Foam Transitioning in a broader (practical) scope

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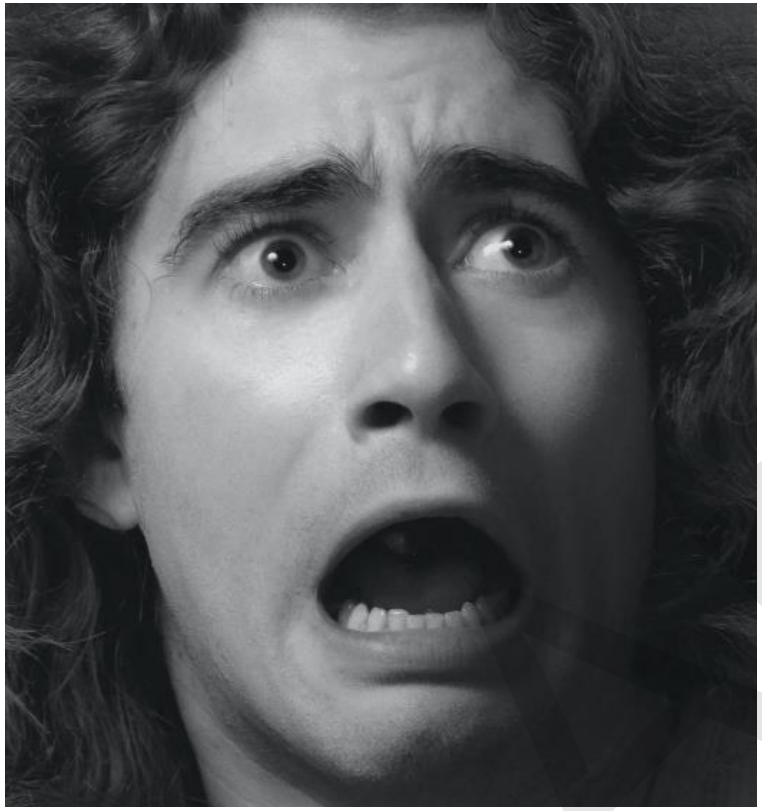
Courtesy: Kenbri Fire Fighting

Not here to scare you…. but to inform you on what is coming



All because of the political pressure to show progress on the PFAS dossier…

This then doesn't help much....

NEWS > SUSTAINABILITY

Top EU officials have toxic 'forever chemicals' in their blood

Margrethe Vestager and Frans Timmermans among officials tested as EU debates potential ban.

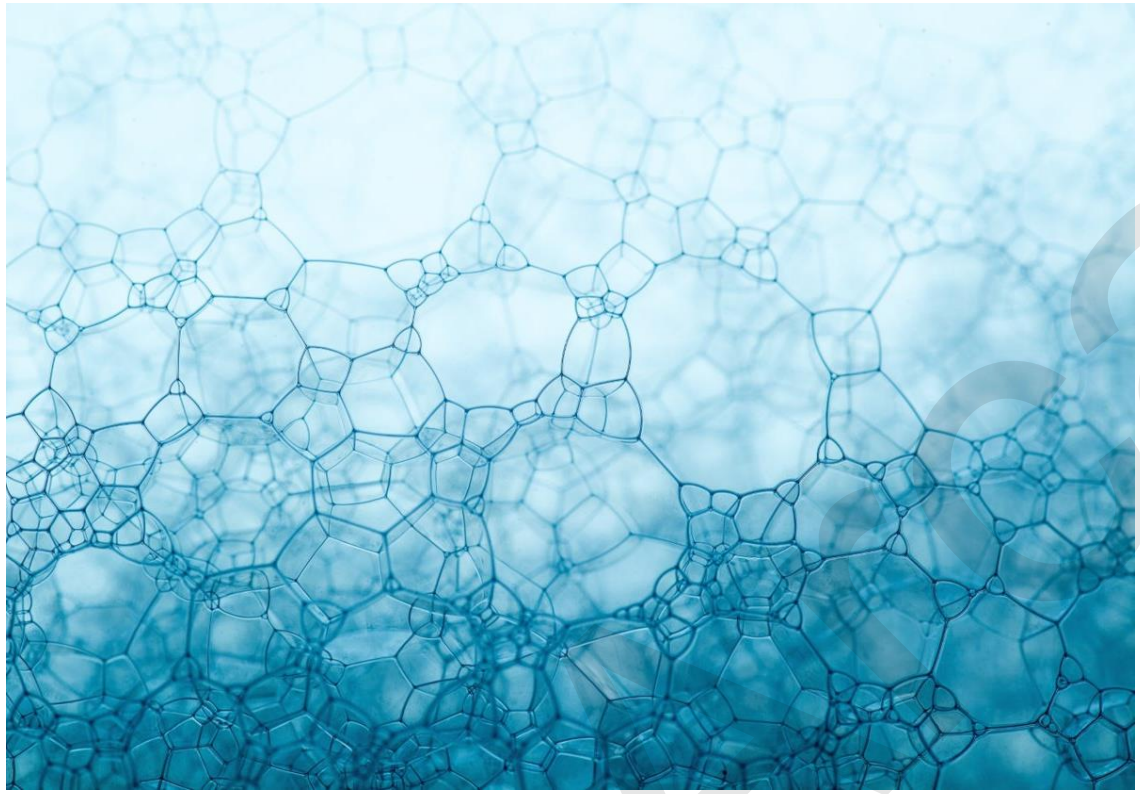
For me: multiple red flags in the last couple of months

- Multiple requests for emergency response support because of PFAS
- Waste processing company: the next slot for treatment of PFAS waste is 8 to 10 weeks from now (and you are using storage tanks that cost you € 4.500,- per week)
- Getting approval for on-site treatment from a competent body is a tough and painstakingly slow process
- Extremely low PFAS discharge levels: from < 1ng/L (1 ppt) for all PFAS to 30 ng/L (30 ppt) for PFOS, no alignment whatsoever
- Dutch authorities are ‘on the hunt’ for PFAS sources
- Feedback laboratory after serious delay: we receive 14.000 PFAS samples per week

Check how well your organization is prepared for PFAS

Introduction: PFAS, its impacts and consequences

PFAS used to be a miracle product



Why are the “forever chemicals” a problem?

… a group of thousands of man-made chemicals

… is abundantly found in human blood

… extremely persistent, bioaccumulative en toxic

… worldwide increased regulatory attention

… used in many industrial applications and consumer goods

… not easily detected

… are very mobile in groundwater

… thread to drinking water sources

What is foam and how does it work?

