AFFF Transition in Vehicles and Fixed Fire Suppression Systems: Concepts and Case Study Review

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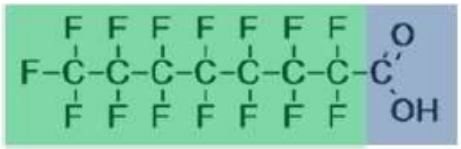
30 September 2024

PFAS Build-Up On Fire Suppression Infrastructure

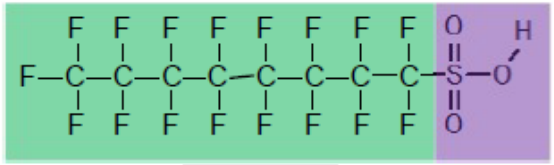
Foam transition is not as simple as foam out, foam in

PFAS Chemistry (as it relates to Foam Transition)

- PFAS are considered amphiphilic due to the hydrophobic (water repelling) fluorinated tail and the hydrophilic (water soluble) head group
- PFAS are surfactants or surface-active substances as they tend to accumulate at the surface of aqueous solutions



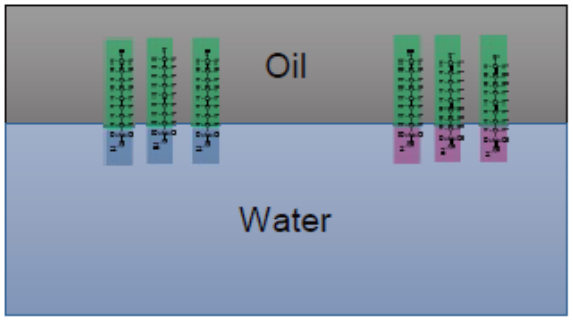
PFOA



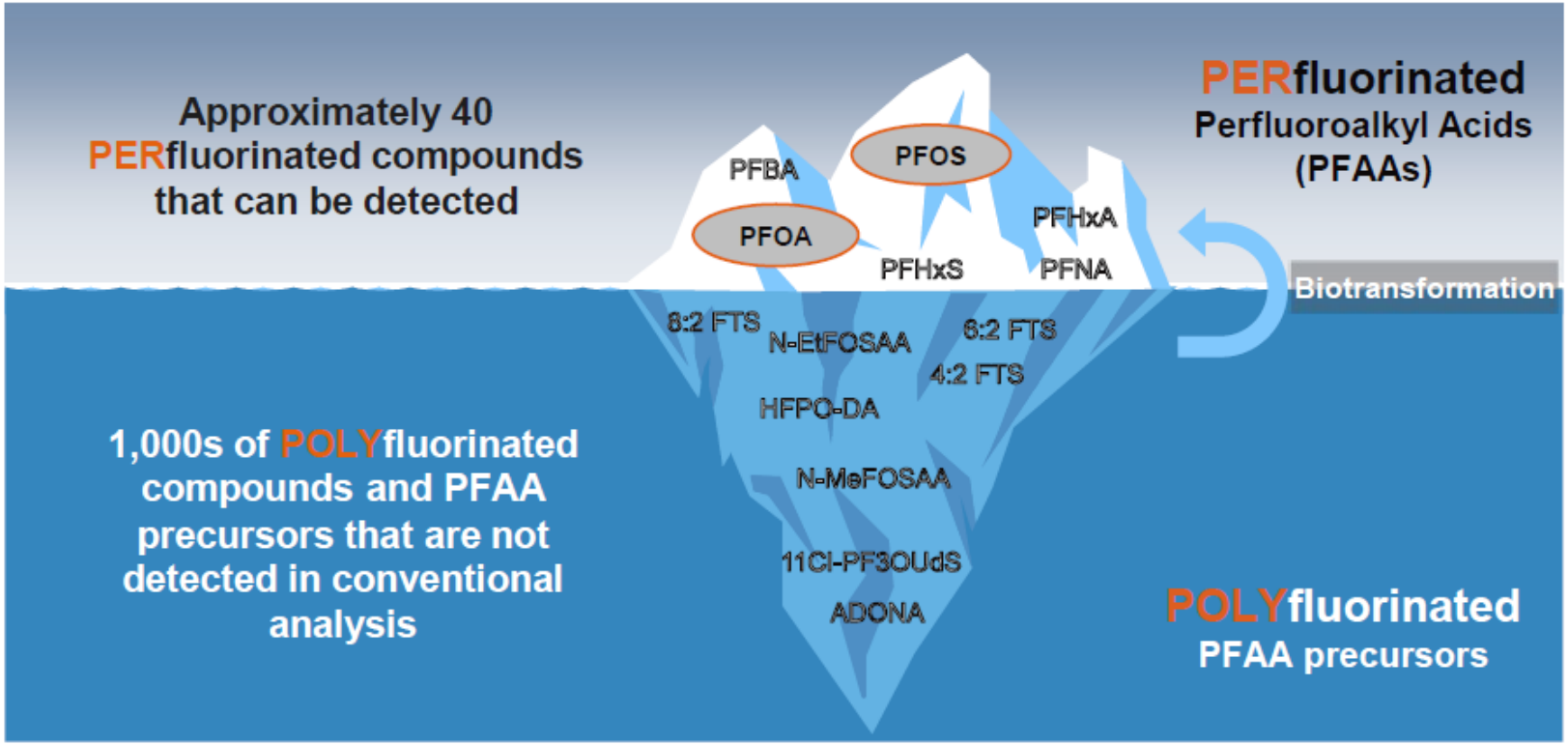
PFOS

= Fluorinated carbon tail

= Head group

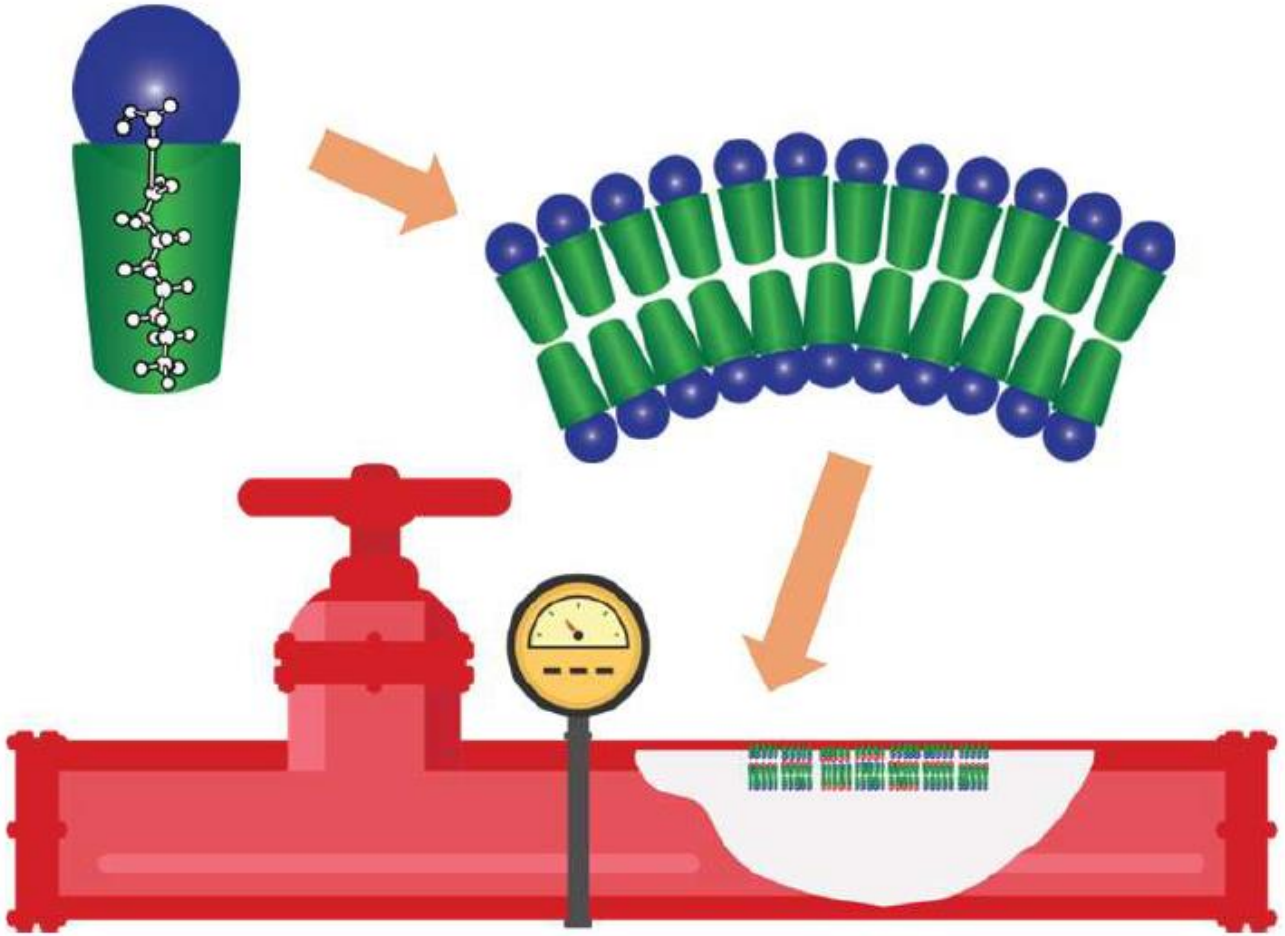


PFAS and Precursors



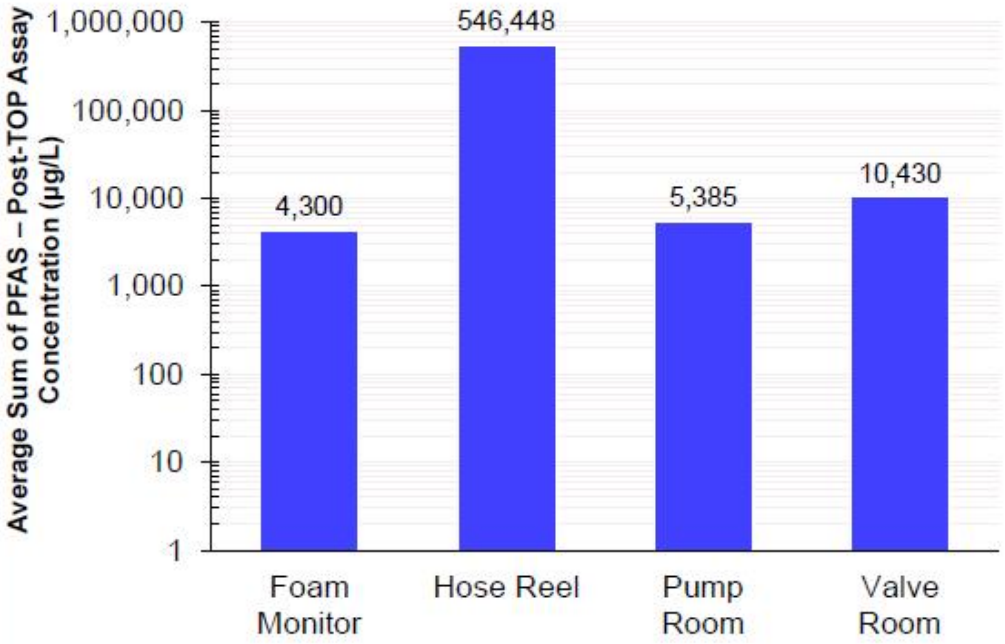
PFAS Self-Assembly Drives Cleaning Necessity

