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Observations on Some Emerging PFAS

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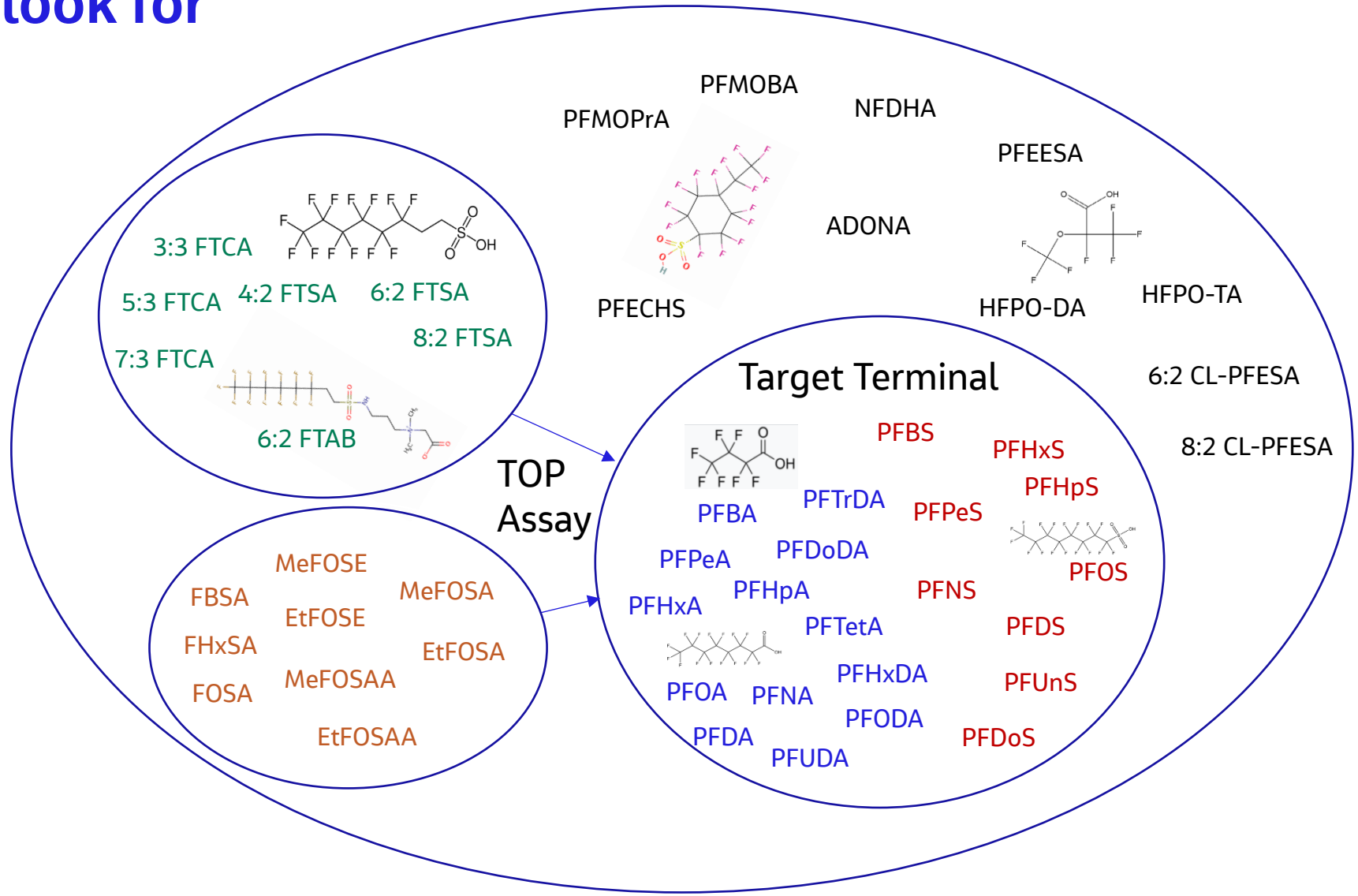
Introduction

- There are potentially millions of PFAS
- Current practice in contamination assessment is to focus on a target list of known PFAS – mainly PFOS, PFOA and longer and shorter homologues
- In England we are now monitoring for a target list of at least 48 PFAS
  - What can we learn from this extended suite monitoring ?
- TOP Assay uses precursor oxidation to assess potential for other precursor PFAS
  - But TOP Assay will only pick up precursors that degrade to those on the target list
  - What about environmentally stable PFAS that do not degrade to the target list ?
- Are there other prevalent PFAS out there which may become future risk drivers ?