- Fire fighting foam concentrates regularly contain surfactants, solvents, stabilizers and thickeners
- PFAS in fire fighting foam act as surfactants that forms a film that covers the burning liquid
- Foam are tested for acceptance according to various certifications EN 1568, ICAO, UL, FM, LastFire
- Particularly effective for industrial fires with flammable liquids (Class B fires)
- PFAS use in fire fighting foam started in the 1970's, after a severe fire incident on USS Forrestal with 134 casualties.
- Since 2000 growing awareness on downsides of PFAS

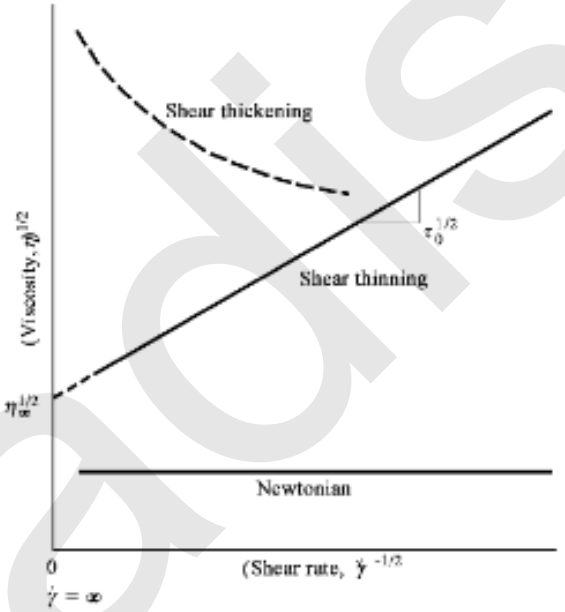
Effective Fluorine Free Foams are now on the market

Replacing products can also extremely persistent, mobile and with poorly understood health effects – **avoid regrettable substitution!**

Fire System Modifications with F3

not simply "foam out, foam in"

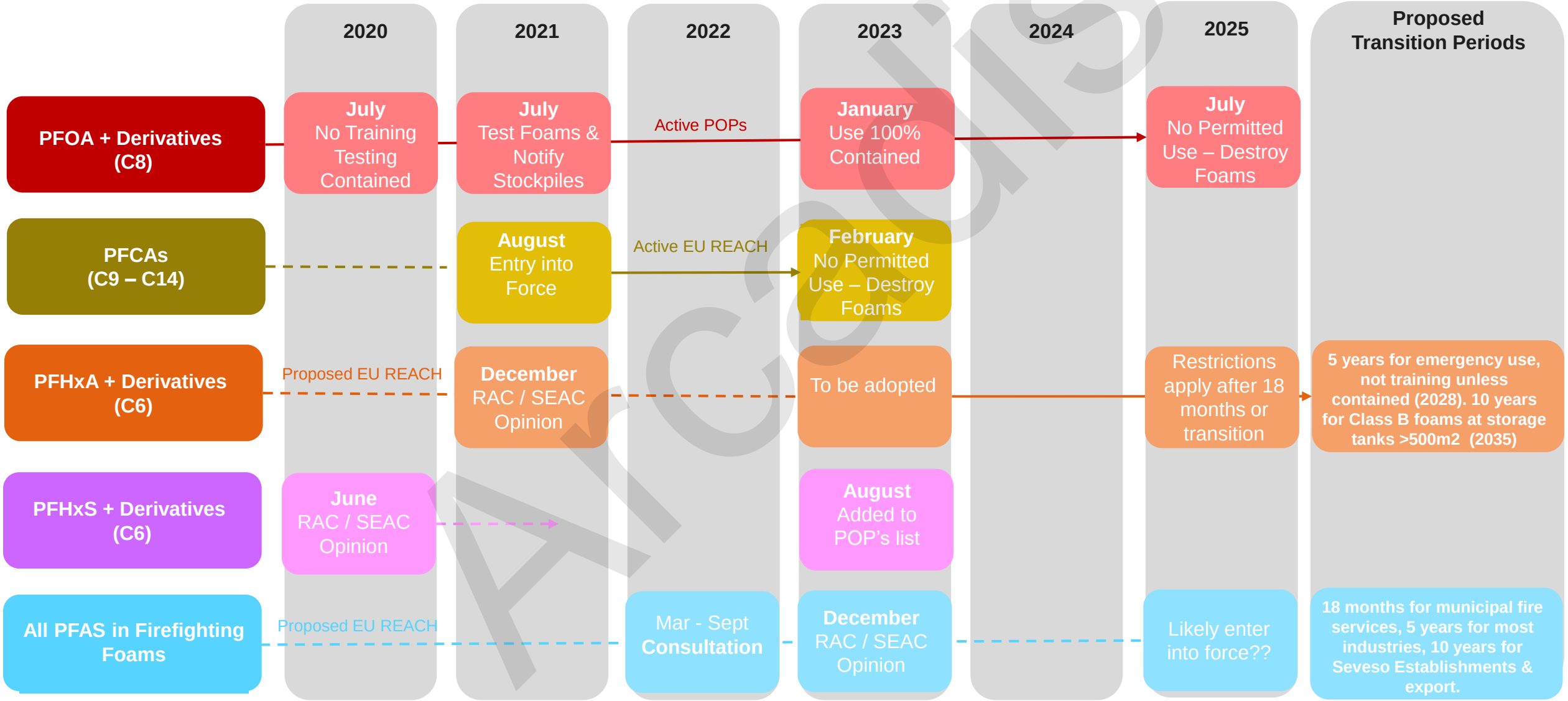
- **F3 physio-chemical properties**
  - Higher viscosity
  - Non-Newtonian behaviour
  - Hygroscopic swelling/gelling
- **Common Equipment Replacement**
  - Proportioners
  - Concentrate Pumps
  - Concentrate Tanks (incl. bladders)
- **Aspirated vs. non-aspirated discharge devices**
- **Insurance Approvals – accreditation of foam/equipment**



Fire system modifications almost always required.

Regulatory framework

Multiple EU restrictions in place and planned



We have large storage tanks, so we have more time for a foam transitioning, right?

- You need to submit a solid plan (not easy to get it approved)
- The Fluorpolymer/Fluorchem industry is rapidly repositioning itself in the market (example 3M, Tyco, Angus)
- Replacement foam not available on the market anymore
- More stockpiling needed

Our experience

Most of the large multinational O&G companies have already made the decision to transition to F3. Cleaning the system is in most cases the way forward.

