# WHAT'S NEW IN PFAS RESEARCH: A WATER RESEARCH FOUNDATION OVERVIEW

GWPC-UIC Conference, Oklahoma City

February 28, 2024

advancing the science of water®

THE Water Research FOUNDATION®

# 2023 Engagement Dashboard

**963** UTILITIES
**67** MANUFACTURERS
**62** CONSULTANTS

**$81M**
RESEARCH CONTRACTED IN CASH & COST-SHARE

**264**
ACTIVE PROJECTS

**$.78**
OF EVERY DOLLAR
SUPPORTS PROGRAM SERVCIES

**1.4B**
MEDIA REACH

**69,926**
SOCIAL MEDIA FOLLOWERS

## Most Viewed Research Project Pages

1. PFAS One Water Risk Communication Messaging for Water Sector Professionals: One Water Toolkit (5124)
2. Residential End Uses of Water, Version 2 (4309)
3. Guidelines for Optimizing Nutrient Removal Plant Performance (4973)
4. Standardizing Methods with QA/QC Standards for Investigating the Occurrence and Removal of Antibiotic Resistant Bacterial/Antibiotic Resistance Genes (5052)
5. An Enhanced Source Control Framework for Industrial Contaminants in Potable Reuse (4960)

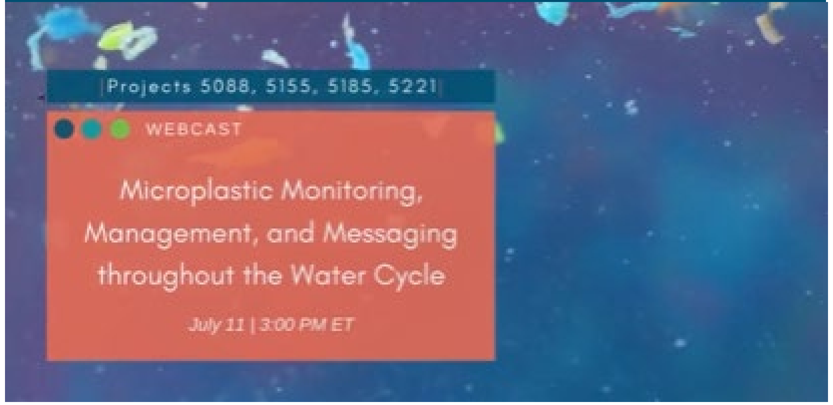
## Top Visitor Countries

1. United States
2. Canada
3. China
4. India
5. United Kingdom
6. Australia
7. Germany
8. Philippines
9. Netherlands
10. Mexico

## Most Popular Topics

1. PFAS
2. Advanced Treatment
3. Climate Change
4. Lead & Copper
5. Integrated Planning & Water Management
6. Biosolids
7. Energy Optimization
8. Resource Recovery
9. Utility Management
10. Water Use & Efficiency

## Most Popular Webcast




## Most Viewed Website Resources

1. Greenhouse Gas Emissions in the Water Sector: Let's Uncover the Basics! *Webcast*
2. PFAS One Water Risk Communication Messaging for Water Sector Professionals: One Water Toolkit (5124)
3. PFAS One Water Risk Communication Messaging for Water Sector Professionals: UCMR5 Toolkit (5124)
4. Residential End Uses of Water, Version (4309) *Report*
5. Standardizing Methods with QA/QC Standards for Investigating the Occurrence and Removal of Antibiotic Resistant Bacterial/Antibiotic Resistance Genes (5052) *Report*

## Highest Reach Article Mention

How dangerous was the Ohio chemical train derailment? An environmental engineer assesses the long-term risks

*64M Reach*

## Top Social Media Post

Dr. William Tarpeh Receives 2023 Paul L. Busch Award

X *21K Impressions*

# 2023 PUBLISHED PROJECTS

advancing the science of water®

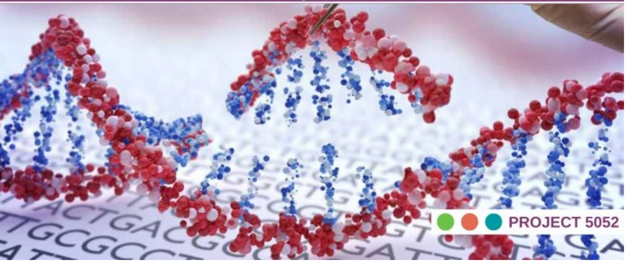
**Optimizing Filter Operation in an Ozone-Biofiltration Plant to Reduce Selection for Opportunistic Pathogens in Drinking Water Production**


**State-of-the-Science Review: Evidence for Pathogen Removal in Managed Aquifer Recharge Systems**


**Evaluation of Source Separated Organic Feedstock Pretreatment and Management Practices**


**Holistic Approach to Improved Nutrient Management**


**Standardizing Methods with QA/QC Standards for Investigating the Occurrence and Removal of Antibiotic Resistant Bacteria/Antibiotic Resistance Genes in Surface Water, Wastewater, and Recycled Water**




**Evaluation of CEC Removal by Ozone/BAF Treatment in Potable Reuse Applications**


**Potential of Oilfield Produced Water for Irrigation in California**


**Establishing Additional Log Reduction Credits for WWTPs**

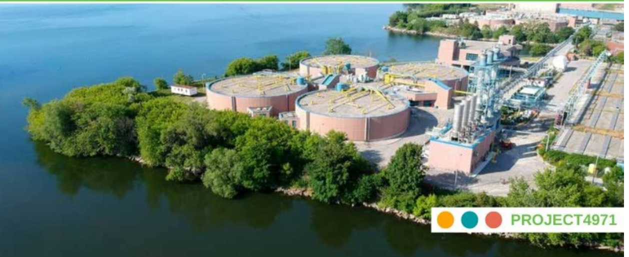

**Framework for the Development of a Utility Research Program**


**An Enhanced Source Control Framework for Industrial Contaminants in Potable Reuse**


**Evaluation of Tier 3 Validation Protocol for Membrane Bioreactors to Achieve Higher Pathogen Credit for Potable Reuse**


**Characterization and Contamination Testing of Source Separated Organic Feedstocks and Slurries for Co-Digestion at Resource Recovery Facilities**


**Leveraging Pretreatment Programs for One Water Initiatives: Synthesis of Best Practices and Path Forward**




**Resilience Practical Framework for Water Infrastructure User's Guide**


**Integrating Real-Time Collection System Monitoring Approaches into Enhanced Source Control Programs for Potable Reuse**


**Developing Guidance for Assessment and Evaluation of Harmful Algal Blooms and Implementation of Control Strategies in Source Water**

## Potable Reuse Demonstration Design & Communication Toolbox


## Assessing the State of Knowledge and Research Needs for Stormwater Harvesting


## Seismic and Multi-Hazard Conference


## Pathogen Removal Credits for Wastewater Treatment: Guidance for Study Plans and Reporting


## Determining the Role of Organic Matter Quality on PFAS Leaching from Sewage Sludge and Biosolids

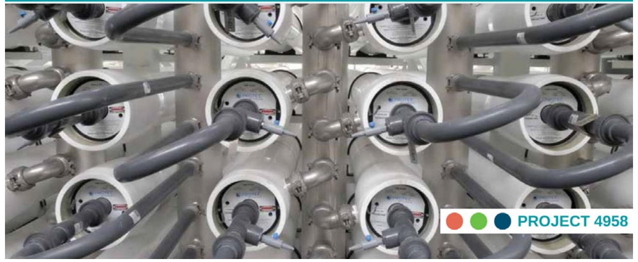

## The Use of Next Generation Sequencing Technologies and Metagenomics Approaches to Evaluate Water and Wastewater Quality Monitoring and Treatment Technologies