Note: These are my personal observations – not a project outcome or company view

So what PFAS do we look for

- DWI list of 48 PFAS
- With TOP assay ome would transform to target terminal compounds
- What about the other PFAS?
- Should we be concerned about them ?
- Only some appear more often in UK monitoring



UK approach to PFAS

- Continually evolving !
- PFAS Plan published February 2026 – a roadmap laying foundations for action
- The Plan is to be scientifically robust and evidence based, delivering proportionate regulation
- So far a lot of evidence gathering, not so much formal action
- Slow progress with REACH restrictions
- Main action to date has been associated with drinking water

https://www.gov.uk/government/publications/pfas-plan/pfas-plan-building-a-safer-future-together

UK Drinking Water Inspectorate Approach to PFAS

- Statutory Guidance requiring testing of raw water for a minimum suite of 48 PFAS
- Thresholds apply to individual PFAS and to the sum of all detected
- Tiered thresholds requiring different levels of action, can be simplified as:
  - Tier 3 > 100 ng/L - unwholesome for water supply, requires immediate measures to reduce concentrations below Tier 2, with a longer-term strategy to reach Tier 1.
  - Tier 2 10-100 ng/L – requires enhanced monitoring, water companies must take action to reduce concentrations to Tier 1 levels
  - Tier 1 < 10ng/L – considered low risk, routine monitoring only
- Water company actions can include blending of sources, water treatment, and catchment management
- Also requirement for risk assessment and mitigation of high risk catchments
- UK water supply includes both groundwater and surface water

Sources of PFAS Monitoring Data in the UK

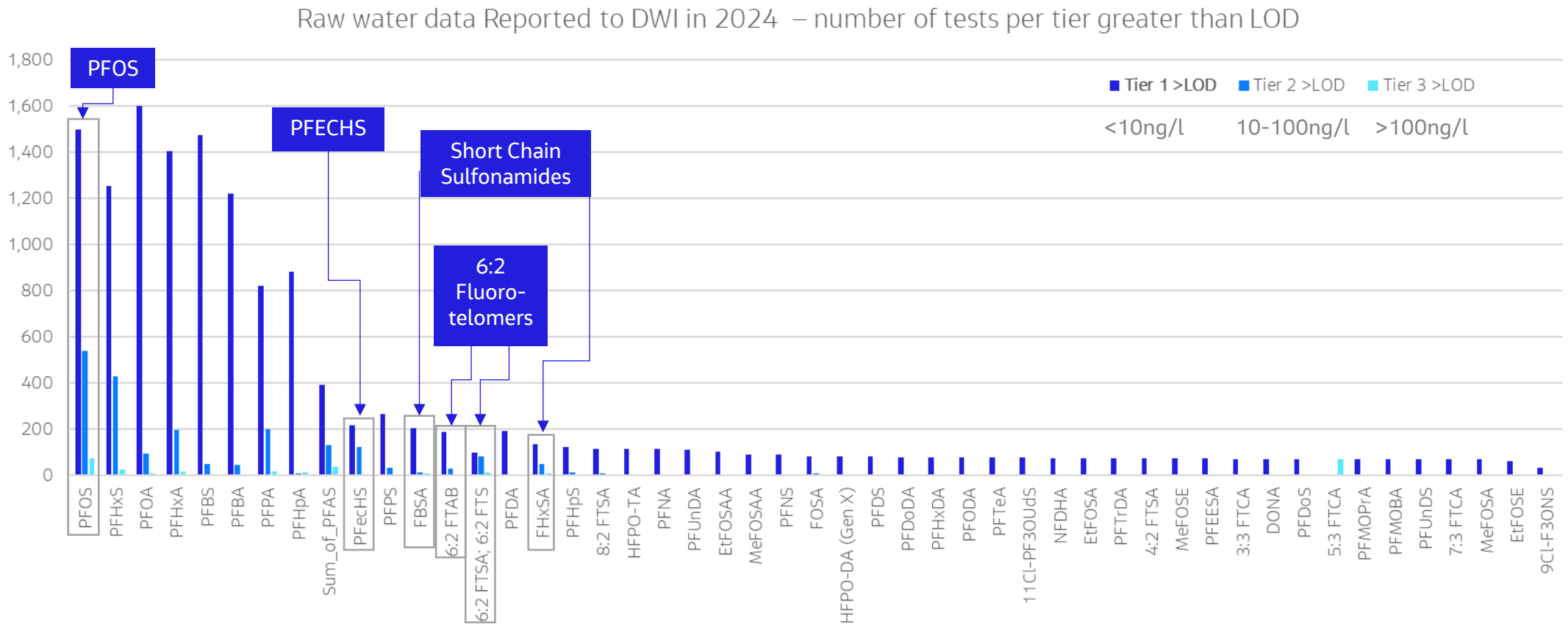
- Water Company monitoring
  - Raw water supply
  - Both surface water and groundwater
  - Not published in full but summarised in DWI annual reports

  https://www.dwi.gov.uk/what-we-do/annual-report/drinking-water-2024/drinking-water-2024-summary-of-the-chief-inspectors-report-for-drinking-water-in-england/perfluoroalkyl-and-polyfluoroalkyl-substances-pfas/
- Environment Agency 'Surveillance' Monitoring
  - Both surface water and groundwater
  - Mainly not targeted but includes some pollution investigation data
  - Publicly available – but the access portal has recently changed
  - Archive back to mid 2000s
  - Since 2023 includes extended suite analysis – 48 PFAS or more

  https://environment.data.gov.uk/water-quality

Water Company monitoring for Drinking Water Inspectorate

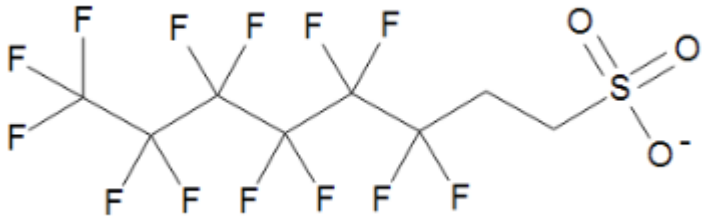
- In 2024 > 770,000 analyses for individual PFAS; 96% below LOD
- PFOS most frequently detected