Strict deadlines are set. Program based approach (based on risks assessment)

Scope for cleaning is in most cases limited to concentrate lines

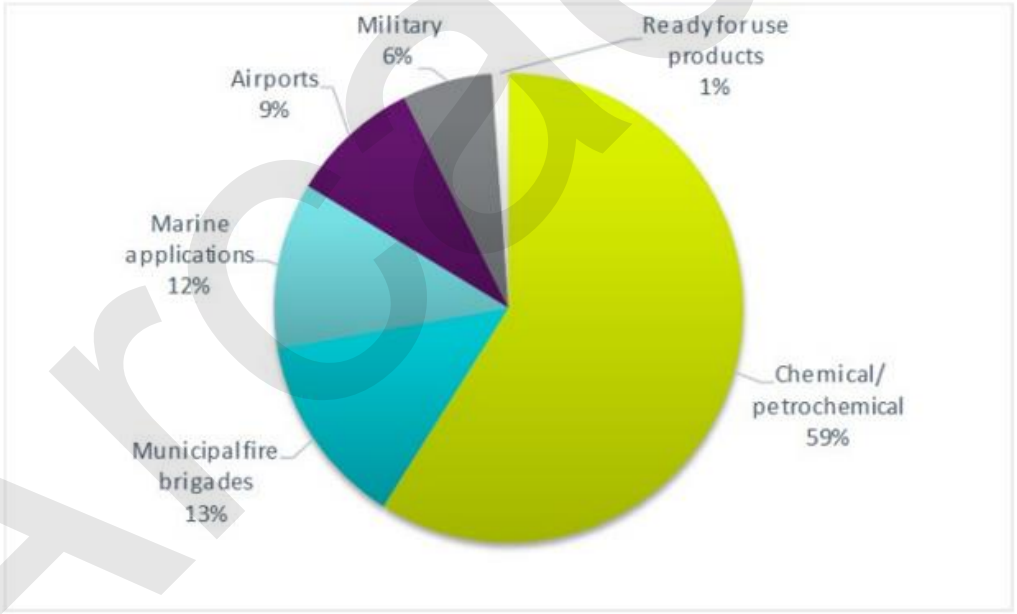
Definitely some grey areas on what is mandatory

Impact is enormous

Most of the 12.000 SEVESO III companies need to execute a foam transition before 2027/2028

Estimated costs of implementing the ECHA restrictions:
3 to 17 billion Euro

- Around 20 000 tonnes of PFAS fire-fighting foams are sold in the EU each year
- Equivalent to around 500 tonnes of PFAS



- Oil/(petro)chemical sector is the largest user
- Most sectors have examples of users that have substituted to F-free foams (typically training)

echa.europa.eu

Conclusion:

If you are using AFFF or equivalent

you will need to change over to F3 foam

or alternative solutions in the upcoming years

Large atmospheric storage tanks have more time

What is allowed and why?

Threshold values (for F3 foams, huh?)

	PFAS Compounds	Threshold	Status / Source
Long Chain PFAS	PFOS (C8) + Derivatives	0.001% (10,000 ppb)	Banned, POPs Regs[1]
	PFOA (C8) / Derivatives	25 ppb / 1,000 ppb	Restrictions, POPs Regs[1]
	PFHxS (C6) / Derivatives	25 ppb / 1,000 ppb 100 ppb in foam	Restrictions, POPs Regs[2]
	C9-C14 PFCAs / Derivatives	25 ppb / 260 ppb	EU REACH[3]
Short Chain PFAS	PFHxA (C6) / Derivatives	25 ppb / 1,000 ppb	Finalised, to be adopted[4]*
Long + Short Chain PFAS	All PFAS in Firefighting Foam	1,000 ppb	Finalised, to be adopted[5]
All PFAS	Wide range of PFAS uses	tbd	Being evaluated

* Proposed PFHxA (C6) exemptions – defence applications, 5 years for training/testing, 12 years for Class B foams at storage tanks >500m^2

PFOA (C8) & C9-C14 Restriction Timeline[1]

July 2020	No Training Testing Contained
July 2021	Notify Stockpiles
Jan 2023	Use 100% Contained
July 2025	No permitted use Destroy

[1]The Persistent Organic Pollutants (POPs) Regulations 2007 No. 3106

[2]POPRC-15/1: Perfluorohexane sulfonic acid (PFHxS), its salts and PFHxS-related compounds

[3]European Commission Regulation (EU) 2021/1297, 4 August 2021

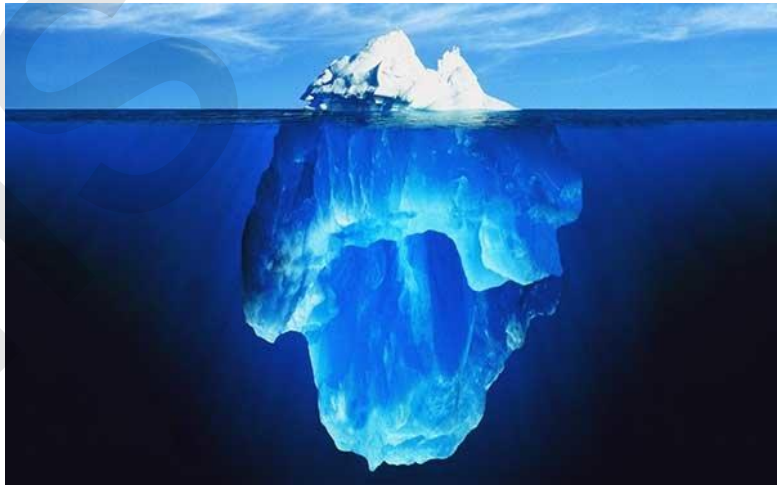
[4]European Chemicals Agency, 27/09/2021. Registry of Restriction Intentions (https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e18323a25d)

[5]European Chemicals Agency. Registry of Restriction Intentions (https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e1856e8ce6)