- In fire fighting infrastructure, PFAS structures aggregate onto surfaces, forming bilayers/residual coating
- Over time, layers thicken with additional PFAS structures and cause water-proofing of the AFFF-wetted surfaces



PFAS Rebound into Fluorine Free Foam (F3)

- System was rinsed with water **two times and** then filled with F3
- F3 analyzed for PFAS after one year in system
- Concentrations: over 500 mg/L in individual locations



ESTCP Characterization

Environmental Security Technology Certification Program (ESTCP) is USDoD's environmental technology demonstration and validation program.

ESTCP Project # ER20-5364

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ELSEVIER

Characterization of per- and polyfluoroalkyl substances on fire suppression system piping and optimization of removal methods

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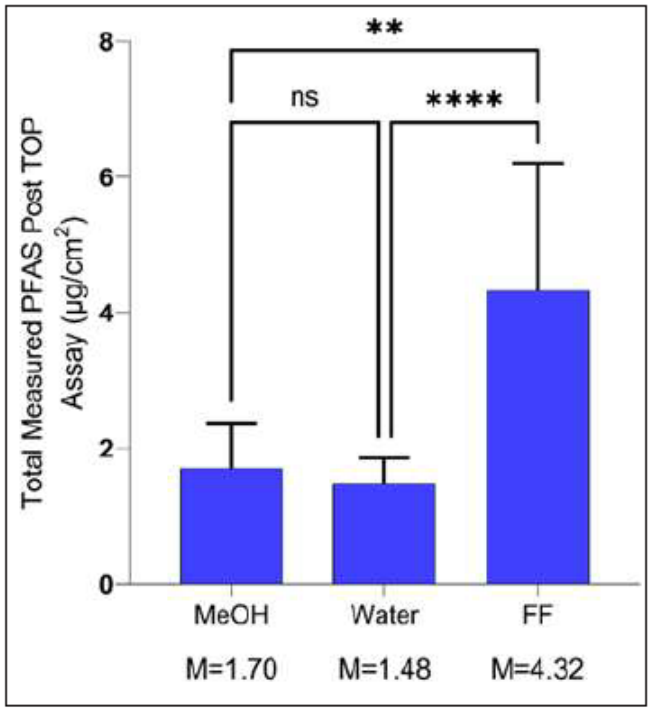
Extraction Solvent Comparison

Water	Methanol (MeOH)	Fluoro Fighter™
Commonly used during foam transition	Commonly used in laboratory solids extractions	Developed for PFAS removal
Easily sourced on most sites	Not field viable: Hazardous Flammable	Readily sourced; Non-hazardous

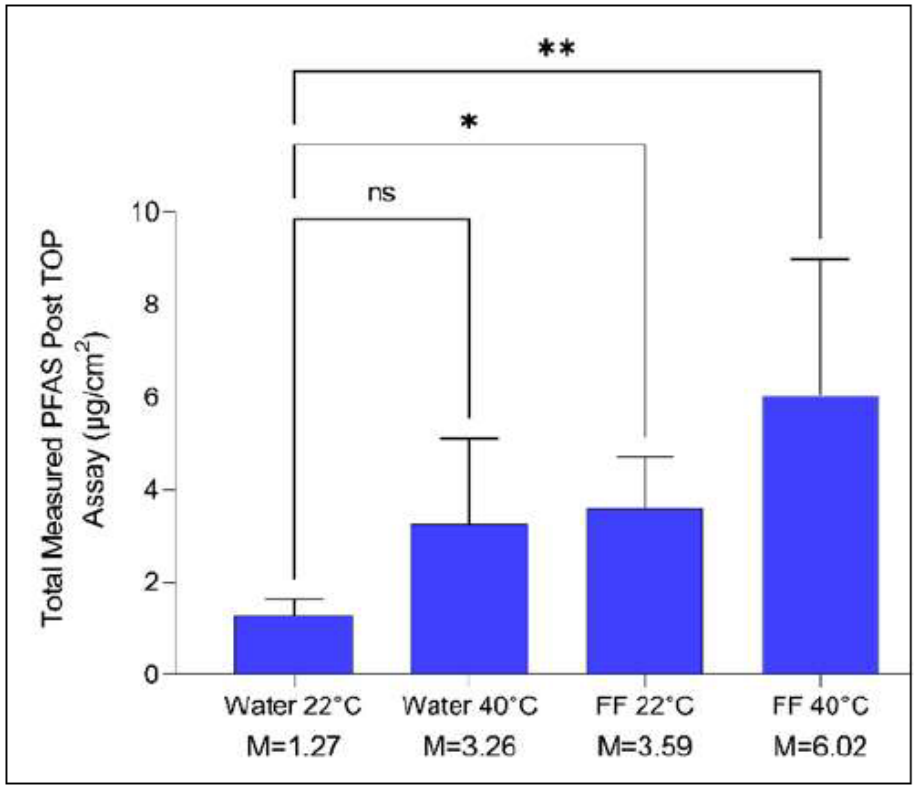
$$\frac{\mu g}{cm^2} = \frac{mass\ of\ PFAS\ extracted}{pipe\ surface\ area}$$