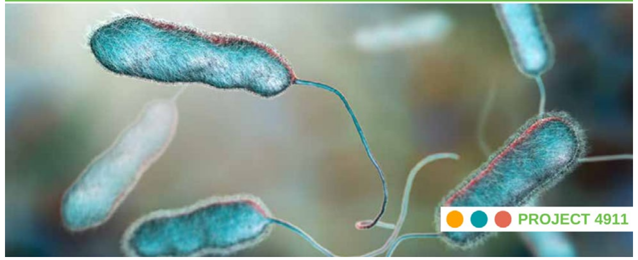
## Demonstration of Progressive Carbon Efficient Nitrogen with Biological Phosphorous Removal in a Conventional BNR Facility



## New Techniques, Tools, and Validation Protocols for Achieving Log Removal Credit Across NF and RO Membranes




## Sampling and Monitoring Strategies for Opportunistic Pathogens in Drinking Water Distribution Systems




## Public Health Benefits and Challenges for Blending of Advanced Treated Water with Raw Water Upstream of a Surface Water Treatment Plant in DPR


## Assessing the Microbial Risks and Impacts from Stormwater Capture and Use to Establish Appropriate Best Management Practices

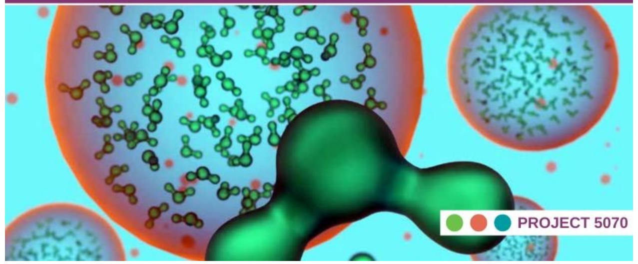

## Enhanced Evaluation of the Removal of Contaminants of Emerging Concern in Decentralized Water Reuse Systems by Non-Targeted Analysis


## Risk Benefit Assessment of Chlorite as a Co-Disinfectant for Nitrification Control in Chloraminated Drinking Water Systems


## Identifying the Amount of Wastewater That Is Available and Feasible to Recycle in California

### Understanding the Impacts of Wastewater Treatment Performance on Advanced Water Treatment Processes and Finished Water Quality


### Investigation of Nanobubble Technology for the Removal of MIB and Geosmin from Drinking Water




### Use of DNA Nanostructures as Viral Surrogates in Potable Reuse Applications


### Guidelines for Optimizing Nutrient Removal Plant Performance


### Water Reuse and Beyond—Water Quality Monitoring Methods, Data, and Interpretation


### Exploring Cost-Benefit Analysis of Post Long-Term Control Plan Approaches to Wet Weather Management


### Practical Considerations for the Incorporation of Biomass Fermentation into Enhanced Biological Phosphorus Removal


### Enhancement of Resilience to Extreme Weather and Climate Events: Proactive Flood Management

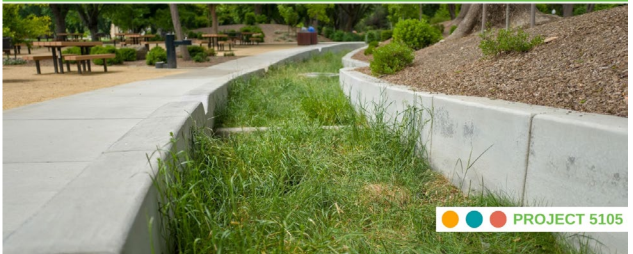

### Guidance for Using Pipe Rigs to Inform Lead and Copper Corrosion Control Treatment Decisions


### Considerations and Blending Strategies for Drinking Water System Integration with Alternative Water Supplies


### When a Detour Becomes a Shortcut: Going Full-Scale with PdNA Strategy for Mainstream Deammonification and Incorporating Biological Phosphorus Removal


### Biogas Harvester Demonstration


### Advancing Benefits and Co-Benefits Quantification and Monetization for Green Stormwater Infrastructure: An Interactive Guidebook for Comparison Case Studies




### Addressing Impediments and Incentives for Agricultural Reuse


### Identifying Causes and Controls for Intermittent Nitrate Release from Granular Activated Carbon


### Holistic Approaches to Flood Mitigation Planning and Modeling under Extreme Events and Climate Impacts

# WRF PFAS PORTFOLIO

February 2024

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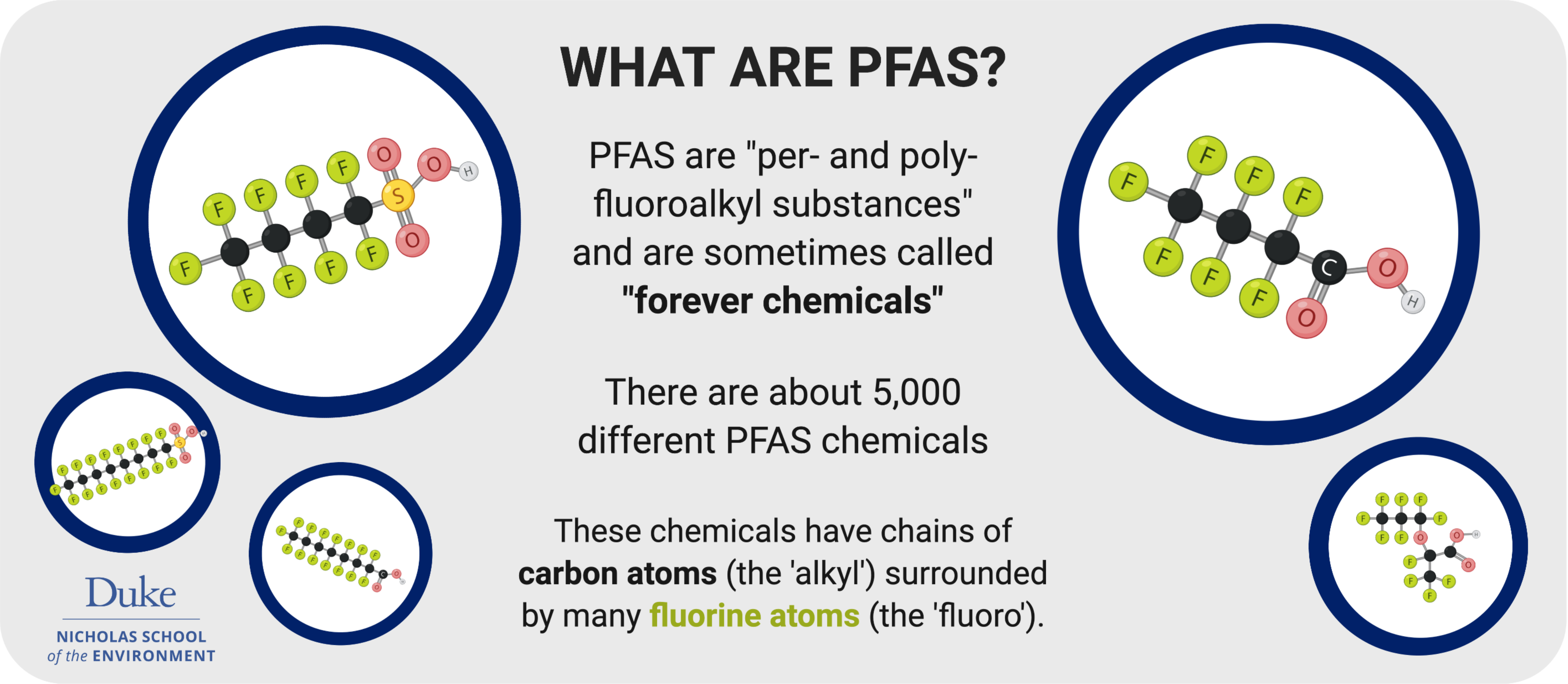



What-are-PFAS-general-2.png (2978×1418) (duke.edu)


PFAS Uses
Fire fighting foams
Fast food packaging
SHAMPOO
Personal care products
Paints
Photographic processes
Stain resistant products
Mist suppressant in metal plating industry
Aviation hydraulic fluids
Floor polishes
Non-stick cookware
Mining and oil well surfactants
Pesticides and herbicides

