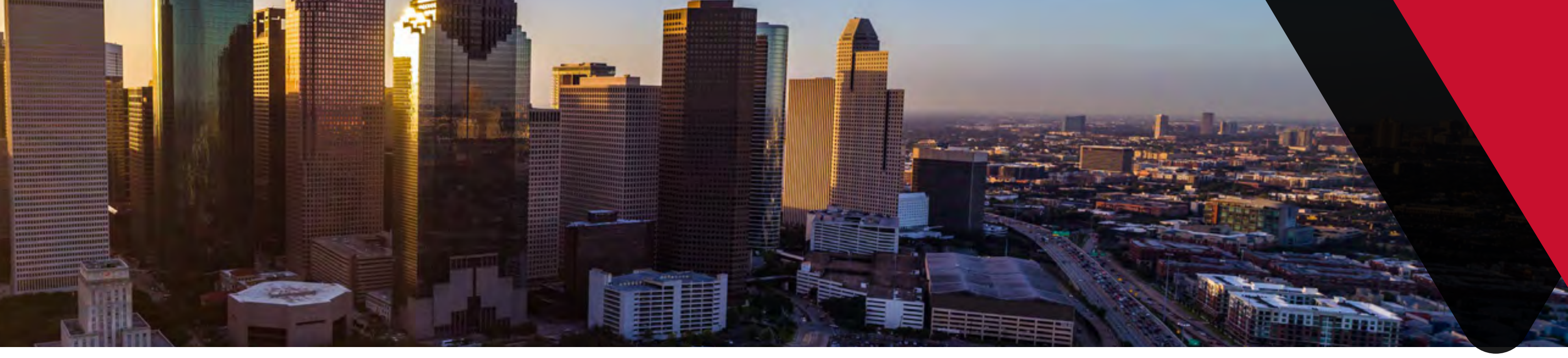
- Targeting PFAS manufacturing facilities.
- Includes electroplating facilities (PFAS-based fume suppressants, wetting agents).
- Landfills also under review for PFAS contributions.

## PFAS Research Priorities

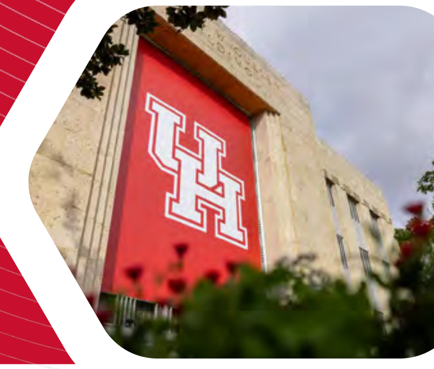
- Agricultural uptake, environmental fate and transport.
- Risk to food crops and soils under study.

## Destruction & Disposal Guidance

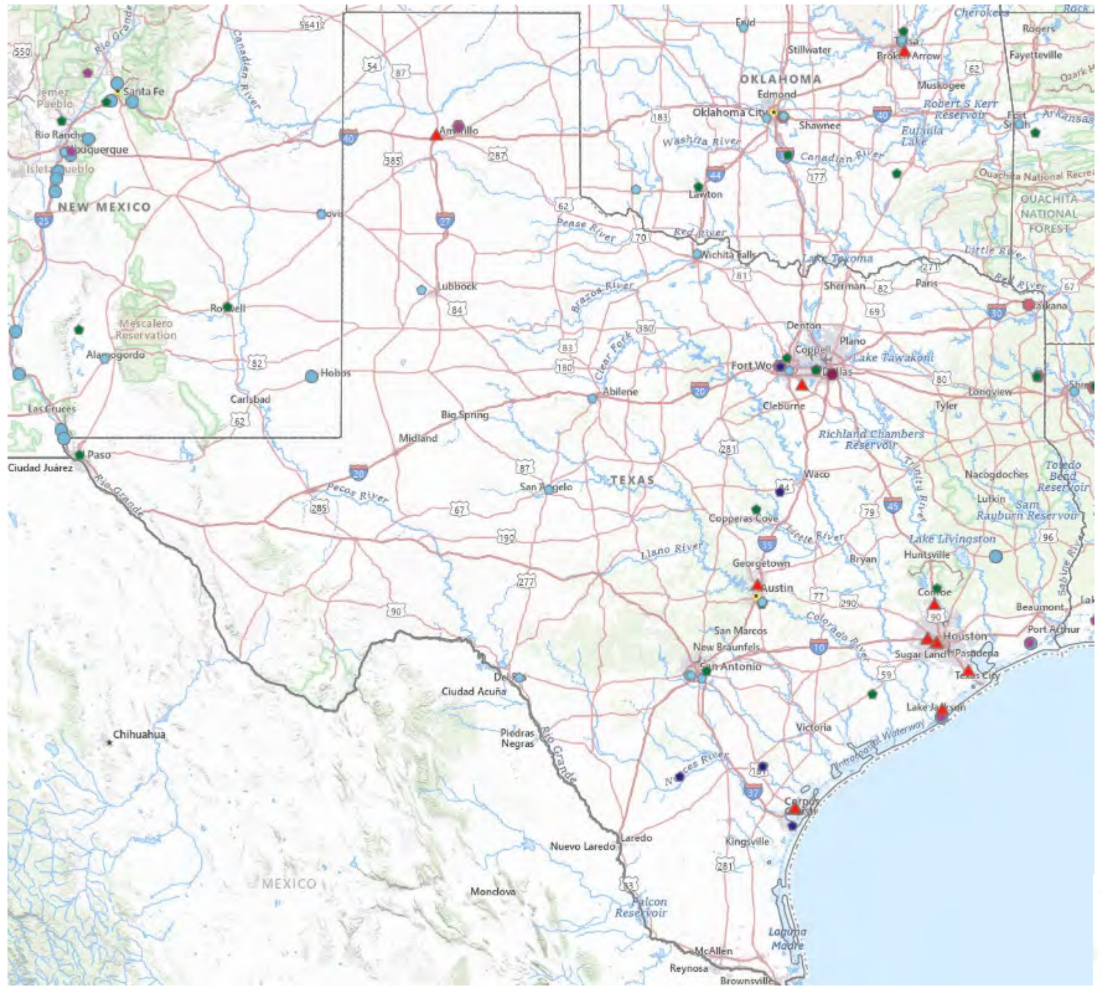
- Continued development of EPA guidance on safe PFAS destruction and residuals management.