- Error bars show one standard deviation
- ns: not significant
- *8 p<0.05 ; **** p<0.005

Elevated Temperature Extractions

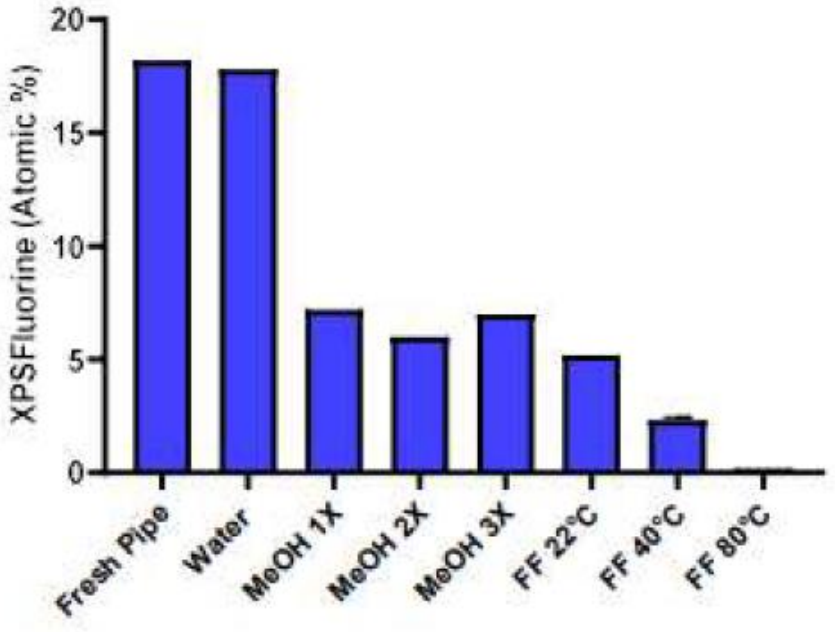
- Elevated temperature Fluoro Fighter (FF): Highest PFAS loading from the pipe surface
- Room temperature Fluoro Fighter had similar loading compared to heated water
- Elevated temperature improved PFAS loading in both solvents (water and FF)



- Error bars show one standard deviation
- ns: not significant
- * p<0.01 ; ** p<0.05

Fluorine Residual Levels using X-Ray Photospectrometry (XPS)

- XPS provides quantification (in percentage of surface coverage) of elements on a solid surface
- Fluorine assumed to be from PFAS
- Pipe flushed with water demonstrated similar fluorine residual compared to the fresh AFFF concentrate pipe
- Pipe extracted with heated Fluoro Fighter (FF) had lowest fluorine residual



ARFF Disassembly and Characterization

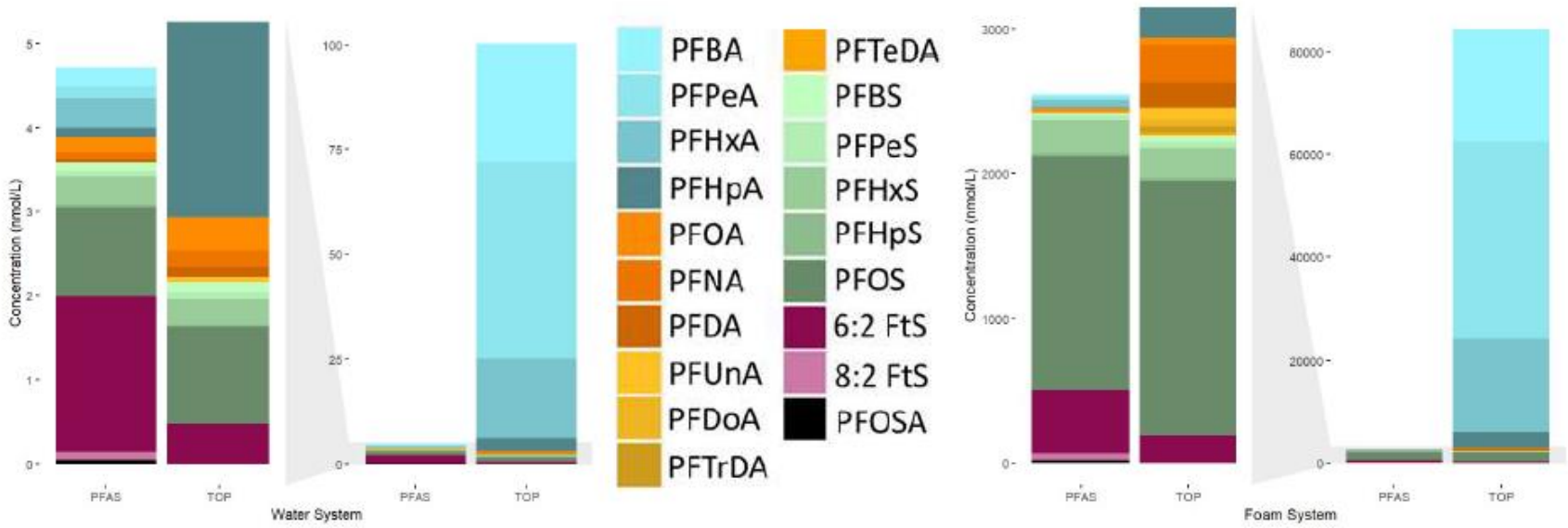
ESTCP Project # ER21-7229

Wetted systems disassembled April 2022: Over 100 parts were shipped to Arcadis Treatability Laboratory after disassembly for PFAS characterization using solvent extraction and surface techniques