# History and Use of Per- and Polyfluoroalkyl Substances (PFAS)

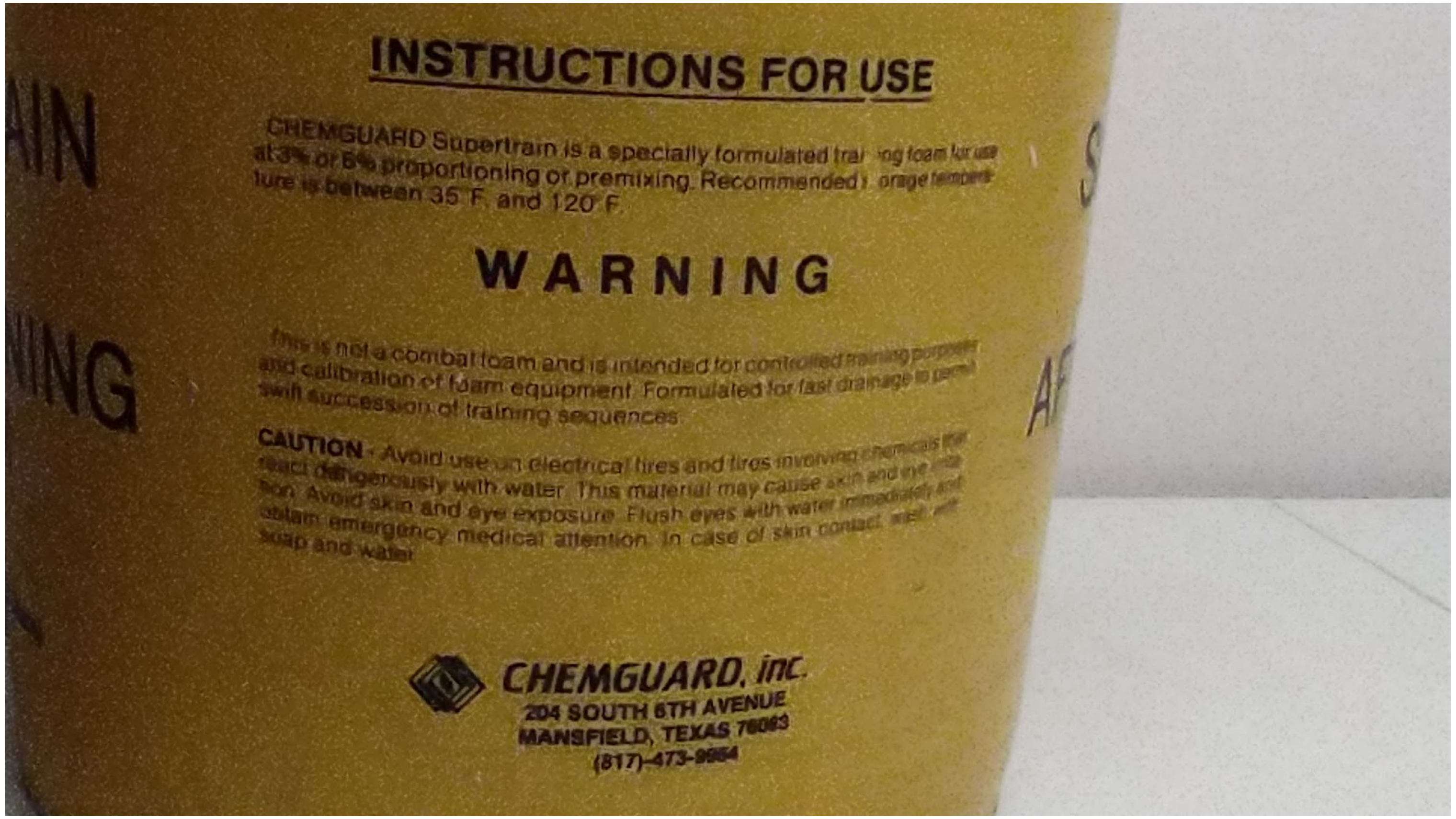
| PFAS[1] | Development Time Period | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1930s | 1940s | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s |
| PTFE | Invented | Non-Stick Coatings | | | Waterproof Fabrics | | | |
| PFOS | | Initial Production | Stain & Water Resistant Products | Firefighting foam | | | | U.S. Reduction of PFOS, PFOA, PFNA (and other select PFAS[2]) |
| PFOA | | Initial Production | Protective Coatings | | | | | |
| PFNA | | | | | Initial Production | Architectural Resins | | |
| Fluoro-telomers | | | | | Initial Production | Firefighting Foams | | Predominant form of firefighting foam |
| Dominant Process[3] | | Electrochemical Fluorination (ECF) | | | | | | Fluoro-telomerization (shorter chain ECF) |

| | | |
|---|---|---|
| Pre-Invention of Chemistry / | Initial Chemical Synthesis / Production | Commercial Products Introduced and Used |

[PFAS_Fact_Sheet_History_and_Use_April2020.pdf (itrcweb.org)](PFAS_Fact_Sheet_History_and_Use_April2020.pdf)

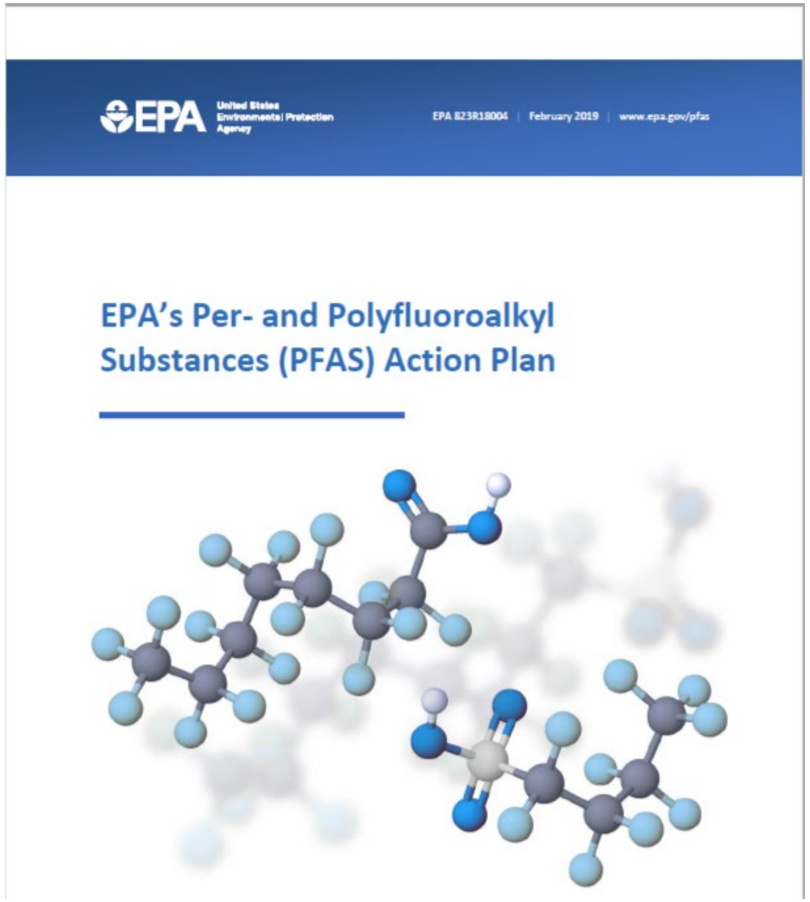
# Have Some Bran for Your Horses

# EPA's PFAS Action Plan

**Key EPA Actions Addressing PFAS-Related Challenges**

- Expand toxicity information for PFAS
- Develop new tools to characterize PFAS in the environment
- Evaluate cleanup approaches
- Develop guidance to facilitate cleanup of contaminated groundwater
- Use enforcement tools to address PFAS exposure in the environment and assist states in enforcement activities
- Use legal tools such as those in TSCA to prevent future PFAS contamination
- Address PFAS in drinking water using regulatory and other tools
- Develop new tools and materials to communicate about PFAS