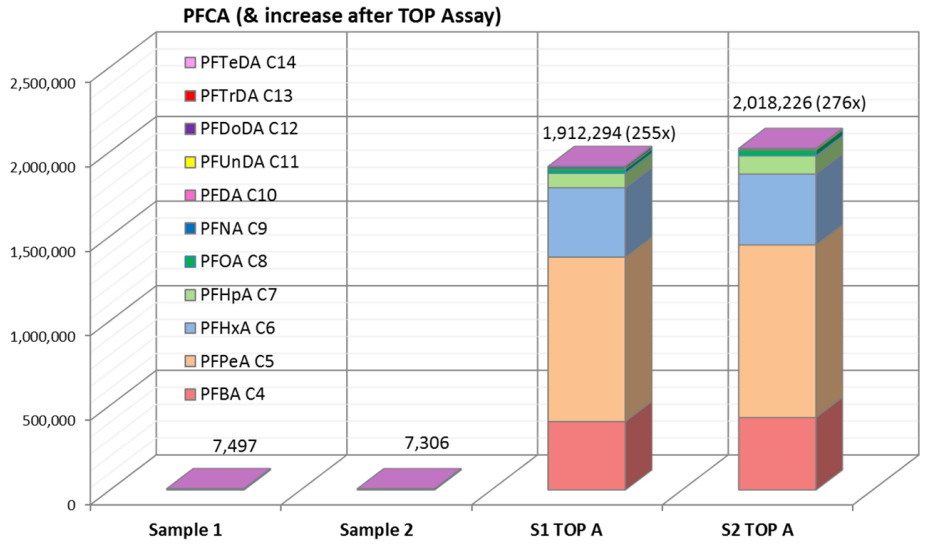
[6]European Chemicals Agency. Registry of Restriction Intensions (https://echa.europa.eu/nl/registry-of-restriction-intentions/-/dislist/details/0b0236e18663449b)

Analysis of derivatives → TOP Assay

PFAS Compounds	Threshold
PFOS (C8) + Derivatives	0.001% (10,000 ppb)
PFOA (C8) / Derivatives	25ppb / 1,000 ppb
PFHxS (C6) / Derivatives	25ppb / 1,000 ppb/ 100 ppb for foam
C9-C14 PFCAs / Derivatives	25ppb / 260 ppb
PFHxA (C6) / Derivatives	25ppb / 1,000 ppb
All PFAS in Firefighting Foam	1,000 ppb



- Regulations include individual PFAS and derivatives (precursors)
- Derivatives are not detected using regular PFAS analyses
- TOP Assay converts hidden PFAS to measurable PFAS
- Precursors in AFFF can range from about 20% (Lightwater) to 100% (fluorotelomer foams)
- **TOP Assay is an essential part of your foam analyses!!**



Conclusion:

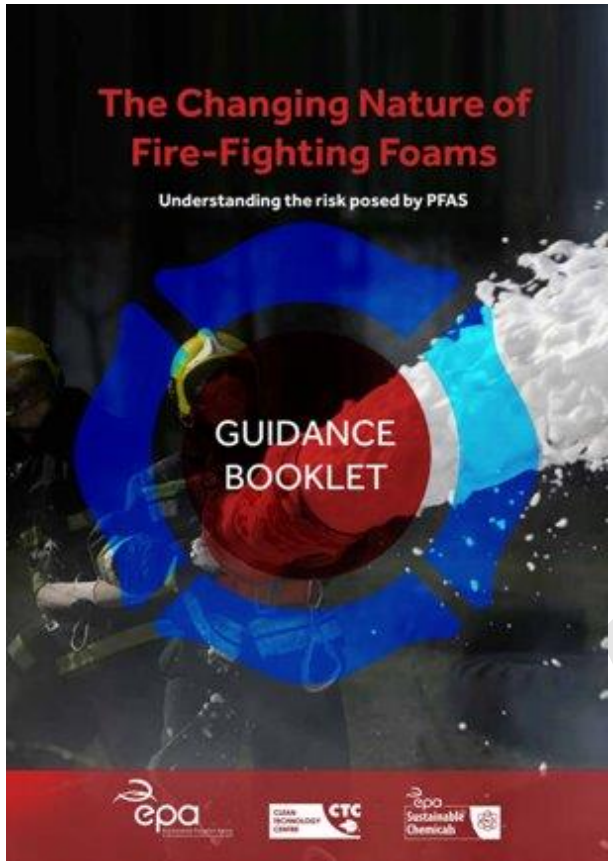
Elevated PFAS levels allowed in your fire fighting system post transition

(from g/L to ug/L)

However: upon use of your fire fighting foam different laws come into place!

FOAM TRANSITIONING – HOW TO GO FORWARD

Foam Transitioning = MoC process



- Authorities and institutes are setting up or have set up guidelines for the MoC process.
- These include: No F3 testing before system clean-out!
- Dutch authorities start to see the need for QA/QC protocols of the cleaning process
- Guideline for cleaning QA/QC currently being set up (funded by multiple stakeholders, a.o. Arcadis and Kenbri). Embraced by authorities!

Arcadis Foam Transition Team

Holistic approach via multidisciplinary partnerships

Environmental Engineer

Fire Service Engineers

Fire Service Contractors

Foam Transition Approach

Safe transition to fluorine-free foam

Management Of Change

1 - System understanding

- Regulatory Drivers
- Insurance Considerations
- Foam Usage & Inventory
- Site & System Inspection
- PFAS & Foam Analysis
- Operational Impacts
- Risk Profile and Compliancy Check

2 - Foam Selection & System Upgrade Design

- Insurance & Accreditation requirements
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- Clean Out Objectives

3 - Clean Out & System Upgrade

- Work Plan
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4 - ITM

(Inspection, Testing & Maintenance)

- Functional Test
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5 - Waste Management

- Minimisation & segregation
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Regular topics

- Quarter mastering
- Desk and laboratory study
- Start a discussion with the client
  - What is desirable, what is smart
  - Insurance and permit check
  - Pre and Post Transition Risk Assessment
- Impact assessment (for instance necessity of back-up systems)