ARFF Apparatus triple rinsed to characterize PFAS existing in system

System Rinse Data (Before Disassembly and After Reassembly)

System rinses serve to provide an indirect measure for the PFAS content that is in the wetted system as a whole

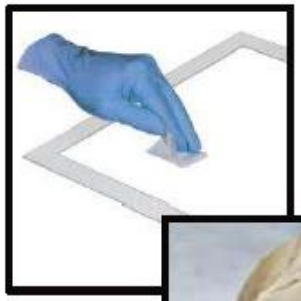


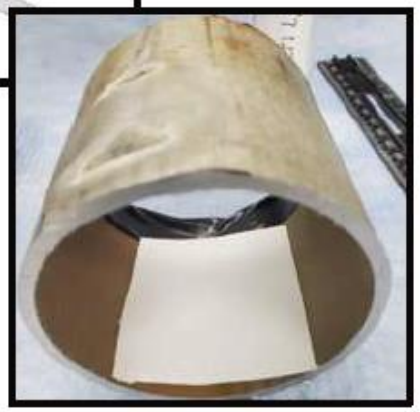
Bench-Scale Characterization Techniques

Established Destructive Extraction

Cap and Fill (with and without Bulking)

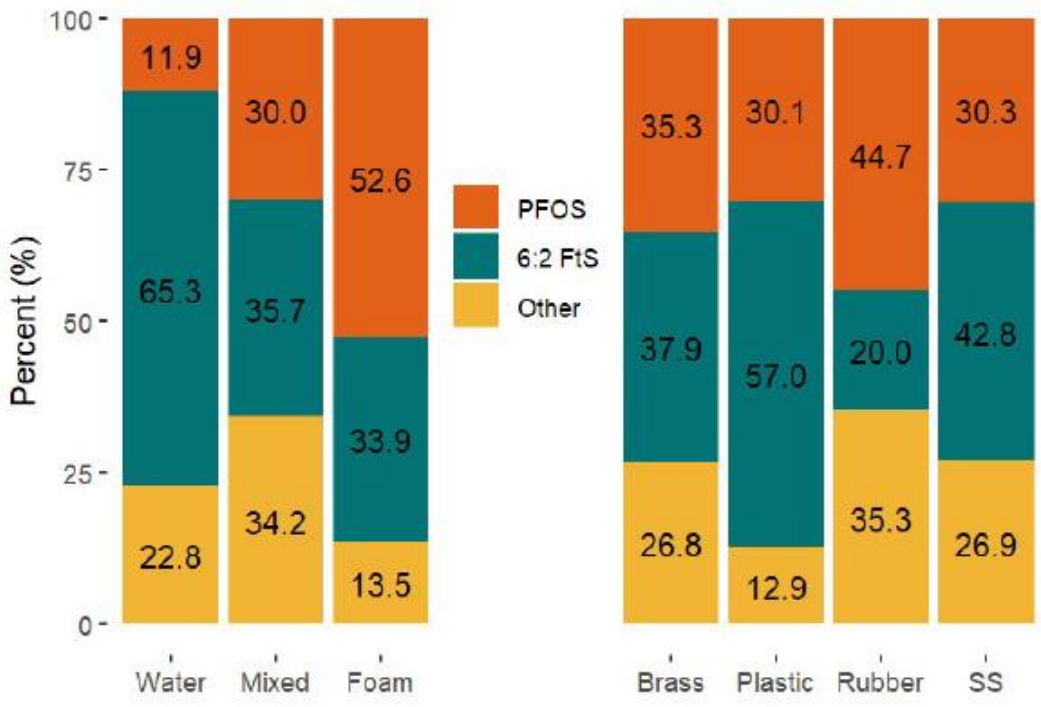
Wipe and Swab Sampling