EPA United States Environmental Protection Agency

EPA 823R18004 | February 2019 | www.epa.gov/pfas

EPA's Per- and Polyfluoroalkyl Substances (PFAS) Action Plan

# WRF PFAS Projects



Updated 02/2024

**1693** **Formation of Nitrosamines and Perfluoroalkyl Acids During Ozonation in Water Reuse Applications**

**4322** **Treatment Mitigation Strategies of Poly & Perfluorinated Chemicals, Final Report plus webcast**

**4344** **Removal of Perfluoroalkyl Substances by PAC Adsorption & Ion Exchange**

**4877** **Concept Development of Chemical Treatment Strategy for PFOS-Contaminated Water**

**4913** **Investigation of Treatment Alternatives for Short-Chain Per- Polyfluoroalkyl Substances**

**5002** **Determining the Role of Organic Matter Quality on PFAS Leaching from Sewage Sludge and Biosolids (NSF grant)**
**Webcast: Relating PFAS Leaching from Sewage Sludge and Biosolids to Water and Sludge Quality (WEF, February 2020)**

**5011** **Evaluation and Life Cycle Comparison of Ex-Situ Treatment Technologies for Per-and Polyfluoroalkyl Substances (PFASs) in Groundwater (DOD grant)**

**5031** **Occurrence of PFAS Compounds in US Wastewater Treatment Plants**

**5042** **Assessing Poly- and Perfluoroalkyl Substance Release from Finished Biosolids**

**5082** **Investigation of Alternative Management Strategies to Prevent PFAS from Entering Drinking Water Supplies and Wastewater**

# WRF PFAS Projects



5102 Application of Novel Method to Estimate Total PFAS Content in Water

5103 Microwave Regeneration of PFAS-Exhausted Granular Activated Carbons

5107 Understanding Pyrolysis for PFAS Removal

5111 Studying the Fate of PFAS through Sewage Sludge Incinerators

5124 PFAS One Water Risk Communication Messaging for Water Sector Professionals

5153 Evaluation of Bench-Scale Methods to Predict Drinking Water PFAS Removal Performance of Ion Exchange and Novel Adsorbents at Pilot- and Full-Scale

5170 State of the Science and Regulatory Acceptability for PFAS Residual Management Options (recently awarded)

5172 Cost-effective PFAS Mitigation Strategies for Communities (RFP)

5211 Understanding the Value Proposition for Thermal Processes to Mitigate PFAS in Biosolids (recently awarded)

5212 Enhanced Aeration and Scum Recovery for Physical Removal of PFAS from Wastewater (recently awarded)

5214 Direct In-Situ Measurement of PFAS Transformation & Leaching from Land-Applied Biosolids (recently awarded)

# WRF PFAS Projects



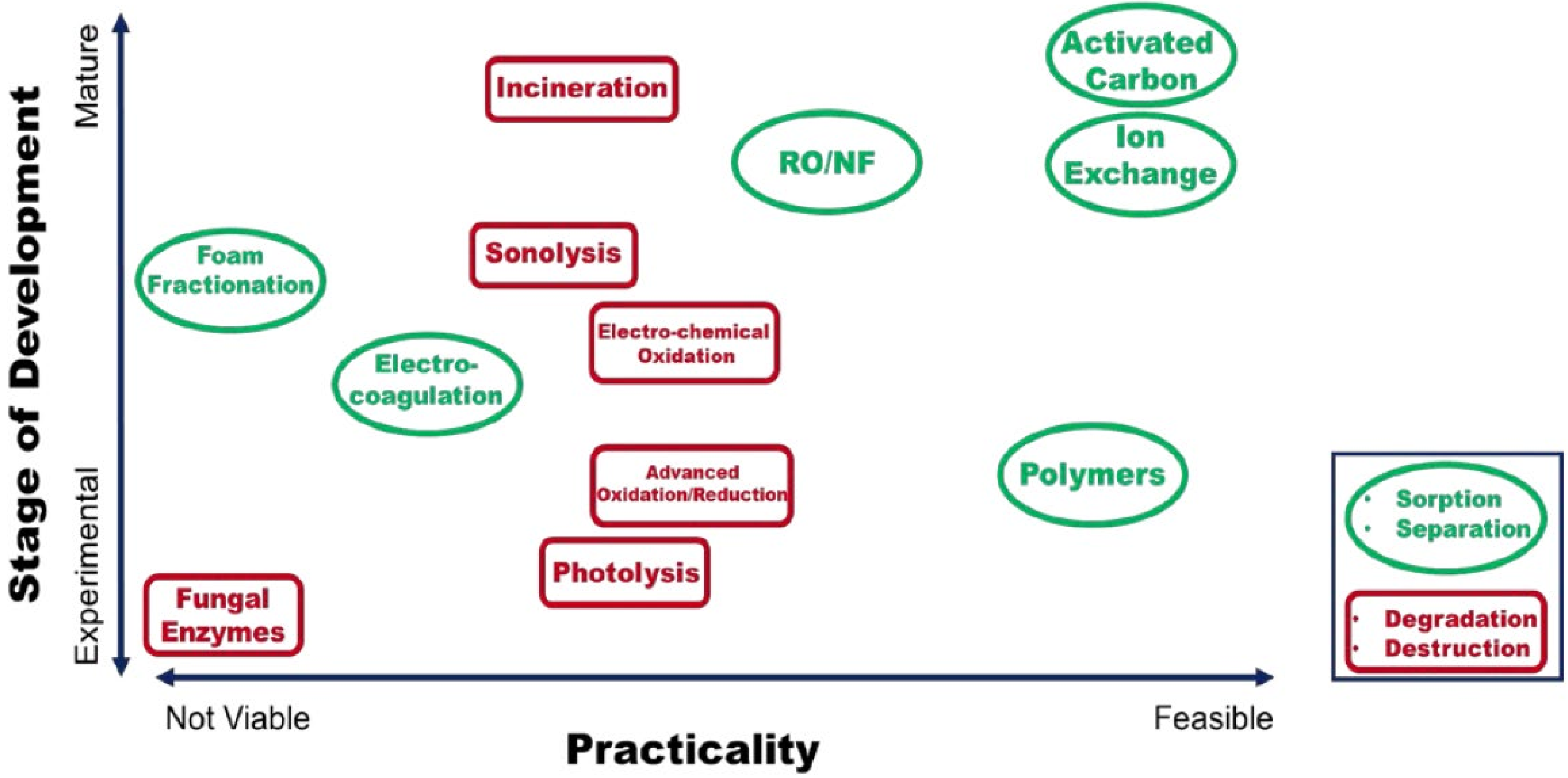
**TBD** **Understanding the Factors Affecting PFAS Variability in the Potomac River Watershed** **(recently funded as a 2023 Tailored Collaboration Project )**

**TBD** **Characterization and Pilot Testing of Microwave Reactivation for PFAS-laden Granular Activated Carbons** **(recently funded as a 2023 Tailored Collaboration Project )**

**TBD** **PFAS Fingerprinting for Source Identification Using Machine Learning** **(recently funded as a 2023 Tailored Collaboration Project )**

# Current PFAS Water Treatment Technologies




Courtesy of – Dr. Tanju Karanfil, Clemson University

# Evaluation & Life Cycle Comparison of Ex-Situ Treatment Technologies for PFASs in Groundwater (WRF #5011)

- WRF PI: Kenan Ozekin (Water Research Foundation)
- Project Team:
  - Chris Bellona (CSM)
  - Detlef Knappe (NCSU)
  - Sherri Cook (CU-Boulder)
  - Charles Schaefer (CDM-Smith)
  - Chris Higgins (CSM)
- $990,452, DOD Partnership, ESTCP

# Technical Objectives

***To accurately & comprehensively compare established & emerging PFAS treatment approaches***

- Comprehensive side-by-side comparisons of competing technologies for removal and/or destruction of a variety of PFASs in impacted waters
- Assessment of PFAS treatment approaches' comparative life-cycle costs and environmental impacts under various treatment scenarios