Foam analyses for compliance check

Component	Date of analysis	Concentration (µg/l)	Reporting Limit (µg/l)
Perfluorobutanoic acid (PFBA)	03/11/2021	920	10
B/E Perfluoropentanoic acid (PFPeA)	03/11/2021	370	10
B/E Perfluorohexanoic acid (PFHxA)	03/11/2021	2700	10
B/E Perfluoroheptanoic acid (PFHpA)	03/11/2021	130	10
B/E Perfluorononoic acid (PFNA)	03/11/2021	44	10
B/E Perfluorodecanoic acid (PFDA)	03/11/2021	100	10
B/E Perfluoroundecanoic acid (PFUnDA)	03/11/2021	18	10
B/E Perfluorododecanoic acid (PFDoDA)	03/11/2021	27	10
Perfluorotridecanoic acid (PFTrDA)	03/11/2021	<10	10
Perfluorotetradecanoic acid (PFTeDA)	03/11/2021	<10	10
Perfluorohexadecanoic acid (PFHxDA)	03/11/2021	<10	10
Perfluorooctadecanoic acid (PFOcDA)	03/11/2021	<10	10
B/E Perfluorobutane sulfonic acid (PFBS)	03/11/2021	40	10
Perfluoropentane sulfonic acid (PFPeS)	03/11/2021	34	10
B/E Perfluorohexane sulfonic acid (PFHxS)	03/11/2021	140	10
Perfluoroheptane sulfonic acid (PFHpS)	03/11/2021	58	10
Perfluorodecane sulfonic acid (PFDS)	03/11/2021	<10	10
4:2 Fluorotelomersulfonic acid (4:2 FTS)	03/11/2021	180	10
6:2 Fluorotelomersulfonic acid (6:2 FTS)	03/11/2021	100000	10
8:2 Fluorotelomersulfonic acid (8:2 FTS)	03/11/2021	510	10
10:2 Fluorotelomersulfonic acid (10:2 FTS)	03/11/2021	170	10
B 2,3,3,3-tetrafluor-2-(heptafluorpropoxy)propanoic acid (HPFO-DA)	03/11/2021	<10	10
B/E Perfluorooctane sulfonamide (PFOSA)	03/11/2021	<10	10
N-methylperfluorooctanesulfonamide (N-MeFOSA)	03/11/2021	<10	10
N-methylperfluorooctanesulfonamidoacetic acid (N-MeFOSAA)	03/11/2021	<10	10
N-ethylperfluorooctanesulfonamidoacetic acid (N-EtFOSAA)	03/11/2021	<10	10
8:2 Fluorotelomerphosphate diester (8:2 DiPAP)	03/11/2021	<10	10
Perfluorooctanoic acid (PFOA) (linear)	03/11/2021	420	10
Perfluorooctanoic acid (PFOA) (branched)	03/11/2021	14	10
Perfluorooctane sulfonic acid (PFOS) (linear)	03/11/2021	880	10
Perfluorooctane sulfonic acid (PFOS) (branched)	03/11/2021	160	10

Client uses a regular C6 foam (6:2 FTS)

Client expects to be compliant with regard to the present legislation

Regular PFAS analyses (not even TOP assay) shows elevated concentrations of C8 (PFOA and PFOS)

Client is non-compliant because of PFOA

Historic site usage of foam types become apparent in analyses

Foam Transition Approach

Safe transition to fluorine-free foam

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Regular topics

- Accreditation
- Foam selection
- Setting the scope and the goals for the transition
- Costing scenario’s
- Select way forward: clean or replace

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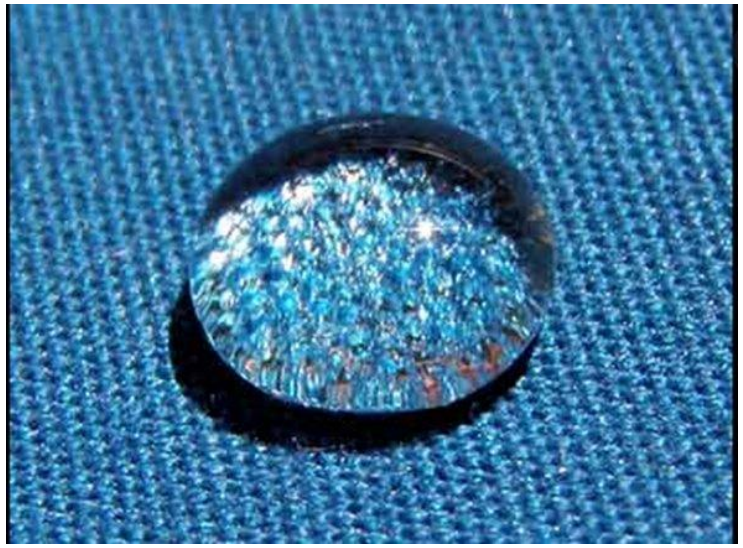
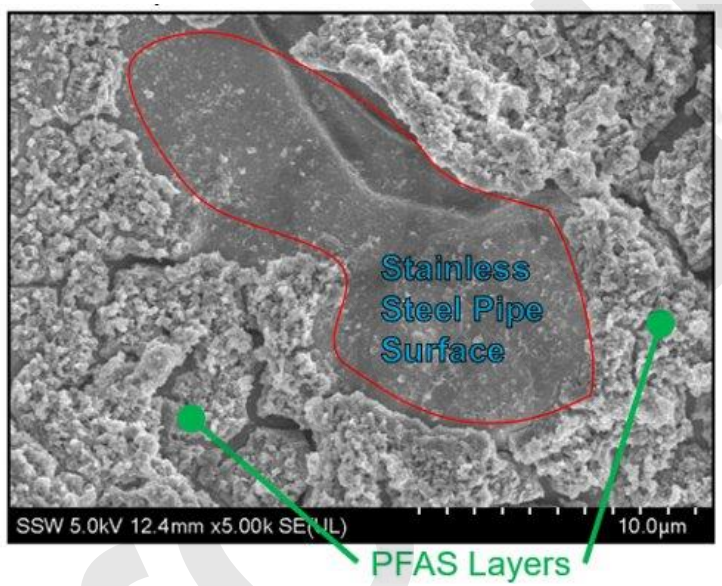
Waste management

- Very important and underestimated area
- Not only fluid waste, but also solid waste like piping, valves in case of system changes
- Cost and liability issue
- Serious costs involved and they seem to vary day-by-day
- Capacity issues already at hand only 44 HTI facilities in Europe (Eurits.org)
- New technologies on the market or under development, some promising
  - **Concentrating:**
    - Fractionation
    - Vacuum evaporation
    - Reversed Osmosis
  - **Destruction**
    - SCWO
    - Sonolysis
    - Electrochemical reduction