PFAS of potential interest in UK Monitoring

- 6:2 Fluorotelomers, 6:2 FTS and 6:2 FTAB
- PFECHS - the cyclic C8 PFAS
- Short Chain sulfonamides - FBSA and FBHxA

6:2 fluorotelomer sulfonate (6:2 FTS)

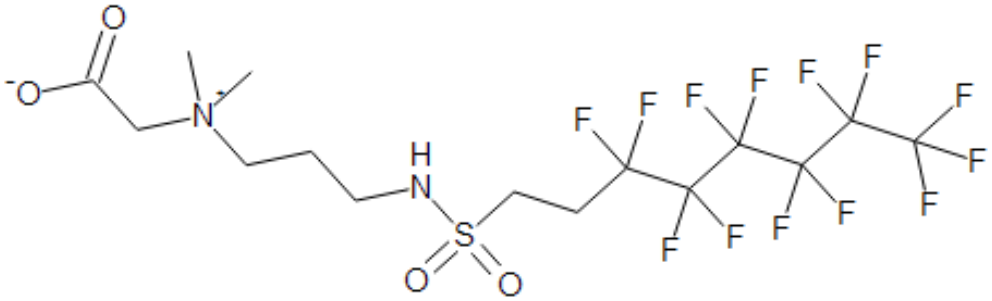


- Prevalence
  - One of the most frequently detected PFAS in groundwater in England
  - Often the most prevalent PFAS in the samples; up to 260 ng/l
  - Less frequently detected in surface water; up to 350 ng/l
- Sources
  - Widespread applications as replacement for C8 chemistry, not just fire-fighting foams
  - Likely intermediate transformation product for many other PFAS including side chain fluorinated polymers
  - Environmental prevalence demonstrates environmental stability
  - May transform to PFPeA, PFHxA, PFHpA
- Toxicity
  - Limited authoritative studies proposing Health Based Guidance Values, variable outcomes
  - RIVM suggest PFOA Relative Potency Factor of 1 based on PFHpA
- Already driving risk management actions
  - Triggering Tier 2 Exceedances in groundwater catchments in England and risk management actions

…. but otherwise not a focus for UK regulation (and not in EU EQS 25)

6:2 Fluorotelomer Sulfonamide Alkylbetaine (6:2 FTAB)

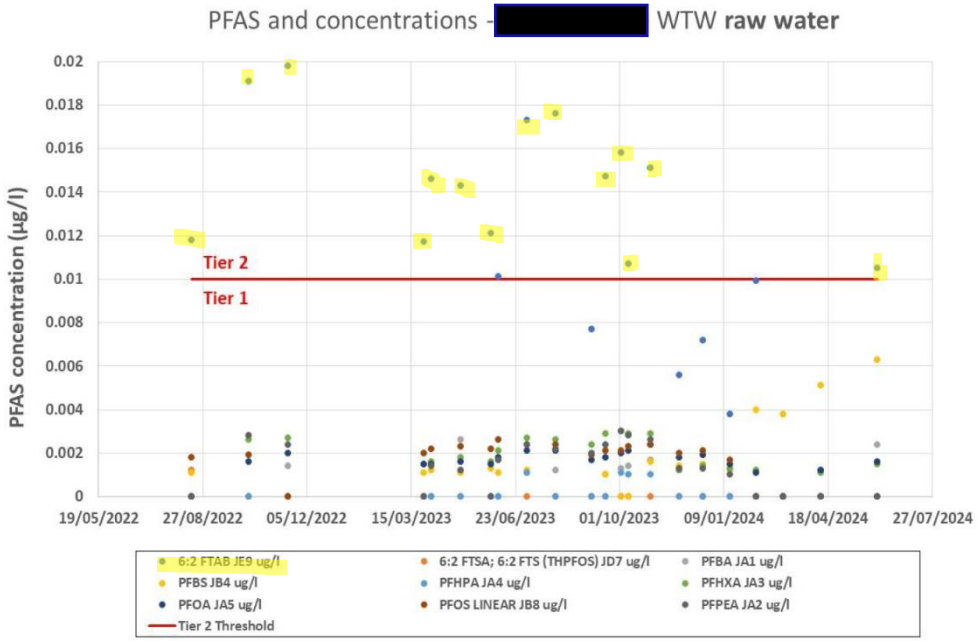
- 'The 48th PFAS' – added to DWI suite after found in surface water at Tier 2 by a water company