***To provide experimental and modeling frameworks for selection of effective treatment technologies***

- Development a treatment technology decision support tool based on performance data, LCA&LCC data, & stakeholder input
- Development of a new technology experimental testing protocol to support continued side-by-side comparisons of technologies as they are developed

# Challenges/Approach

## Challenges

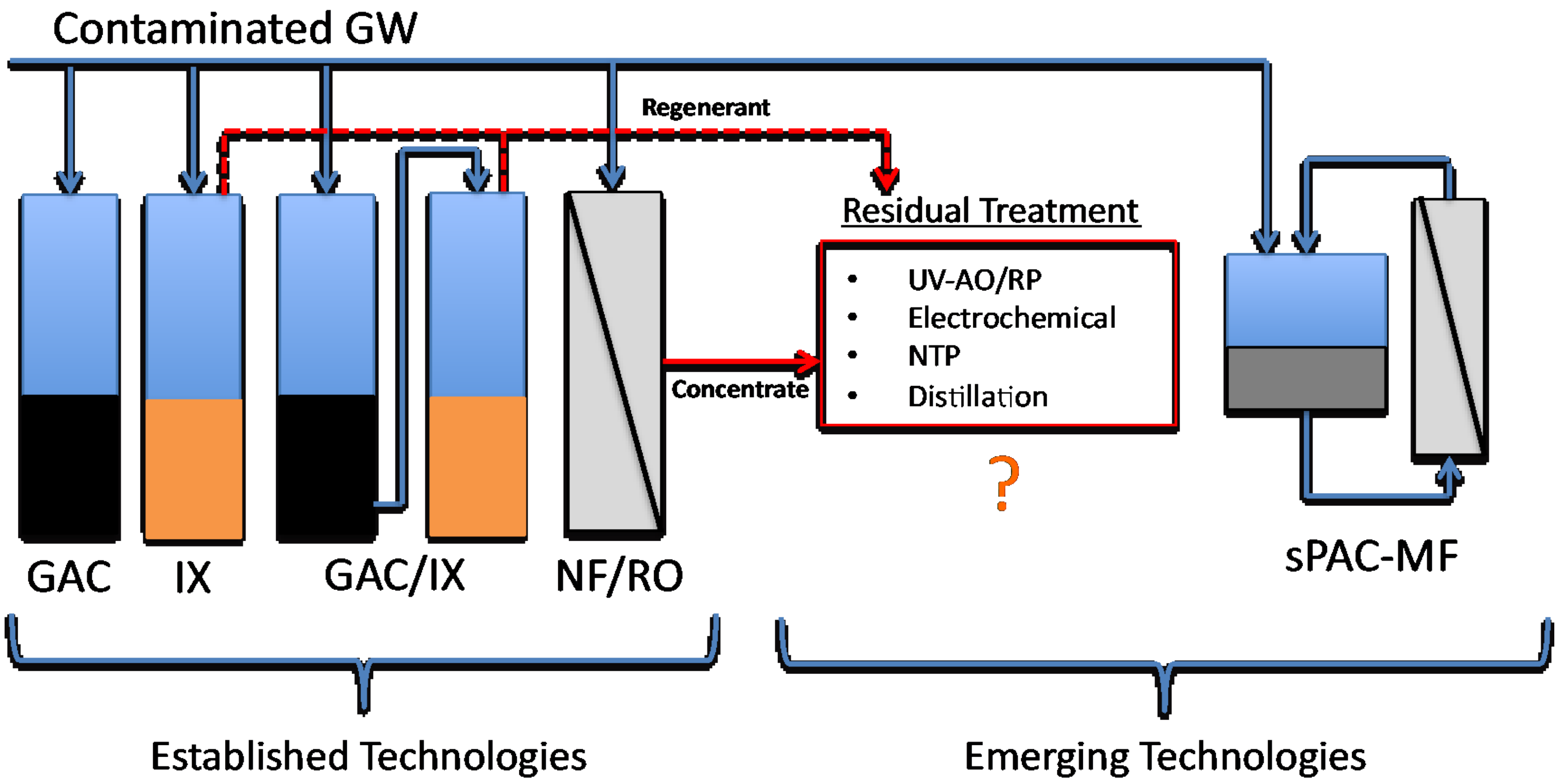
- Performance often dependent upon site conditions
- Pilot-scale testing of technologies is costly and time intensive
- Lab-scale testing of technologies often does not mimic performance at larger-scale
- Everchanging list of ‘viable’ technologies

## Approach

- Develop scalable laboratory testing protocol and collect directly comparable treatability data
- Develop treatability database from literature, full-scale, pilot-scale, and bench-scale data
- Develop decision-support tool to evaluate competing PFAS removal technologies under different treatment scenarios
- Apply decision-support tool to variety of treatment scenarios

# Evaluation and Life Cycle Comparison of Ex-Situ Treatment Technologies for PFASs in Groundwater



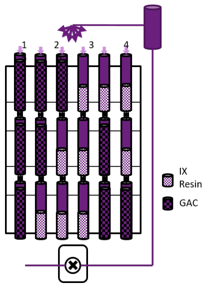

Status – Started October 1, 2018

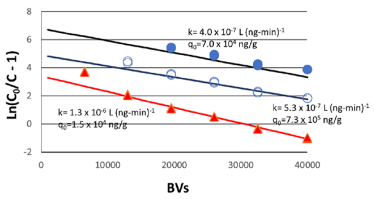
 

# Comprehensive Experimental and Modeling Evaluations

Lab- and pilot-scale Experiments → Performance Process Models
Utility & Literature Data → Performance Process Models

Performance Process Models → Technology Designs → Life Cycle Inventory → Economic & Environmental Performance