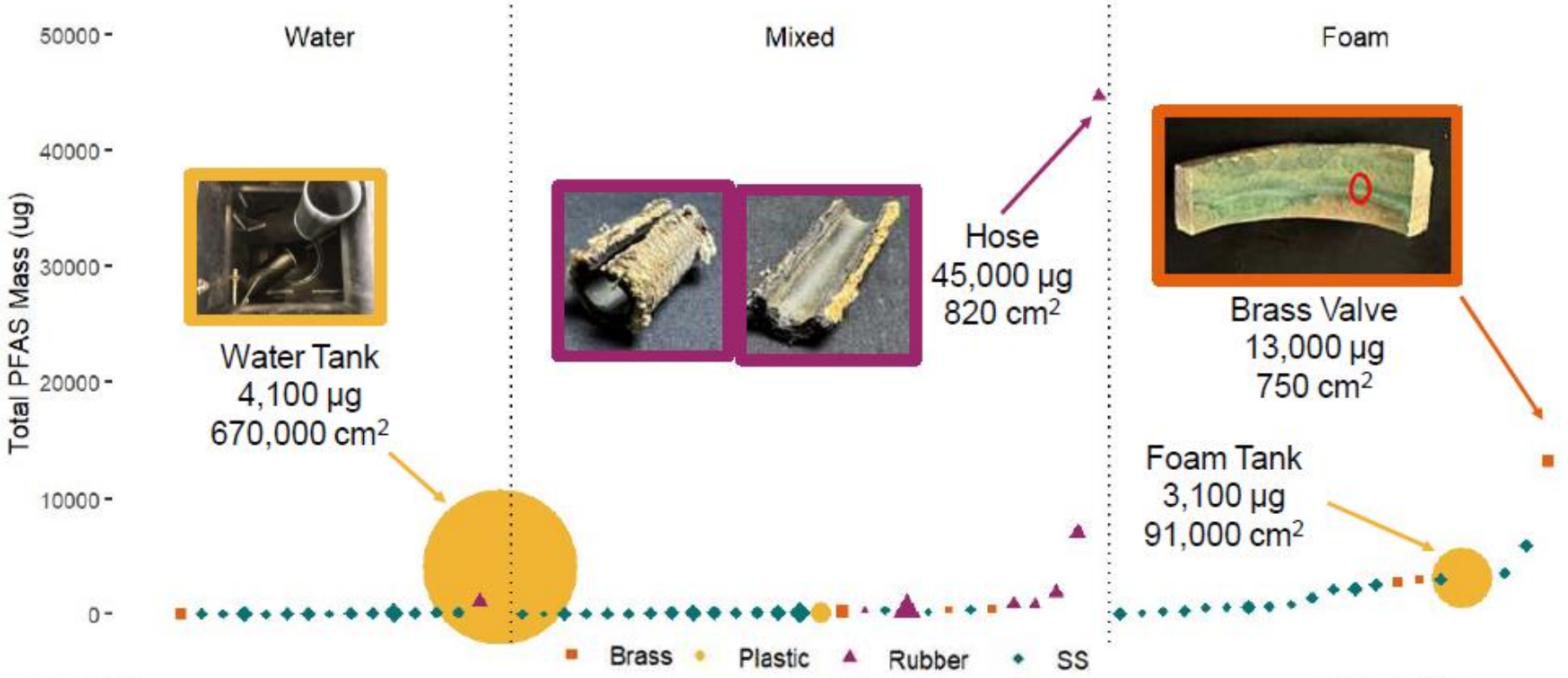


PFAS Species Distribution by System Location

Higher proportion of PFOS in foam and mixed foam system components as compared to 6:2-FTS



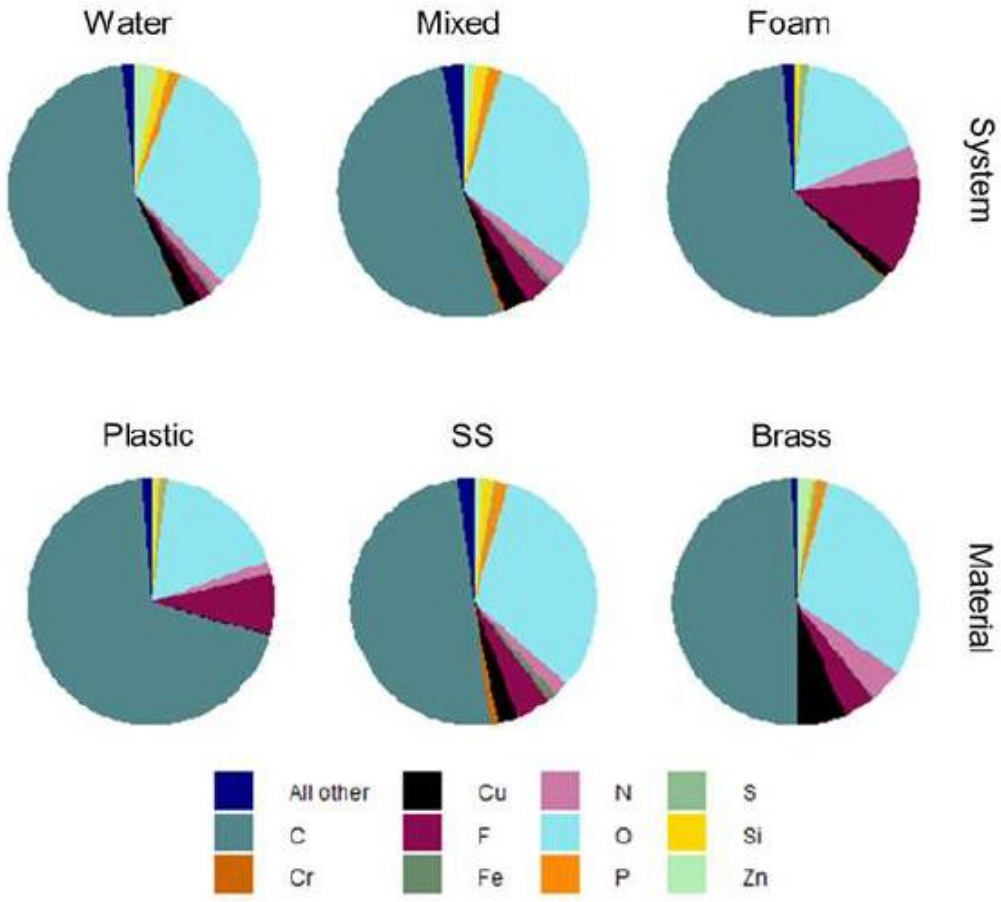
Total PFAS Mass on Individual Parts (After TOP Assay)



Surface Characterization by XPS

Higher proportional fluorine content on plastics as compared to other materials

Higher proportional fluorine content in foam system as expected, but present in water system