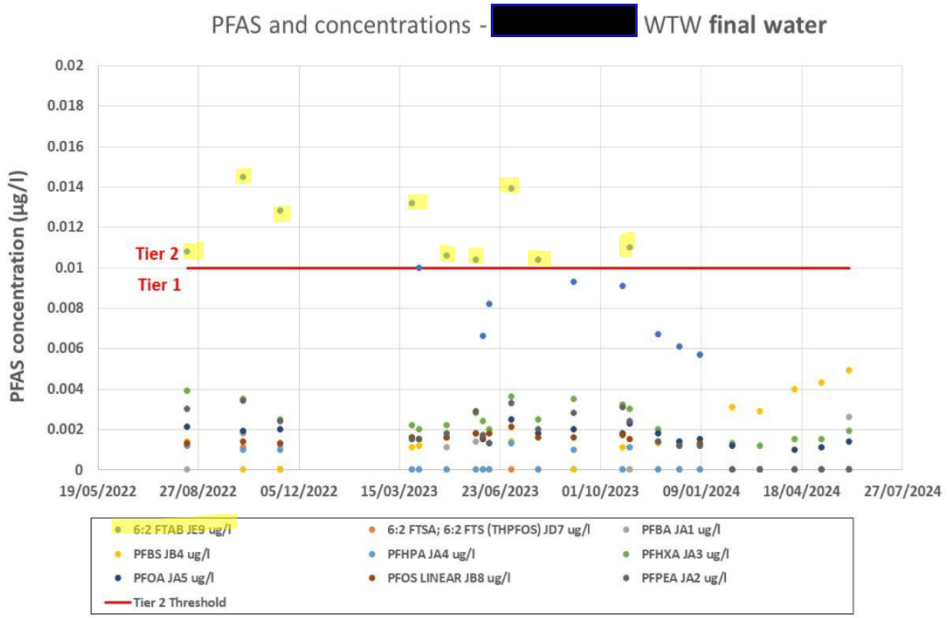


- Less current monitoring data available – but the data we have show, where found, it is frequently >> other PFAS in surface water
- Primary source is probably fire-fighting foams – appears to be major component in many modern 'C6' foams in recent and continuing use
- No relevant human health toxicity studies and only limited ecotoxicity studies
- A 'precursor' - likely to transform to 6:2 FTS and then to PFPeA, PFHxA and PFHpA
- Likely to be picked up in TOP Assay so present in 'PFAS Total'
- Data shows it can be persistent in the environment and through conventional water treatment

6:2 Fluorotelomer Sulfonamide Alkylbetaine (6:2 FTAB)

- UK experience is that 6:2 FTAB is currently driving the need for additional risk management activities in drinking water supply
- When included in monitoring, Triggers Tier 2 exceedances even when other PFAS are still Tier 1
  - 6:2 FTAB is driving risk management activities; we need a better understanding

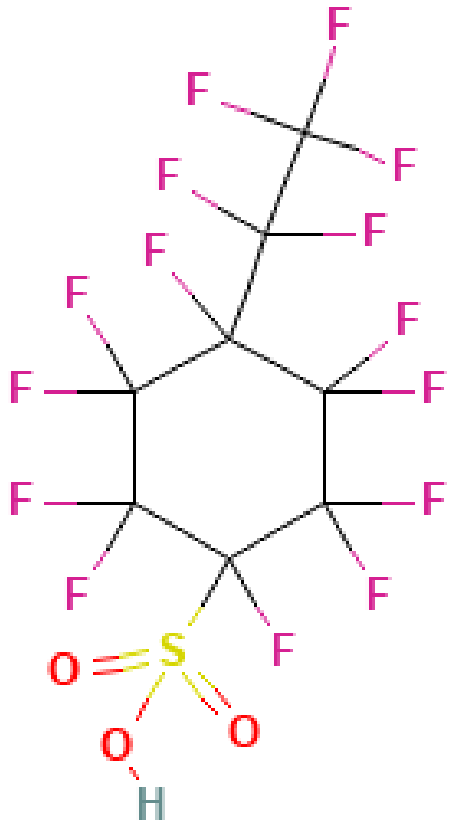




From https://www.stwater.co.uk/content/dam/stw/about_us/pr24-response/totex/sve4-28-pfas-updated-regulations-r.pdf

PFECHS - Perfluoro-4-ethylcyclohexane – “Peaches”

- A sulfonic acid with eight fully fluorinated carbon atoms
- Includes a cyclic structure; multiple potential isomers
- Cis- and trans- isomers most abundant, reported together
- Technically a ‘PFOS Related Compound’
- But doesn’t meet Stockholm Persistent Organic Pollutant (POP) definition as that is for “Perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride”
- Commercial use in aircraft hydraulic fluids since the 1940s
  - Used for erosion inhibition and flame resistance
  - Landing gear, flight control systems, actuators including in defence systems
- May also have been present as an impurity in POSF-based products such as fire fighting foams
- Possible use in printer inks but not confirmed



PFECHS Toxicity

- Limited research – no animal / human toxicity studies identified
- Significant structural similarity to PFOS
- PFECHS has been shown to accumulate in kidney, liver, bladder, blood, muscle, and plasma of fish, in bird eggs, and in human serum
- PFECHS has the potential to be as toxic as PFOS based on developmental toxicity
- New Approach Methods (NAMS) may be best way forward to evaluate its toxicity