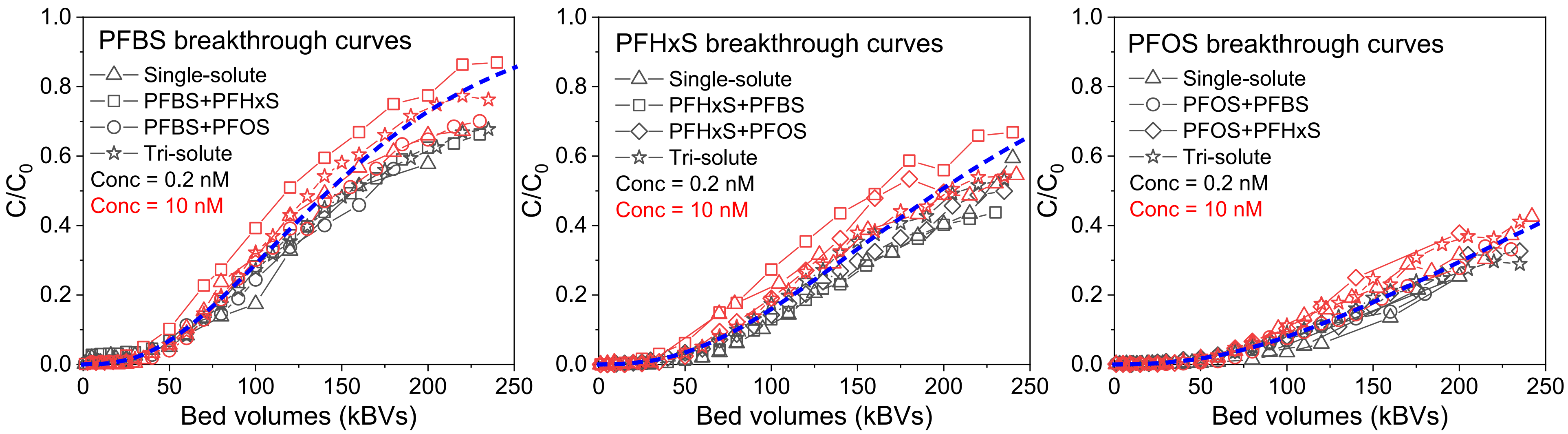

*Energy*
*Materials*
*Chemicals*
*Waste*

→ *translate to costs & impacts* →

*Relative Costs & Environmental & Health Impacts*

**Support development of treatability database through bench- and small pilot-scale experiments**

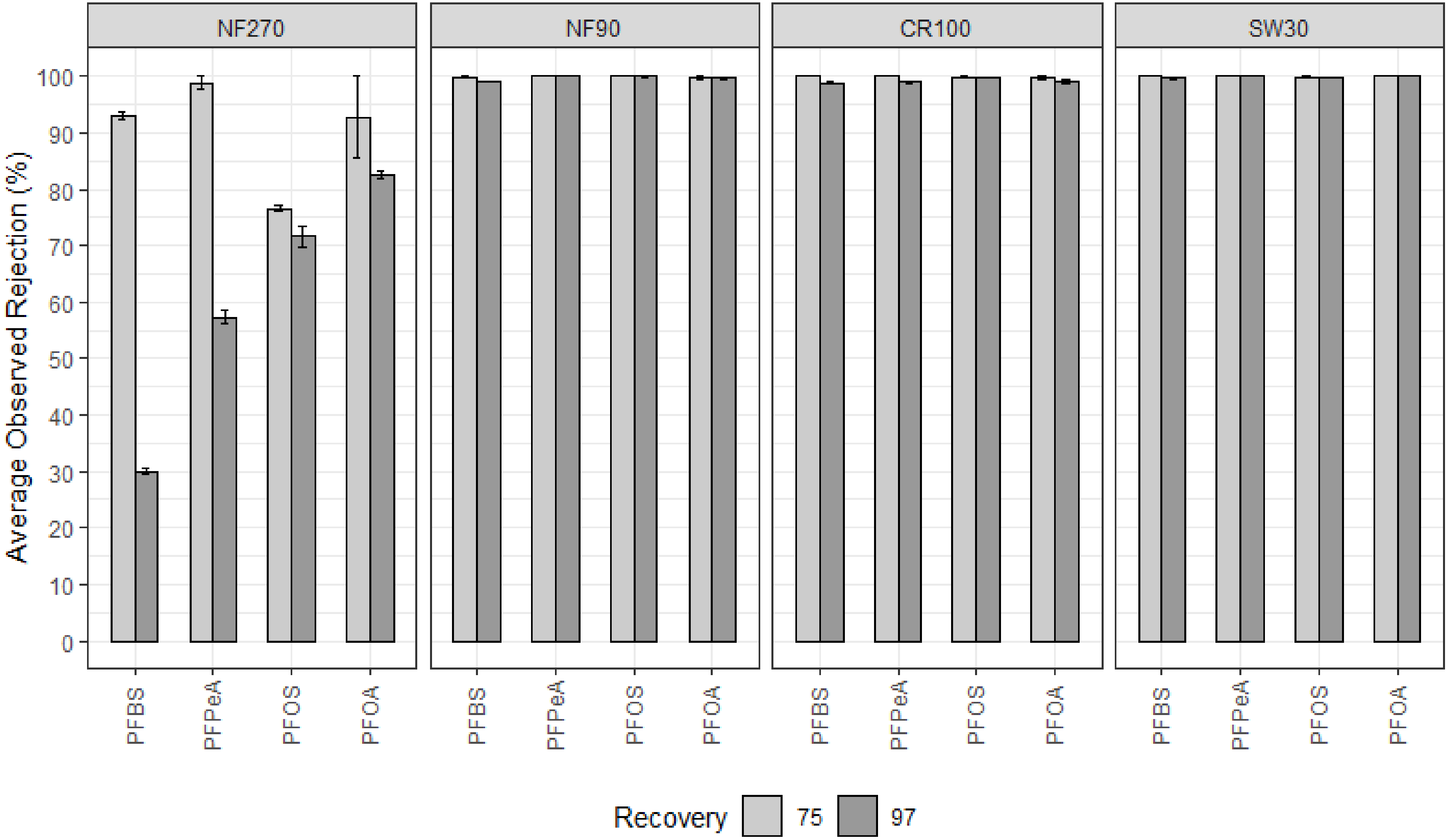
# Initial concentration and co-existing PFAS have little influence on PFAS breakthrough




- ❑ GAC: GAC 1
- ❑ Simulated EBCT: 10 min
- ❑ Water: NC groundwater, TOC < 0.3 mg/L