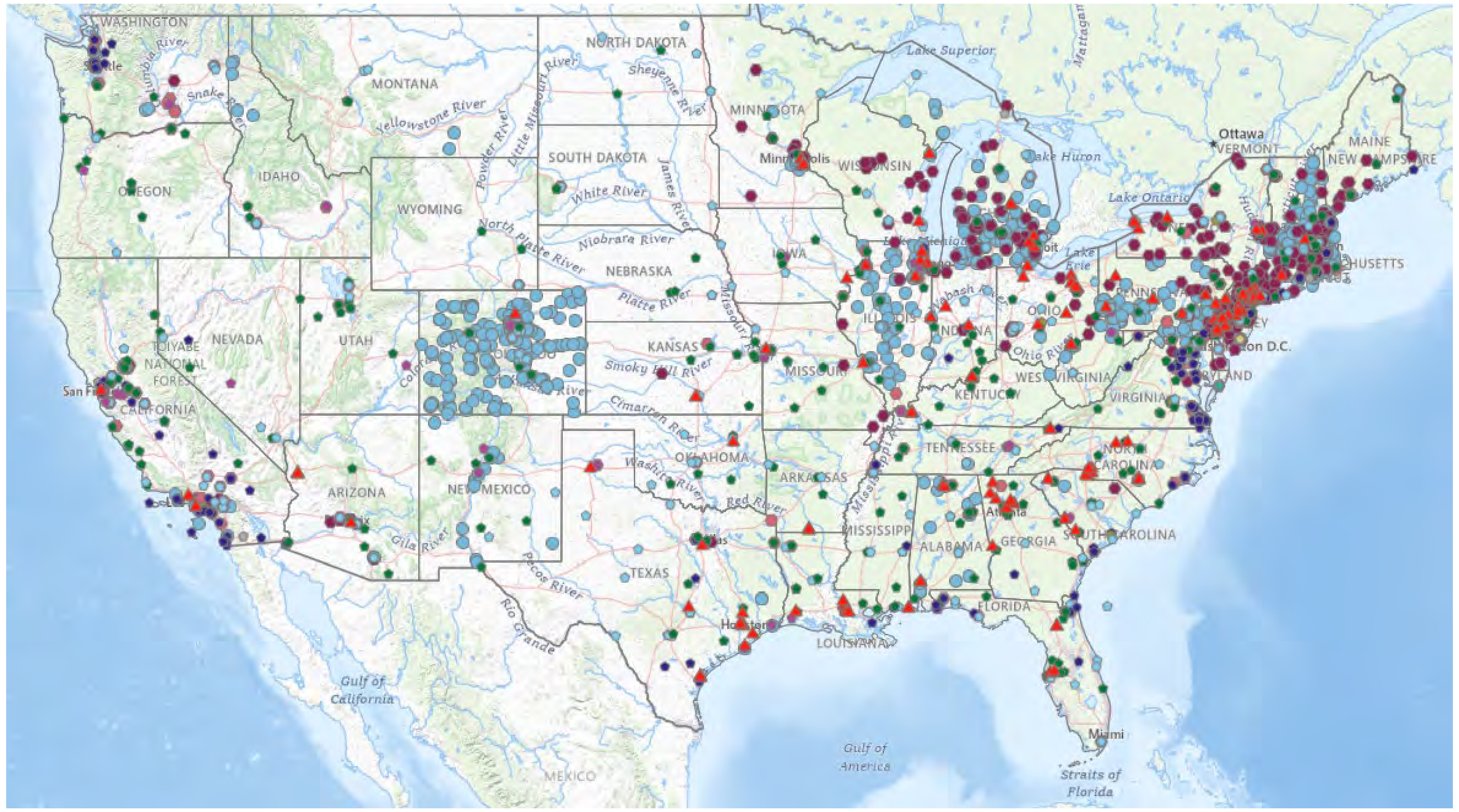


# Suspected Industrial Discharges of PFAS




**Other Locations with Known or Suspected PFAS:**

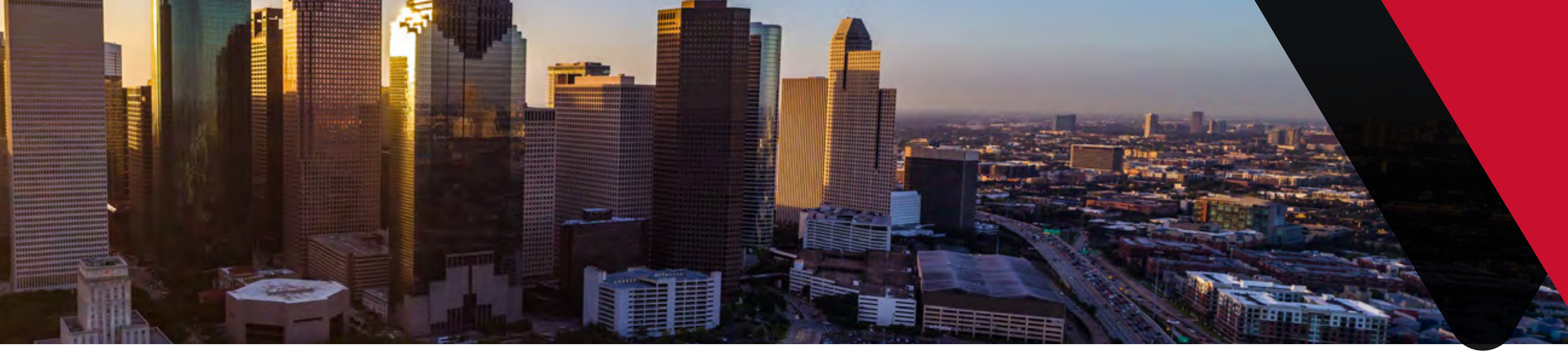
- PFAS Manufacturer or Importer
- Water Discharger with PFAS Monitoring
- Superfund (Private)
- Superfund (Federal)
- Federal Site with Known or Suspected PFAS:
  - DoD Air Force
  - DoD Army
  - DoD Navy
  - DoD DLA
  - FAA
  - DOE
  - NASA
  - Other



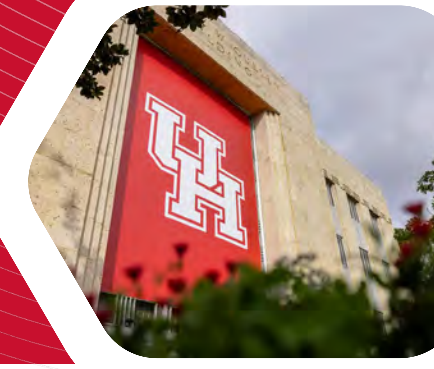

*Source 5

# Guidance

- Slide: Role of Civil, Chemical & Environmental Engineers
- Technical Guidance
  - Evaluate treatment feasibility (GAC, IX, RO, hybrids).
  - Optimize design parameters (EBCT, bed volumes, residual handling).
  - Incorporate surface water–groundwater interactions in site studies.
- Regulatory & Risk Support
  - Interpret evolving EPA/state regulations for utilities.
  - Translate complex standards (MCLs, HI, biosolids guidance) into actionable plans.
  - Provide input on permitting & compliance strategies.
- Community & Utility Engagement
  - Support risk communication with stakeholders.
  - Help utilities secure funding and settlement resources.
  - Ensure decisions balance cost, compliance, and public health protection.







# Take-Home Messages

## 01 Challenge Represented by PFAS = Technical + Regulatory + Environmental

Addressing PFAS is a multifaceted issue, requiring coordination and comprehension of many angles and stakeholders`

## 02 Treatment is solvable with thorough design and sampling

Confounding contaminants, target speciation in sources, footprints, O&M, residuals are all part of treatment selection process
Residuals and Costs remain major considerations

## 03 PFAS Treatment requires Holistic Viewpoint – not just Removal

Treatment is not the biggest challenge for PFAS and is only part of the picture. Treatment may focus on concentrating or removing PFAS, but ultimate fate in residuals, biosolids and other water treatment streams requires coordination.
Industry shift will reduce sources, but legacy contamination persists.

## 04 Path forward: integrated monitoring, adaptive treatment design, sustainable disposal, and proactive communication.

Chemical, Civil & Environmental engineers must understand issues and guide owners

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# Thank You

Corey Smith, PE, BCEE, CWO
Civitas Engineering Group, Inc.
csmith@civitasengr.com

civitas
ENGINEERING GROUP

Ramanathan Ganesan, MS (Chem.)
Civitas Engineering Group, Inc.
rganesan@civitasengr.com