Regulation

- Included in UK DWI guidelines as one of the DWI 48
- No known other current environmental standards / guidelines
- Not restricted under Stockholm Convention
- Included in EU Universal Restriction – but likely to have derogations as safety critical specialist uses

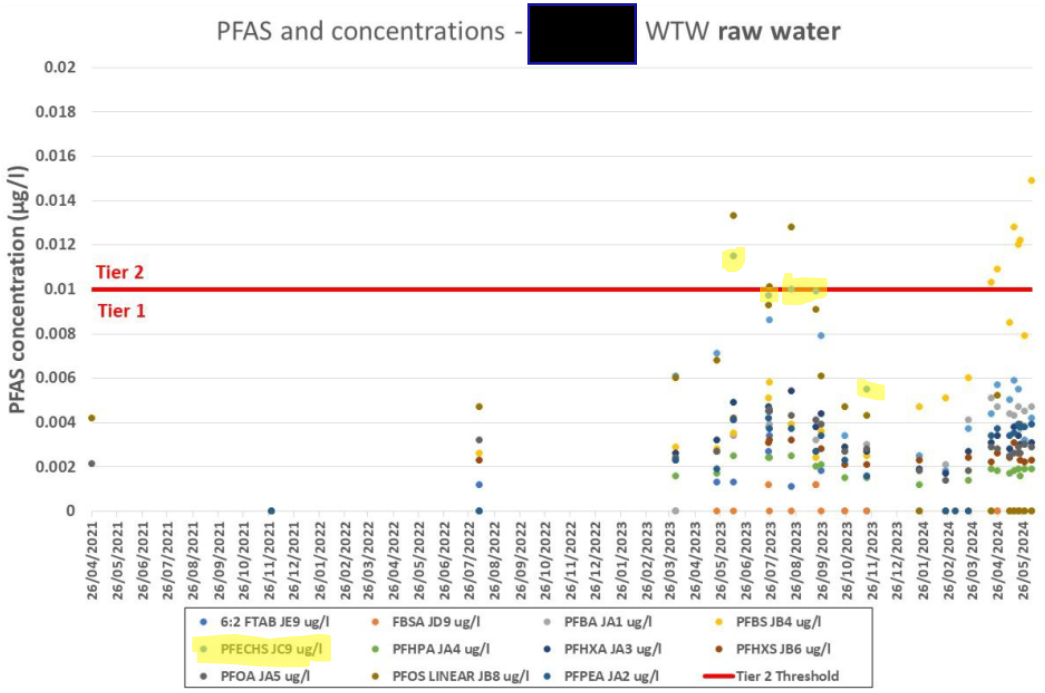
PFECHS Prevalence

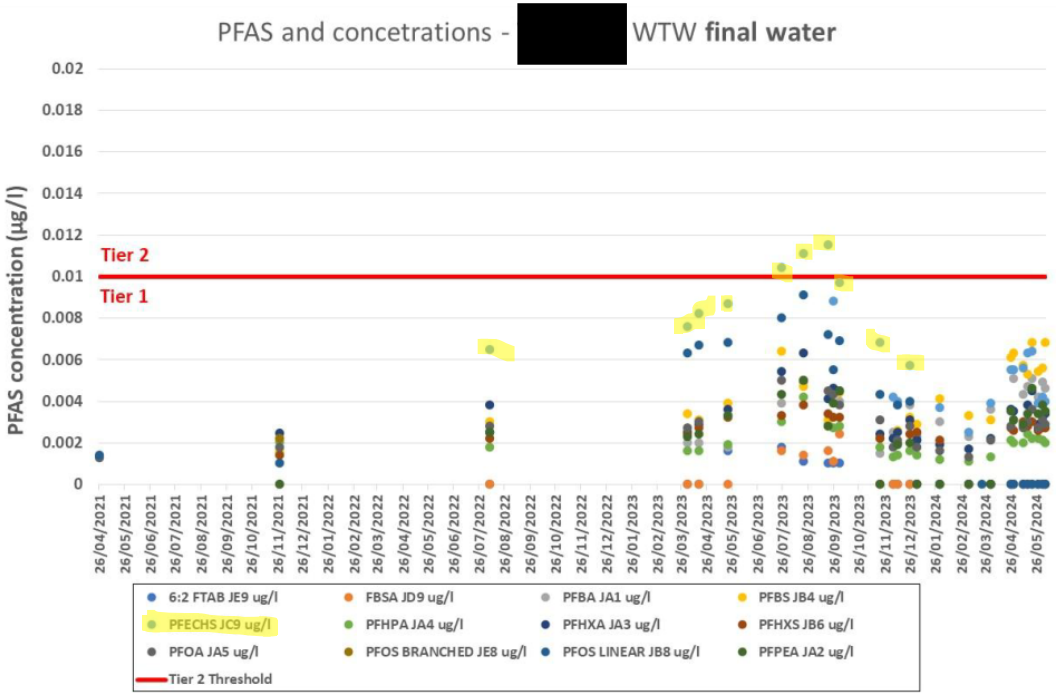
- The most frequently detected ‘novel’ PFAS in the DWI monitoring – at Tier 2 (>10 ng/l) as well as Tier 1
- In EA surveillance monitoring, present in 11% of surface water samples and 2% of groundwater samples
- Elsewhere in the world, widely detected in water, sediment and biota (where it has been looked for, mainly academic studies)
  - In the vicinity of airports, but also in the wider environment
  - Aviation hydraulic fluids commonly considered to be most likely source
  - Notable occurrences in Great Lakes and Baltic Sea* (but not North Sea)
  - In Baltic likely linked to long residence time / large catchment surface / shallow water / limited water exchange with the wider ocean
- Some examples from publicly available information