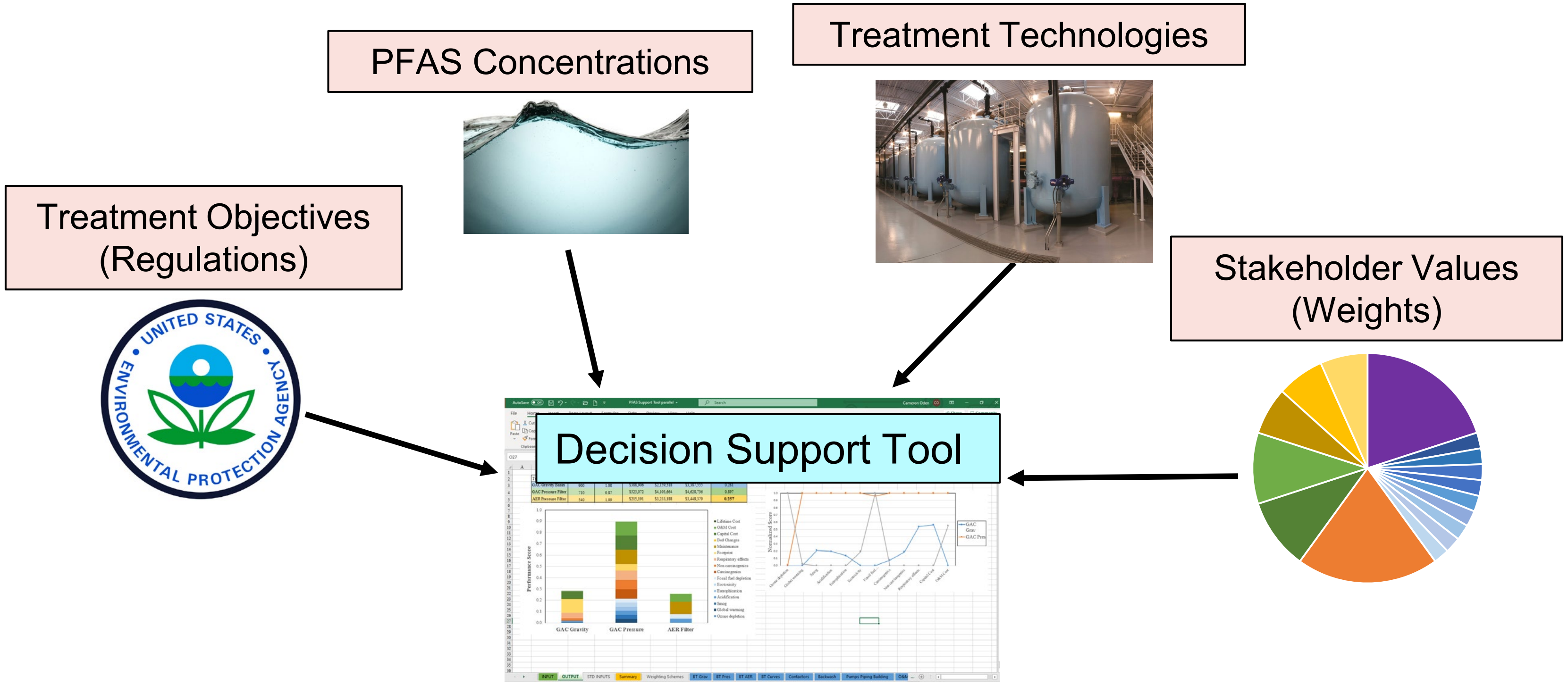
 

# For high pressure membranes, PFAS removal was lowest with loose NF at high recoveries



# Decision Support Tool Provides Customized Recommendations Based on User Specific Inputs

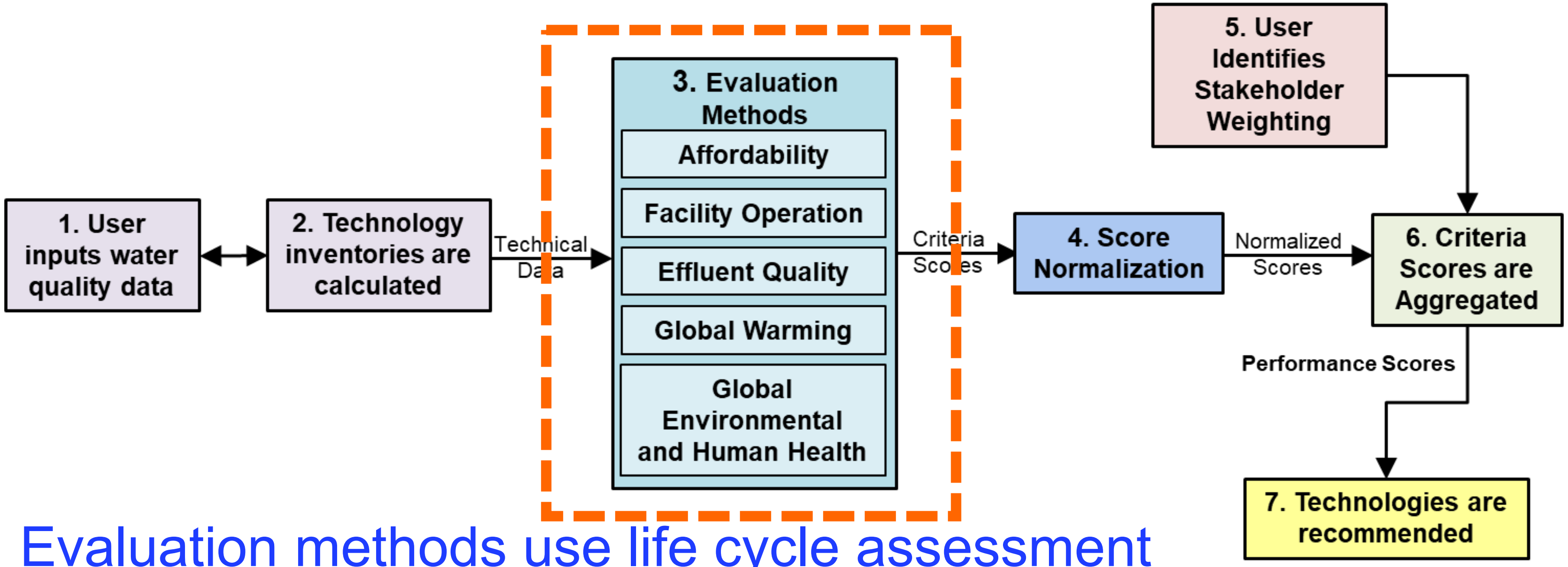


# Relies on Multiple Methodologies, Including Multi-criteria Decision Analysis

Stakeholder values impact the recommendation calculations

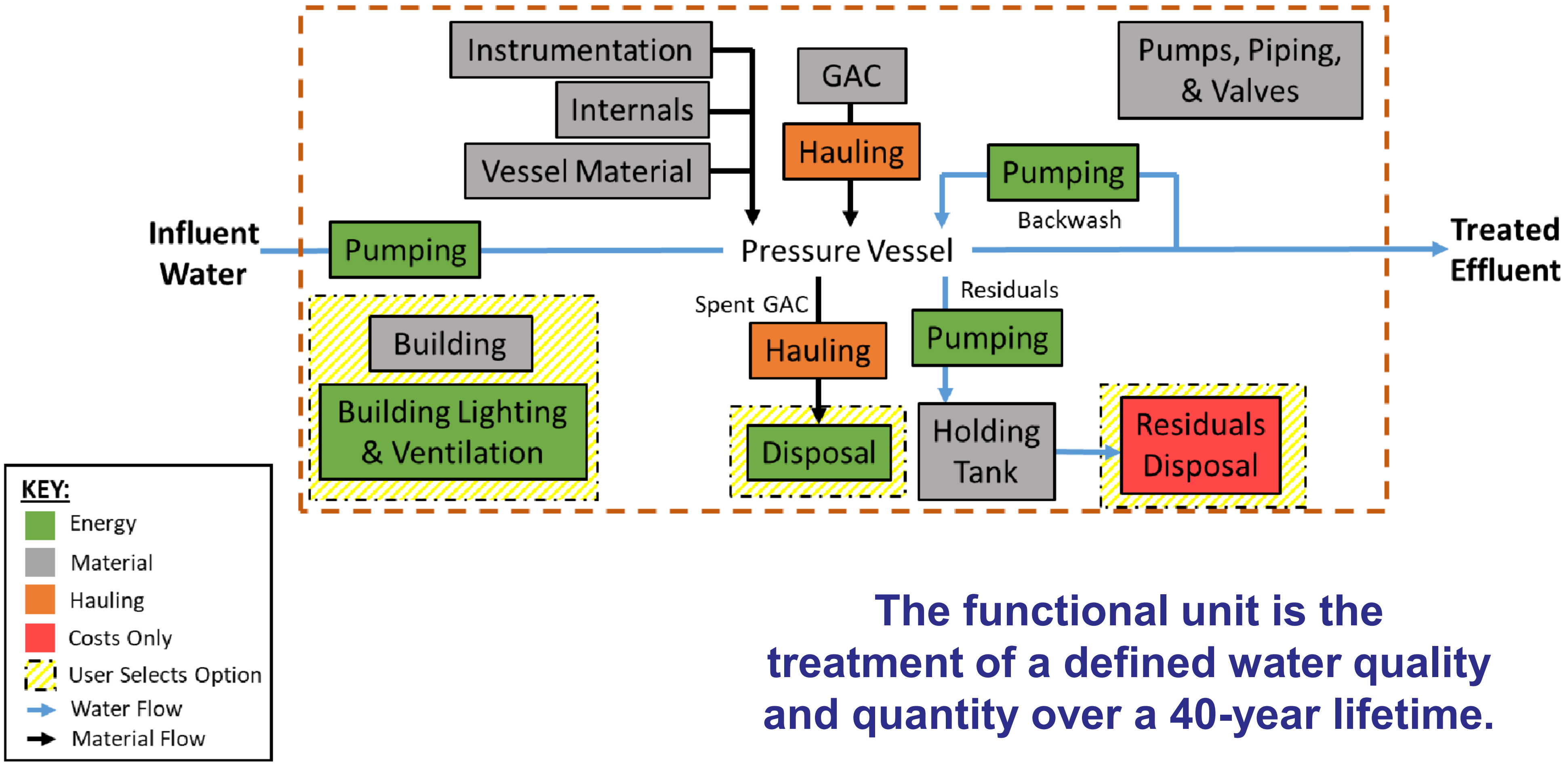
| Equal Weighting | |
|---|---|
| Affordability | 20% |
| Facility Operation | 20% |
| Effluent Quality | 20% |
| Global Warming | 20% |
| Global Environmental and Human Health | 20% |




Evaluation methods use life cycle assessment and life cycle costing methodologies.