Site-Specific Approach to Foam Transition

Each system requires different inputs and management of change

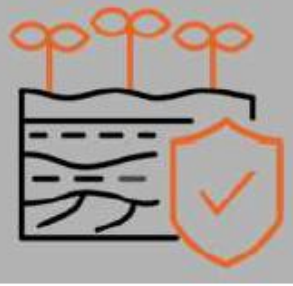
1 System Understanding

2 Foam Selection and System Upgrade Design

3 System Cleaning and Upgrade

4 Inspection, Testing, and Maintenance

5 Waste Management



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Step 1: System Understanding

The foundation for foam **transition at** the site level

Information to Gather:

- Regulatory Drivers
- Foam Usage and Inventory
- PFAS & Foam Analysis
- Operational Impacts
- Insurance Considerations
- Risk Profile and Compliance Check

Tools for collection:

- Foam Questionnaire
- Site Documents/Drawings
- Site and System Inspection

1

Fire Suppression Downtime Requires Pre-Planning

Fire suppression modifications directly affect site operations

- System modifications require offline fire suppression
- Site operations can consider:
  - Temporary alternative fire suppression means
  - Alteration of site operations to accommodate lack of fire suppression
  - Temporary operational shutdown
- Proposed alternatives may require:
  - Authorities having jurisdiction approval
  - Corporate approval
  - Insurance provider input

2

Step 2: Foam Selection And System Upgrade Design

Developing the path to AFFF removal

Foam Specification and Selection

- Insurance and Accreditation Requirements
- Effect on Existing System Operation

System Upgrade Design

- Cost Benefit Analysis
- System Upgrade Drawings and Specifications
- Permitting and Approvals
- System Clean Out Objectives and Criteria

2

Foam Selection Process

Fire Fighting Effectiveness No Longer the Only Consideration

MIL-PRF-32725

3.3 Toxicity and prohibited materials.

3.3.1 Toxicity. When evaluated in accordance with 4.4.1, the concentrate shall pose no serious or high risk to the health of personnel or the environment as defined by the risk assessment matrix in MIL-STD-882 when used for its intended purpose (see 4.4.1 and 6.8).

3.3.2 Prohibited materials. The concentrate shall not contain any chemicals categorized as "prohibited" in accordance with NAS 411-1.

3.3.3 PFAS content. The concentrate shall not contain more than 1 part per billion (ppb) per- and polyfluoroalkyl substances (PFAS) (see 4.4.5 and 4.5.7).

3.4 F3 characteristics. The concentrate shall conform to the chemical and physical requirements shown in table I.

TABLE I. Chemical and physical requirements for concentrates and full-strength solutions.

Characteristic	Type 3 Requirement	Standard	Test Paragraph

Decision Points:

- PFAS Content
- Other Constituents of Concern
- Fire Fighting Effectiveness
- Compatibility with Existing Equipment

2

How Clean is Clean?

Most asked question for foam transition and a critical decision point for system upgrade design

The Five "Ws" to address the "H"

What PFAS are Site Relevant?

- Individual PFAS vs Total Detected PFAS
- Is there a Regulatory Target?

Why is the System being Transitioned?

- PFAS liability reduction
- Regulatory pressure/compulsion
- System disrepair

Which Analytical Method?

- Targeted Methods
  - USEPA 537 Modified
  - Draft USEPA 1633
- Non-targeted Methods:
  - Total Oxidizable Precursor Assay
  - Total Organofluorine

Who will Analyze the Samples?

- Site-associated laboratory
- National lab with MSA

Where is the System Sampled

- Final water rinsate
- Post-foam installation
- Wipe or swab sample of equipment

2

Cost Benefit Analysis

Equipment Replacement vs Cleaning

- Some components (e.g., valves, tank bladders, hose lines) may be more difficult to clean and may be more cost-effective to replace.
- Large equipment, such as storage tanks and piping, may be too costly to replace or would negatively affect system downtime.
- Underground and elevated piping may not be accessible for easy replacement but can be cleaned.

System Component	Status of Component	Alternative Description	Effectiveness	Ease of Implementation	Estimated Cost	Outcome
Foam Mix Distribution Piping						
Test Line - Proportioner to Discharge Point	To be decommissioned	Remove and Dispose Offsite	High	Easy	$20,000	Remove, Dispose, and Replace
	Highly Impacted with PFAS Dry, solid residual only	Remove, Decontamination, and Dispose Offsite	Medium	Easy	$30,000	
SC1 Distribution Line – Proportioner to SC1	To be considered for new system	Remove and Dispose Offsite, Replace	High	Difficult	$61,000	Retain and Clean On-site
	Highly Impacted with PFAS Dry, solid residual only	Retain and Clean Onsite	Medium	Moderate	$40,000	