SYSTEM CLEAN-OUT

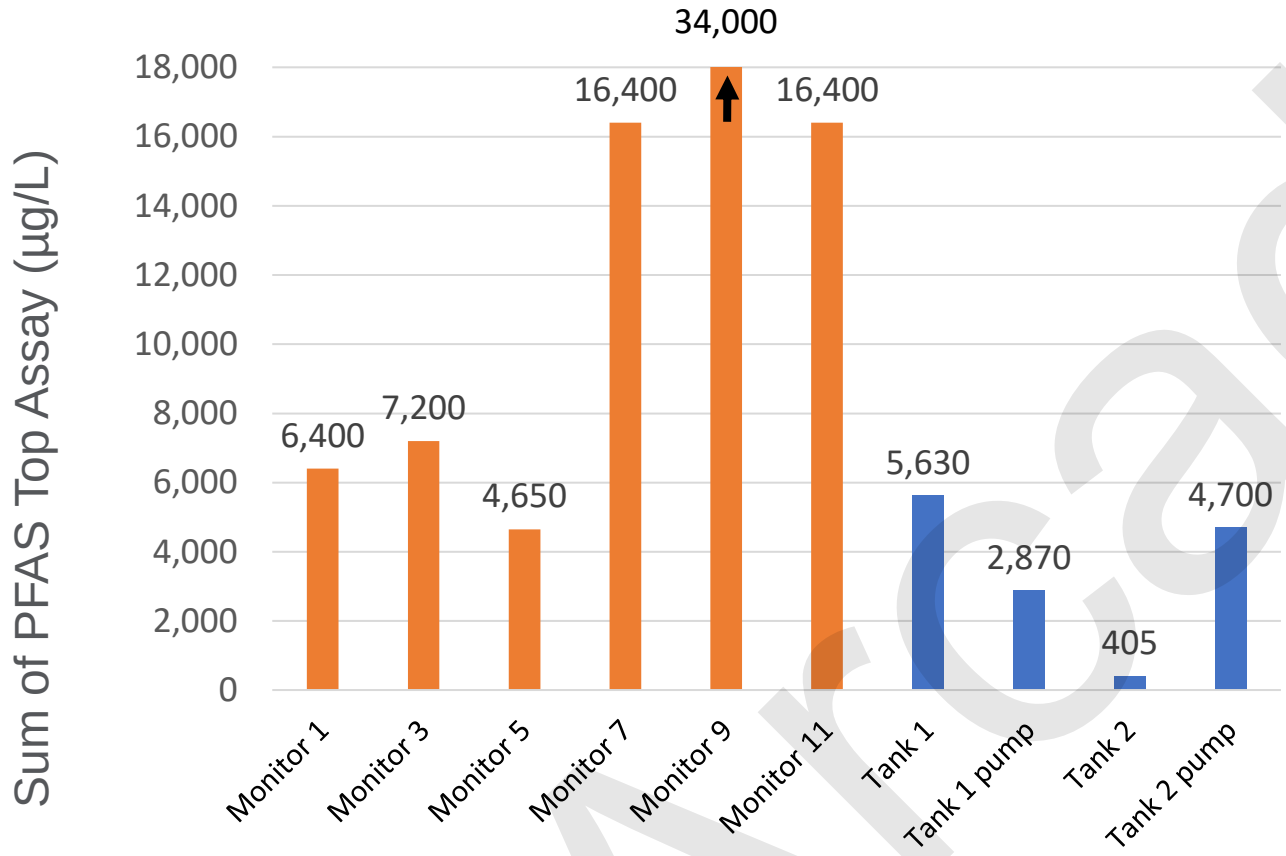
Why is PFAS removal so difficult





- In AFFF infrastructure, PFAS structures will build up in layers on the interior surfaces
- Over time, layers thicken with additional PFAS structures and cause water-proofing of the AFFF-wetted surfaces
- Removing PFAS from impacted systems is very difficult
- The ECHA guidelines are very strict as they are

Cleaning with water? PFAS Rebound



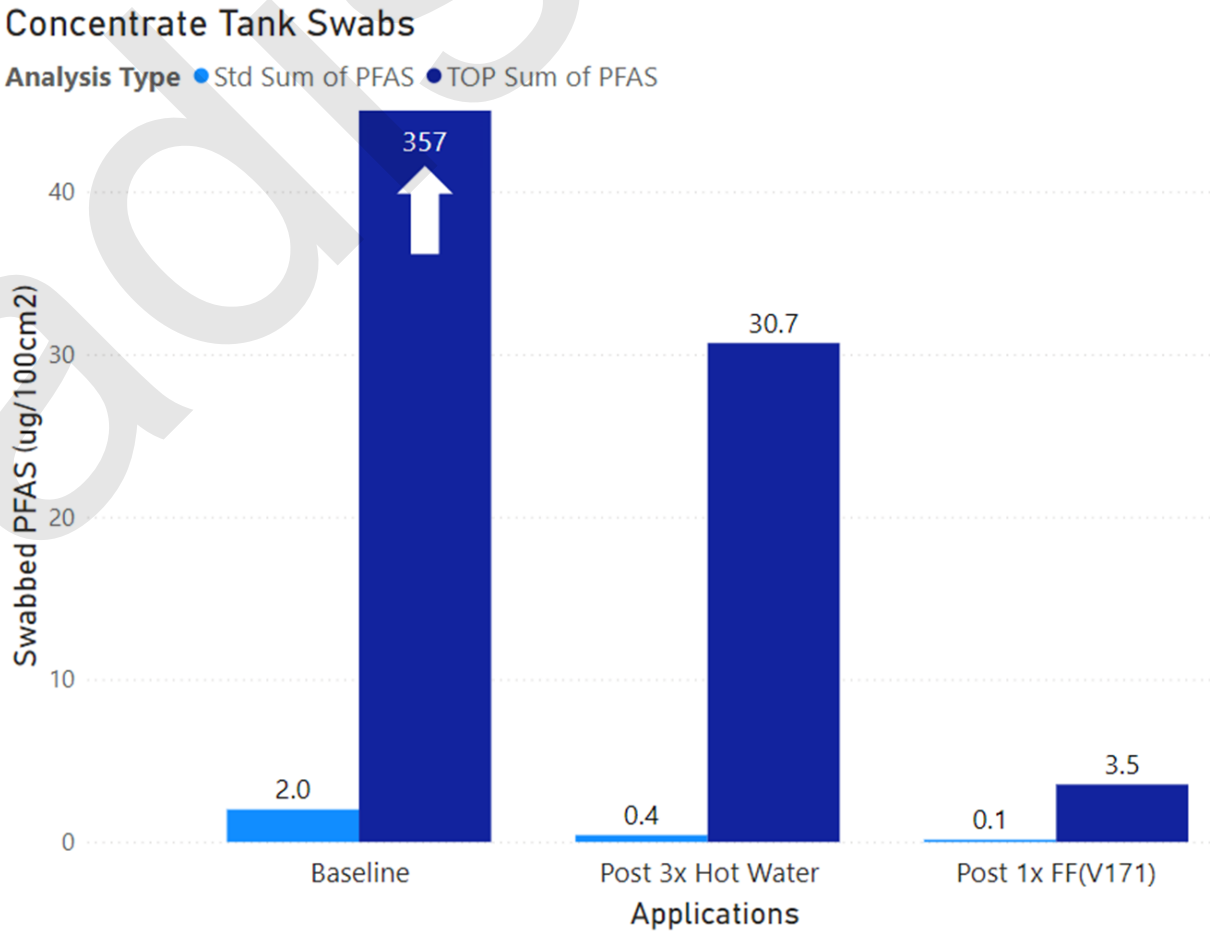
Two years after changeout to F3 using a dual water flush

PFAS residual typically 1,000's of µg/L in F3 piping and tanks

Significant desorption of PFAS into F3 foams after two water flushes.