*Joerrs et al 2019 https://doi.org/10.1016/j.scitotenv.2019.05.363

Example 1: PFECHS in Surface Water abstracted for Drinking Water

- Drinking water source with mixed urban / rural catchment
- PFECHS has triggered Tier 2 exceedance – in both raw and treated water
- Driver for mitigation action – treatment and catchment studies

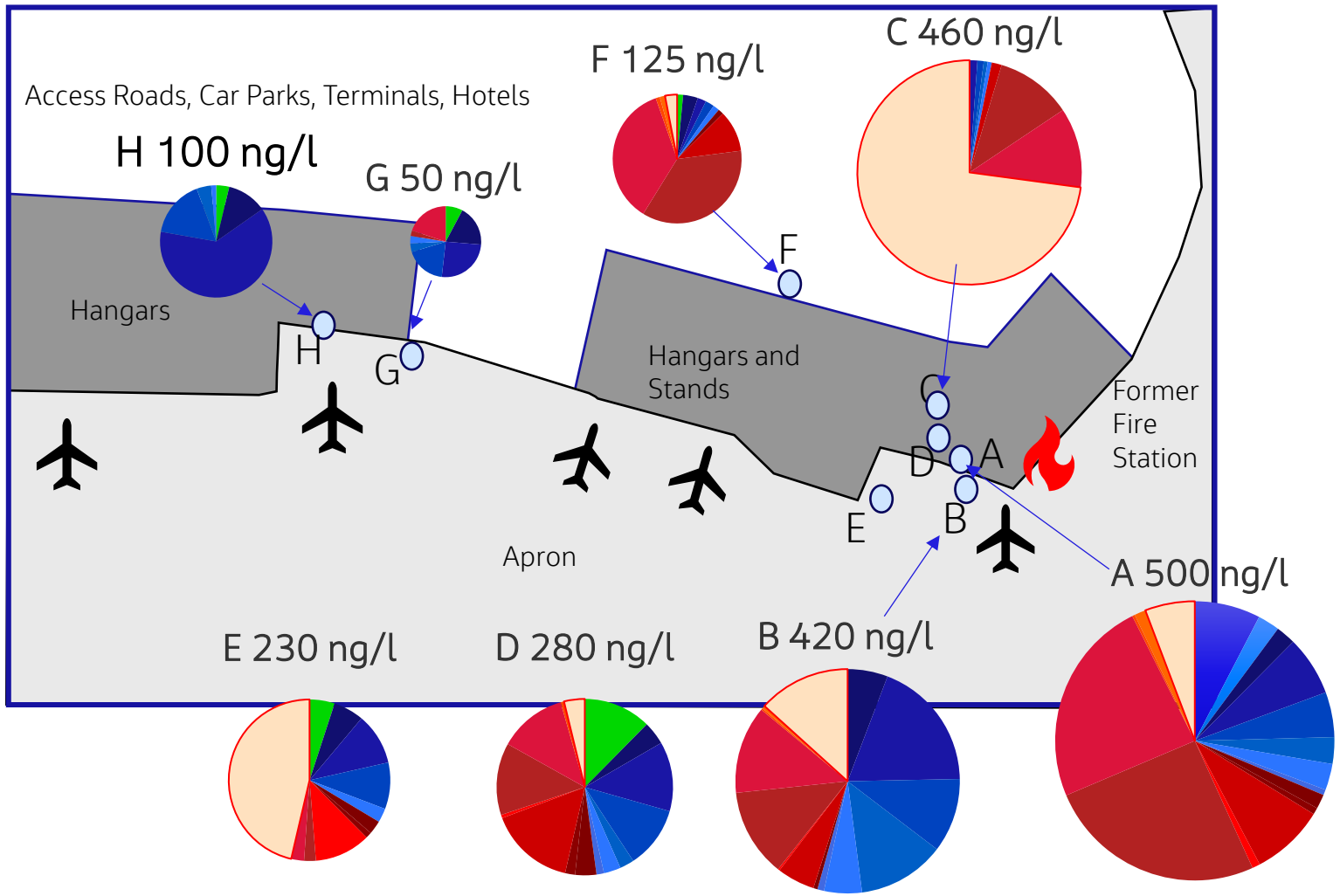




From https://www.stwater.co.uk/content/dam/stw/about_us/pr24-response/totex/sve4-28-pfas-updated-regulations-r.pdf