# Each Technology has a Comparable System Boundary for a Treatment System that Operates for 40 Years




**The functional unit is the treatment of a defined water quality and quantity over a 40-year lifetime.**

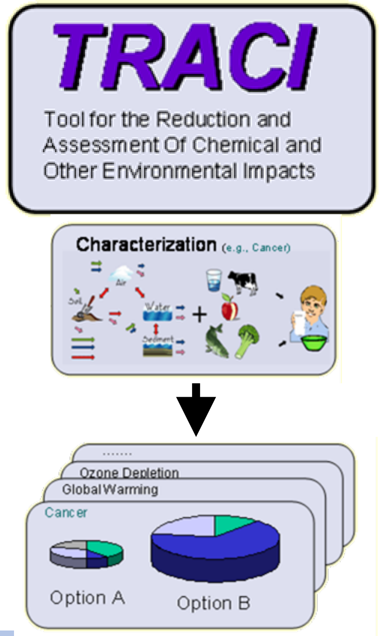
 

# Life cycle inventory data is translated into environmental impacts and costs

## Life Cycle Inventory

Materials
Energy
Chemicals
Labor

| Category | Decision Criteria | Scoring Method |
|---|---|---|
| **Affordability** | Capital Cost | Total initial costs |
| | O&M Cost | Total recurring costs |
| **Facility Operation** | Footprint | Sqare feet |
| | Maintenance | Total man hours |
| | Residuals Discharge | gal/yr |
| **Effluent Quality** | Effluent quality | kg PFAS discharged |
| **Global Warming** | Global warming | kg CO2 eq |
| **Global Environmental and Human Health** | Ozone depletion | kg CFC-11 eq |
| | Smog | kg O3 eq |
| | Acidification | kg SO2 eq |
| | Eutrophication | kg N eq |
| | Ecotoxicity | CTUe |
| | Fossil fuel depletion | MJ surplus |
| | Carcinogenics | CTUh |
| | Non carcinogenics | CTUh |
| | Respiratory effects | kg PM2.5 eq |

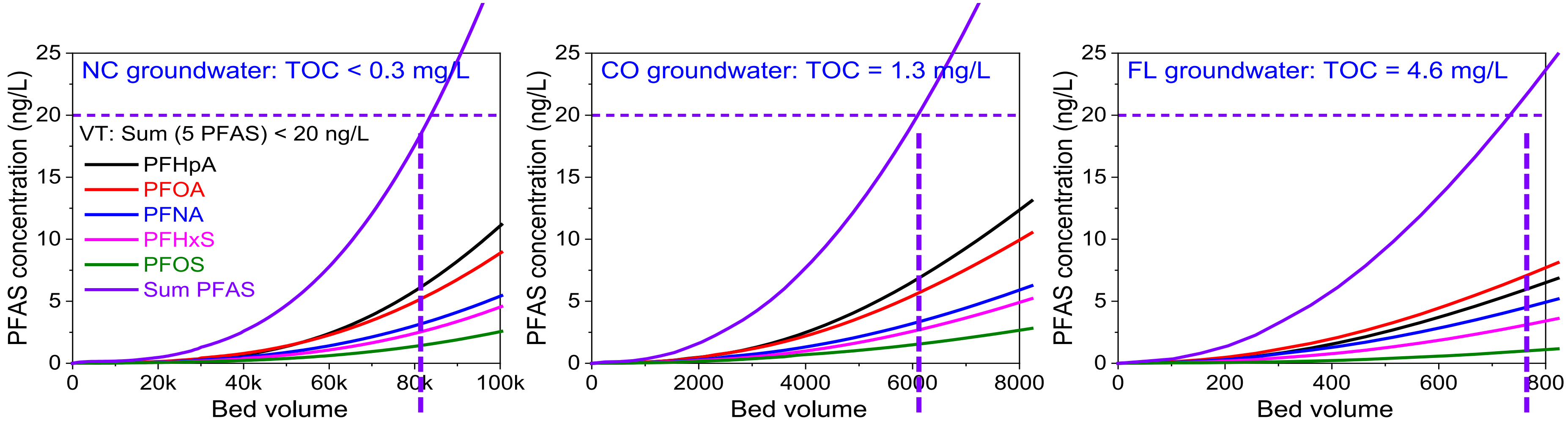



[epa.gov]

Present value of costs over the 40-year lifetime.

| Capital Costs | |
|---|---|
| *Concrete* | $15,538 |
| *Internals (Underdrain/Backwash System)* | $140,319 |
| *Aluminum Railing* | $4,003 |
| *Aluminum Stairs* | $27,089 |
| *Excavation* | $25,724 |
| *Backfill and Compaction* | $7,979 |
| *Plastic/HDPE Tanks* | $26,905 |
| *Process PVC Piping* | $3,626 |
| *Backwash PVC Piping* | $4,533 |
| *In Out PVC Piping* | $3,626 |
| *Residuals PVC Piping* | $1,288 |
| *Process PVC Manual Valve* | $17,390 |
| *Residuals PVC Manual Valve* | $1,493 |
| *Residuals PVC Check Valve* | $488 |
| *Residuals Pump* | $21,119 |
| *Level Switches/Alarms (for vessels)* | $3,781 |
| *Turbidity meters* | $33,329 |
| *SS Sampling Ports* | $375 |
| *Building* | $117,061 |
| *Concrete Pad* | $12,546 |
| *Indirect Capital Costs* | $185,885 |
| Total: | $654,098 |

# Scenario Analysis Example: GAC Use Rates for Vermont State MCL for Different Source Waters




| Groundwater | TOC (mg/L) | Bed volumes to reach criterion | GAC use rate (lb/1000 gal) |
|---|---|---|---|
| NC | < 0.3 | 84,000 | 0.05 |
| CO | 1.3 | 6,100 | 0.71 |
| FL | 4.6 | 750 | 5.75 |

Assumption: GAC influent contains 0.2 nM of each of five PFAS

PFHpA: 72 ng/L
PFOA: 82 ng/L
PFNA: 92 ng/L
PFHxS: 80 ng/L
PFOS: 100 ng

# Key Points 5011

- Key performance criteria for each technology included in the tool
- GAC use rates adversely impacted as TOC increases, EBCT decreases, and treatment criteria become stricter (e.g. removal requirements for shorter-chain PFAS)
- IX use rates adversely impacted as TOC increases, nitrate increases, and treatment criteria become stricter
- Membrane efficiency lowest for loose NF at high recoveries
- Decision support tool allows estimation of life cycle costs and impacts for PFAS treatment
- Tool will allow comparison of different approaches and impact of system conditions on effectiveness

# PFAS in Biosolids

Concern regarding potential re-release of PFAS to environment from land application of biosolids, current land application restrictions in some states

**Competed Studies**

1. Assessing PFAS Release from Finished Biosolids (WRF #5042, published 2022)
2. Determining the Role of Organic Matter Quality on PFAS Leaching from Sewage Sludge and Biosolids (WRF #5002, Published 2023)

**Ongoing Studies**

1. Understanding the Value Proposition for Thermal Processes to Mitigate PFAS in Biosolids (WRF #5211, recently awarded)
2. Direct In-Situ Measurement of PFAS Transformation & Leaching from Land-Applied Biosolids (WRF #5214, recently awarded)

# PFAS in Biosolids, 5002 & 5042

- PFAS levels (40 measured) similar among all biosolids studied (seven), 238 $\pm$ 48.8 to 768 $\pm$ 102 micrograms/kilogram of biosolids
- PFAS leaching sustained over 6-month study, leachate concentrations were 10s – 100 nanograms/liter
- Decreased leaching of longer chain PFAS compounds
- Decreased leaching with greater organic carbon content of biosolids
- Transformation of precursor compounds accounts for the vast majority of PFAS release
- Majority of organic fluorine associated with precursors not currently quantified in commercial laboratories
- Precursor transformation to perfluorinated carboxylates likely occurs during land application of biosolids
- The sorption capacity of biosolids varies widely by compound
- Greater organic content of biosolids and greater protein content of biosolids generally increases sorption capacity
- Biosolids stabilization decreases sorption capacity, in order of decreasing PFAS sorption capacity: anaerobic digestion > aerobic digestion > composting

# PFAS Summary

- Considerable work ongoing
- Considerable regulatory uncertainty
  - RCRA designation
  - Biosolids leaching
  - Many state-level actions
- Treatment technologies are available, but challenging
- Working to refine our ability to design systems to treat effectively given the wide range of PFAS compounds
- Still defining major environmental release sources

THE Water Research FOUNDATION

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