Hot Water Considerations

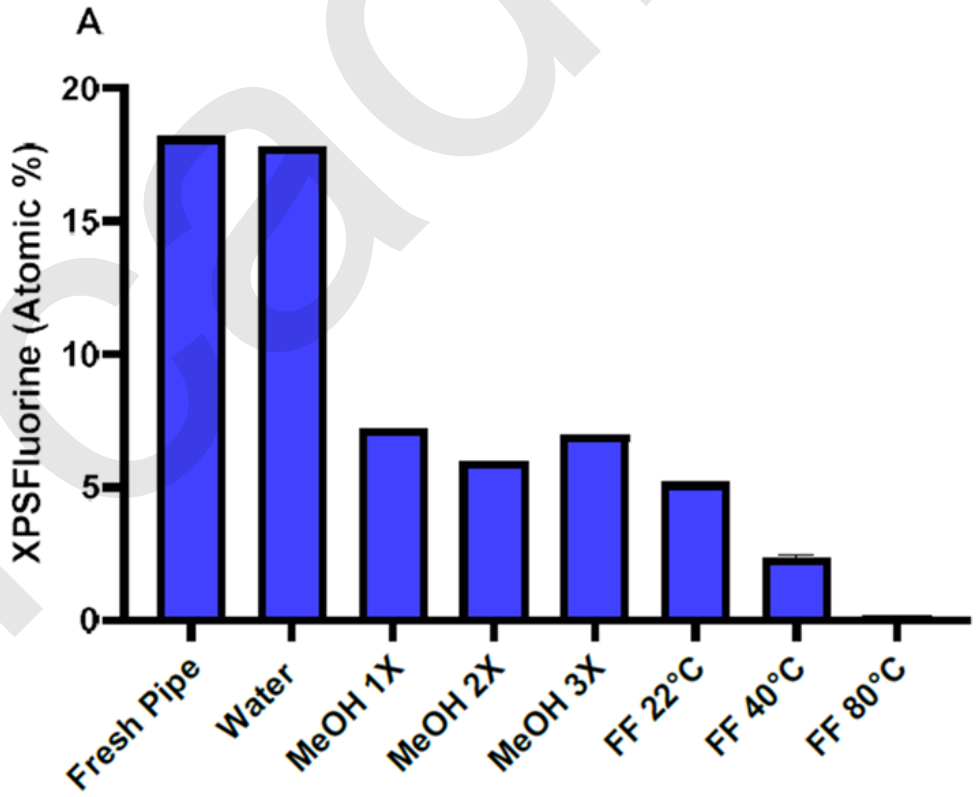
1. High wastewater volume generated.
2. Health and safety issue: ***scald hazard.***
3. Logistics: skid delivery, generator, ***time to heat.***
4. Increased labour and time.
5. Fine sediment contamination from boiler.
6. PFAS detected in control hot water sample.
7. Temp losses: high in ancillary bath, moderate in truck.
8. High temp triggered thermal switch and opened drains.

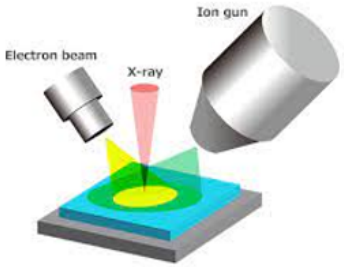


Cleaning using FluoroFighter™

- Arcadis developed, low volatility, biodegradable cleaning agent
- FluoroFighter™ recipe optimized based on the foam(s) used
- Efficiency demonstrated in US DOD ESTCP Demonstration Project – lab and field

PFAS Residual on AFFF Concentrate Pipe





Fluoro Fighter
Pioneered by Arcadis

Our procedure (non-destructive / in-situu)

- Preparation phase (workplan, H&S)
- Verify system settings with client
- First phase of removal of residual foam concentrate (already very effective)

Perfluorinated Compounds (TOPA)					
PFCs Total Oxidizable Precursors (TOP) (M4)	W-PFCLMS04	0.050	µg/L	180000	± 40.0%
Perfluorobutanoic acid (PFBA)	W-PFCLMS04	0.010	µg/L	48000	± 40.0%
Perfluoropentanoic acid (PFPeA)	W-PFCLMS04	0.010	µg/L	95500	± 40.0%
Perfluorohexanoic acid (PFHxA)	W-PFCLMS04	0.010	µg/L	26200	± 30.0%
Perfluoroheptanoic acid (PFHpA)	W-PFCLMS04	0.010	µg/L	8150	± 30.0%
Perfluorooctanoic acid (PFOA)	W-PFCLMS04	0.0050	µg/L	922	± 30.0%
Perfluorononanoic acid (PFNA)	W-PFCLMS04	0.010	µg/L	701	± 30.0%
Perfluorodecanoic acid (PFDA)	W-PFCLMS04	0.010	µg/L	253	± 40.0%

- Fixed number of cleaning phases using FluoroFighter™ by means of 24 hr circulation
- Complete draining of the spent FluoroFighter™
- Sample taking and PFAS analyses after each phase, final sample analyzed using TOP assay
- Check system settings and verify with the client
- Waste destruction under direct contract with incineration plant (no waste brokers)!