Example 2: Groundwater at an Airport – PFECHS in Groundwater

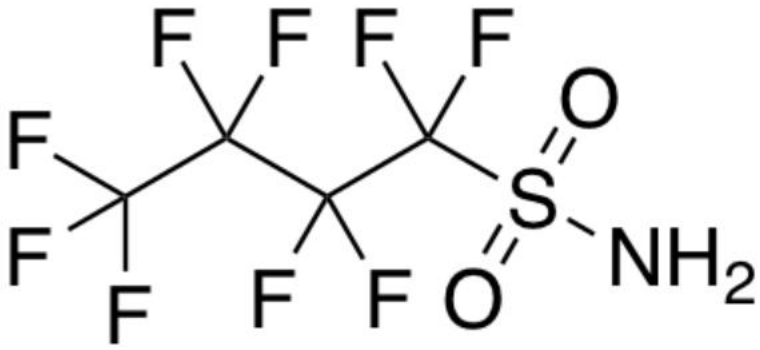
- PFECHS is locally present at very high concentrations in groundwater – not just a minor constituent
- More predominant in shallow installations
- Appears associated with stands and hangars
- Insufficient information to identify possible sources
- Also present in downstream surface water samples (up to 10% total PFAS)



Short chain sulfonamides – including FBSA

- FBSA - Perfluorobutane sulfonamide
- Short chain PFAS homologous to PFOSA
- Probably a precursor to PFBS
- Frequently appears in environmental monitoring
- In both groundwater and surface water
- Sources not well studied
- **Not** usually the most prevalent PFAS

  …. but does appear to be very bioaccumulative in fish

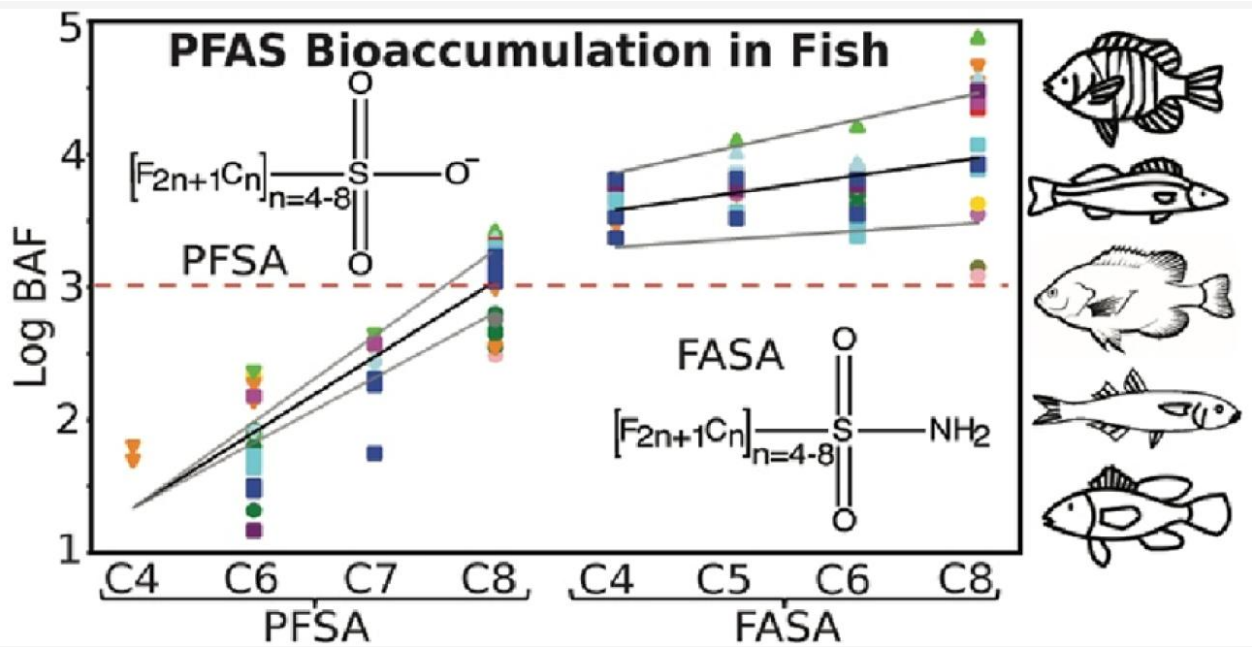


Sources of FBSA and other FASAs

- Sources are not well documented
- FHxSA frequently detected associated with fire fighting foams manufactured using electrochemical fluorination (ECF)
- Likely widely used as a short chain alternative to PFOS
  - FBSA transformation product of 3M Scotchgard post 2002 – Chu and Letcher 2014
  - FBSA in 3M patent for acid etch solution
- FBSA found in effluents from semiconductor industry – Chen et al 2024
- Likely in many other specialist surfactant applications
- Likely used in side-chain fluorinated polymers
- Likely in wastewater effluent
- 3M has admitted releases of FBSA to the Tennessee River from production plant