3

Step 3: System Cleaning and Upgrade

Work completed on the system to address foam transition

Pre-Mobilization

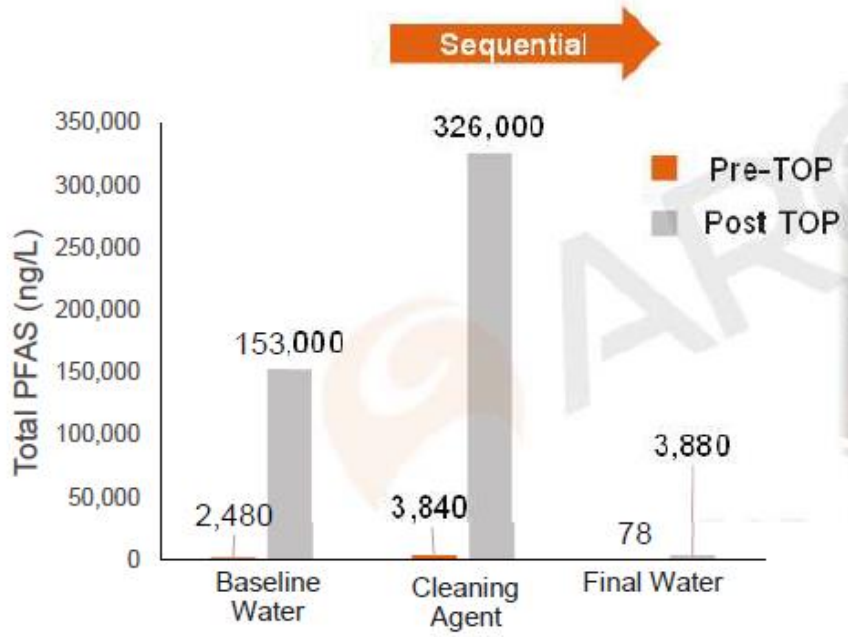
- Work Plan Development
- Fire Safety Contingency

On-Site Execution

- Site Setup and Containment
- Foam Removal
- System Cleaning
- Cleaning Verification
- System Upgrade

3

Australian Case Study: Fixed System Concentrate Tank - 2017



Cleaning agent resulted in more effective decontamination.

3

ESTCP Characterization Project Field Demonstration

Fixed Fire Suppression System

Former Naval Air Station (NAS) Joint Reserve Base (JRB) Willow Grove, Pennsylvania, August 2022

- Hazardous/flammable materials storehouse constructed in 1990s
- Building no longer operational
- No electricity in the building

System Cleaning Procedure

Two identical 500-gallon AFFF storage tanks with associated piping:

- One cleaned with piping
- One uncleaned

Cleaning steps:

- First water rinse
- Cleaning agent application
- Final water rinse
- Add 25 gallons of F3 for rebound testing

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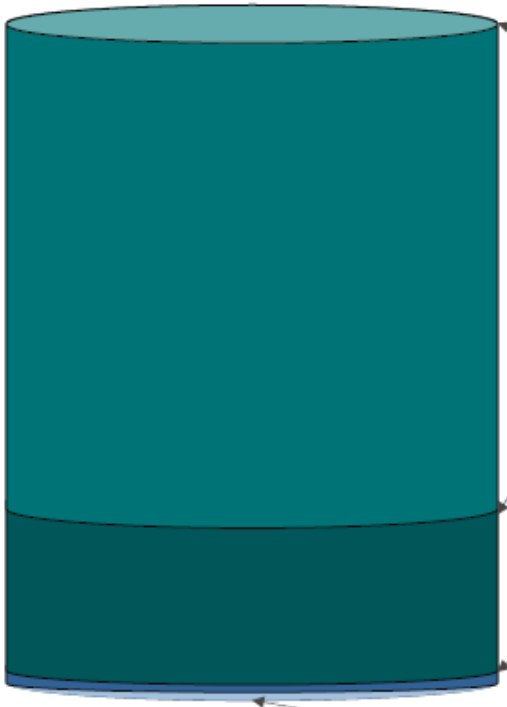
Cleaning Demonstration Analysis



Pre-Clean
(88g total PFAS;
0% Removal)

Post-Water Rinse 1
(15.9g; 81.8%)

Post-Fluoro Fighter™
(0.651g; 99.2%)

Post Cleaning Process
(Rebound Testing)
(0.006 g [6 mg]; 99.99%)

Post-TOP Assay PFAS Species Present in Sample		
Cleaned	**Uncleaned**	
12 ug/L	1,543 ug/L	
PFBA	PFBA	PFDA
	PFPeA	PFUnA
	PFHxA	PFDoA
	PFHpA	PFTriA
	PFOA	PFTreA
	PFNA	

4

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Step 4: Inspection, Testing, and Maintenance

Putting the new system to work

Post-Cleaning and Upgrade Commissioning

- Functional Test
- Third-Party Validation

On-Going System Attention

- System Maintenance Plan
- Foam Management Plan
- Foam Rebound Testing

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Step 5: Waste Management

Identifying and Utilizing Options for Waste Disposal

Primary Waste Types

- AFFF Waste
- Cleaning Agent Waste
- Rinsate Waste
- PPE and Incidental Solid Waste

Foam Transition Planning

- Minimization and Segregation
- Selecting Disposal Methods

Foam Transition Execution

- Classification and Disposal
- Transfer and Disposal Documentation

5

PFAS Disposal and Destruction Options

US EPA Interim Guidance – December 18, 2020

Revised and Issued April 8, 2024

https://www.regulations.gov/document/EPA-HQ-OLEM-2020-0527-0002

1. Interim storage
2. Permitted deep well injection (Class I, non-hazardous)
3. Permitted Haz Waste Landfill (Subtitle C)

Higher Uncertainty (Useful Under Certain Conditions)

4. Solid Waste Landfills (Subtitle D): Disposal of stable polymeric PFAS
5. GAC Reactivation units with Thermal Oxidizers with afterburners >1,100°C
6. Thermal Treatment Units (incinerators, cement kilns, lightweight aggregate kilns
7. Municipal Solid Waste Landfills with composite liners and leachate and gas collection

Uncertain Utility Under Any Conditions

8. Lower Temperature Thermal Treatment (<1,100°C)
9. Construction and Demolition (C&D Landfills)

Thank you for your attention!

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  - Peter Storch
  - David Liles
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