Performance Validation

Measuring Residual PFAS - Three Lines of Evidence

PFAS in Rinsates

- Baseline Rinse
- Post Application
- Final Rinse

PFAS on Surface

- Baseline Swabs
- Intermediate Swabs
- Final Swabs

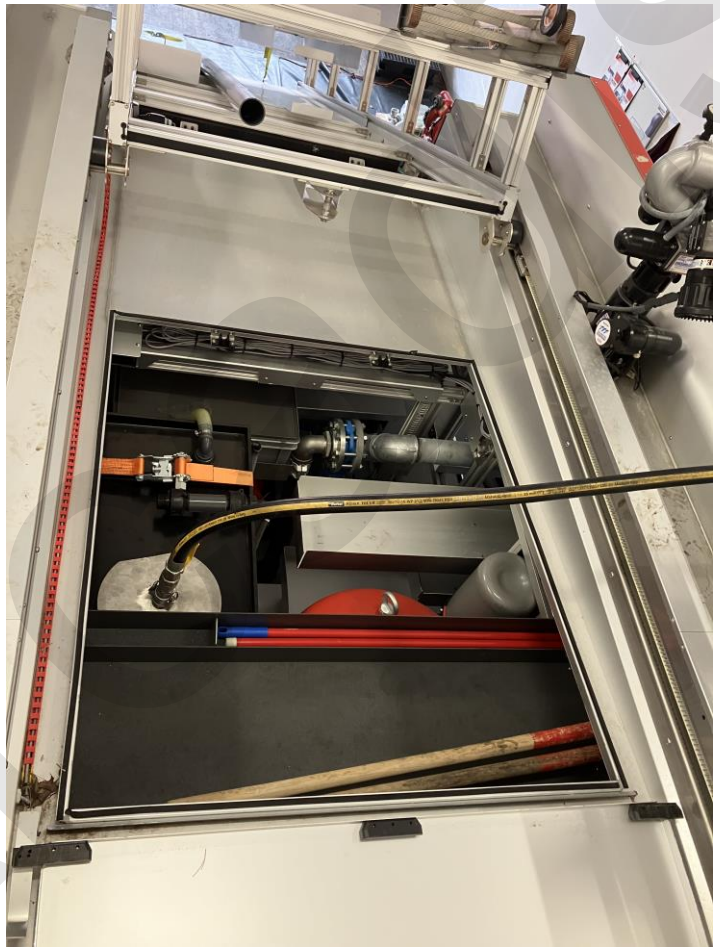
PFAS in F3 Post Transition

- 2 and 12 months after transition is complete

Our Dutch and Belgium portfolio incl. references

- Kenbri and Arcadis have an order portfolio of 255 fire systems to be cleaned
- So far 80 mobile and fixed fire systems in Belgium and the Netherlands have been cleaned successfully
- Larger fixed systems in coming up (> 800 m of piping). Tailor-made approach, learning by doing. Support from NAM team
- Clients from Oil and Gas sector and Safety Regions

Active clean-out at facility of Kenbri



Picture taken this Tuesday. Fire truck of pharmaceutical client

Adapt the clean-out process where needed

Example project BZA (Antwerp fire brigade, 3 trucks)

Truck	PFAS analyses in **final** flush with FluoroFighter™ (ug/L)		
	PFOS	**PFOA**	**6:2 FTS**
1-CYE-817	<0,1	<0,1	2,78
1-JHG-554	<0,1	<0,1	1,09
1-CYK-728	<10	<10	40,4

PFAS concentration in replaced F3 foam (6 months after cleaning&replacement)

PFAS analyses (PFOS, PFOA, 6:2 FTS)

Registration plate	PFOS conc. (µg/L)	Threshold PFOS (C8) (µg/L)	Verification	PFOA conc. (µg/L)	Threshold PFOA (C8) (µg/L)	Verification	6:2 FTS conc (µg/L)	Threshold 6:2 FTS (C6)
1-CYE-817	**<d.l.**	10.000	☑	**<d.l.**	25	☑	**< d.l.**	n.a.
1-JHG-554	**<d.l.**	10.000	☑	**<d.l.**	25	☑	**< d.l.**	n.a.
1-CYK-728	**<d.l.**	10.000	☑	**<d.l.**	25	☑	**< d.l.**	n.a.

Derivates analyses (Top Assay, 25 PFAS components)

Registration plate	PFOS derivates (µg/L)	Threshold PFOS (C8) (µg/L)	Verification	PFOA derivates (µg/L)	Threshold PFOA (C8) (µg/L)	Verification	PFPeA (C5) (µg/L)	Suggested threshold value 'PFAS in foam' (2026?)
1-CYE-817	**<d.l.**	10.000	☑	**<d.l.**	1000	☑	**46**	1000
1-JHG-554	**<d.l.**	10.000	☑	**<d.l.**	1000	☑	**35**	1000
1-CYK-728	**<d.l.**	10.000	☑	**<d.l.**	1000	☑	**50**	1000

What to expect from us in 2024?

What to expect (from us) in 2024

- Our 100th system will be cleaned
- Capacity increase in the EU
- Further development of our Thought Leadership (R&D, practically)
- National Dutch guideline for clean-out of systems to be finalized
- Use of innovative cleaning technologies, preferably via Ecosystem Partners
- Invest in and test innovative waste destruction technologies, for certain in SCWO in EU

Summary

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Chemosphere

September 2022

Characterization of Per- and Polyfluoroalkyl Substances on Fire Suppression System Piping

Johnsie R. Lang[a***], Jeffery McDonough[b], T.C. Guillette[c], Peter Storch[d], John Anderson[e], David Liles[f], Robert Prigge[g], Jonathan A. L. Miles[h], and Craig Divine[i]

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Groundwater Monitoring & Remediation | NGWA

30 April 2021

Groundwater Monitoring & Remediation — Advances in Remediation Solutions

Transitioning Per- and Polyfluoroalkyl Substance Containing Fire Fighting Foams to New Alternatives: Evolving Methods and Best Practices to Protect the Environment

by John Horst, Joseph Quinnan, Jeffrey McDonough, Johnsie Lang, Peter Storch, Jeffrey Burdick and Corey Theriault

https://doi.org/10.1111/gwmr.12444

1. Foam Transition – not simply "Foam Out/Foam In"
2. Multidisciplinary team & end user – foam specification & system modification
3. PFAS layers can re-contaminate replacement foam
4. Decontamination
   - Chemical agent - better efficiency at lower cost compared to hot water.
5. Cleanout end points – multiple lines of evidence to demonstrate compliance and best practice

HOME SERVICES NEWS CONTACT

PFAS Cleaning Treatment Solutions

PFAS CLEANING & TREATMENT SOLUTIONS

This is the information website of PFAS Cleaning & Treatment Solutions (PCTS). PCTS is a collaborative initiative with a focus on the treatment and cleaning of PFAS contamination in soil, water (groundwater, wastewater and surface water) and fire suppression infrastructure.

In addition to being the primary contact for PFAS treatment and cleaning related questions, PCTS aims to further collaborate, understand and advance PFAS remediation, treatment and cleaning techniques across Europe. This platform will allow all participating parties to build international networks and share knowledge and experiences focused around PFAS and PFAS-related issues.

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