FBSA – Tendency of Perfluoroalkyl Sulfonamides to Bioaccumulate

- FASA are 1 – 3 orders of magnitude more bioaccumulative than related PFSAs
- Note that the short chain reduction in BAF is much less than for PFSAs



- Zebrafish studies comparing C4 PFAS with different functional heads
  - FBSA induced abnormal morphology
  - Measured tissue concentrations FBSA> PFBS> 4:2 FTS> PFPeA
- Functional head groups impact bioactivity and bioconcentration

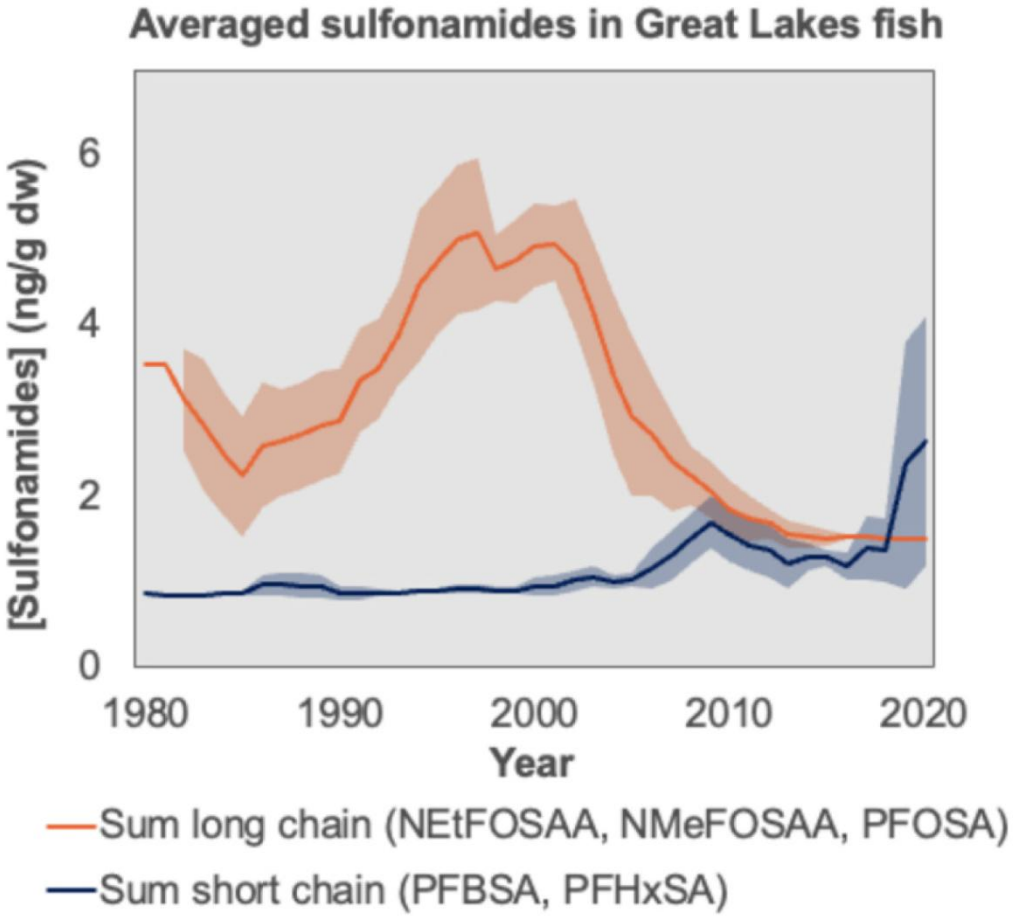
Pickard et al., 2024
https://pubs.acs.org/doi/abs/10.1021/acs.estlett.4c00143

Rericha et al., 2022
https://www.sciencedirect.com/science/article/pii/S2589004222000591

Perfluoroalkyl Sulfonamides in Predator Fish in the Great Lakes

- Study used archive fish samples to quantify PFAS bioaccumulation from 1975 – 2020
- Total bioaccumulative PFAS peaked in 2008 and now decreasing
- FBSA the only short chain PFAS detected in the fish
- FBSA only seen after phaseout of long chain PFAS
- FBSA shows a continuing increasing trend not seen in other PFAS
- Will this be an increasing issue elsewhere ?

Balgooyen et al. 2026
https://www.sciencedirect.com/science/article/pii/S0380133026000018



n.b. Non-detects are replaced by the detection limit to provide a baseline for detection.

Concluding Remarks

- The ‘novel’ PFAS we find have different implications
  - 6:2 FTAB
    - Associated with FFF – ongoing use should cease with REACH restrictions
    - Increases ‘sum of PFAS’, or ‘PFAS total’ via TOP Assay
    - Can drive risk management actions
  - PFECHS
    - Unlikely to be picked up without targeted analysis - if you are not currently testing for it, you won’t know it’s there.
    - Expected continuing use in specialist hydraulic fluids – dispersive uses
    - Could be as toxic as PFOS
    - Will it be a risk management driver of the future ?
  - Short chain sulfonamides
    - May be greater concern than other short chain PFAS
    - Due to bioaccumulation, prevalence

Thank you for listening

Tak fordi du lyttede

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Important