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What’s wrong with persistence -don’t we want to build things to last?

Ian Ross Ph.D.
Global PFAS Practice Lead
Tetra Tech

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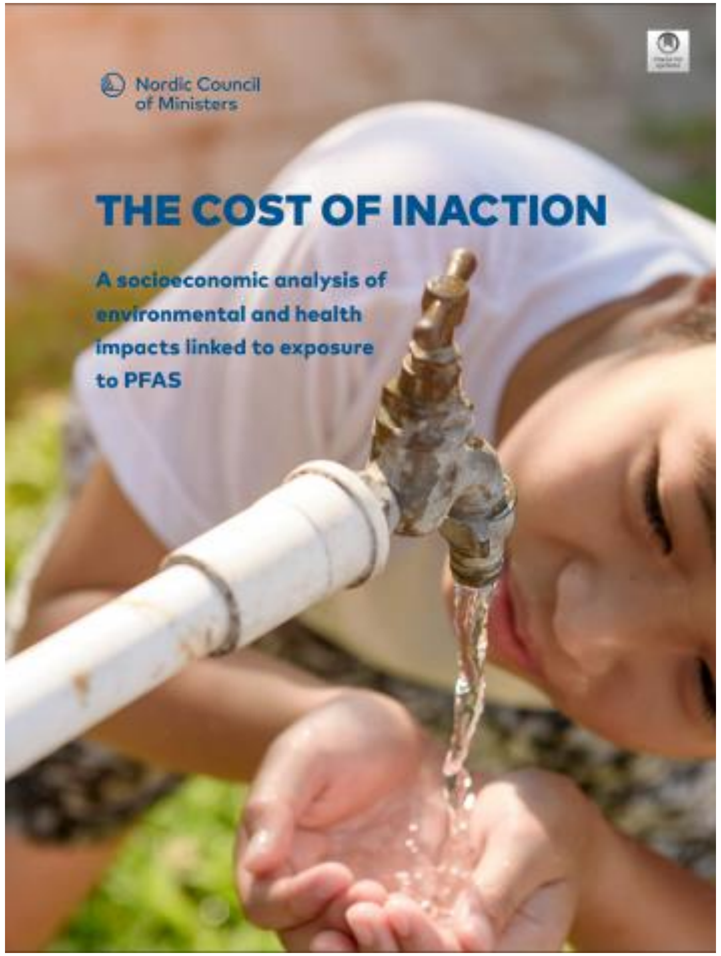
Leading with Science®

The main challenges for PFAS – their management and regulation – within the UK context.

- What are PFAS
- How to measure PFAS
- Replacement of one PFAS with another
- Regulatory frameworks
- PFAS point sources
- UK waters
- PFAS destruction
- Green Chemistry Solutions
- Summary



Poly- and Perfluoroalkyl Substances (PFASs)

(~4,730 manufactured compounds)

More Commonly Regulated

Polyfluorinated "Precursors" -Proprietary PFASs

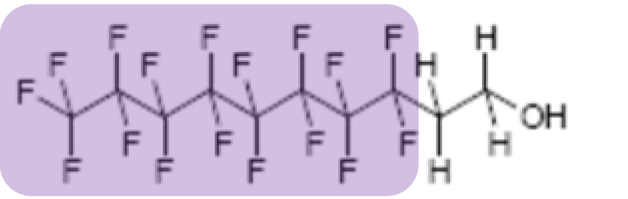
Thousands of individual parent compounds, sharing common daughters e.g. 6:2 FTS, 5:3 acid

Perfluorinated Compounds(PFCs) or Perfluoroalkyl Acids (PFAAs)

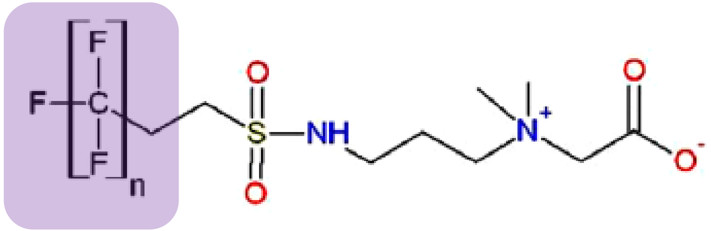
~25 common individual compounds, terminal daughters i.e. "forever chemicals"
e.g. PFOS, PFOA, PFHxS, PFBA, PFHxA

Environmental / Higher Organism Biotransformation

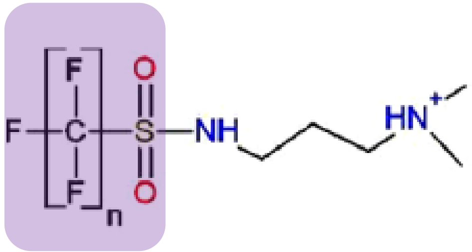
Perfluoroalkyl group –confers extreme persistence



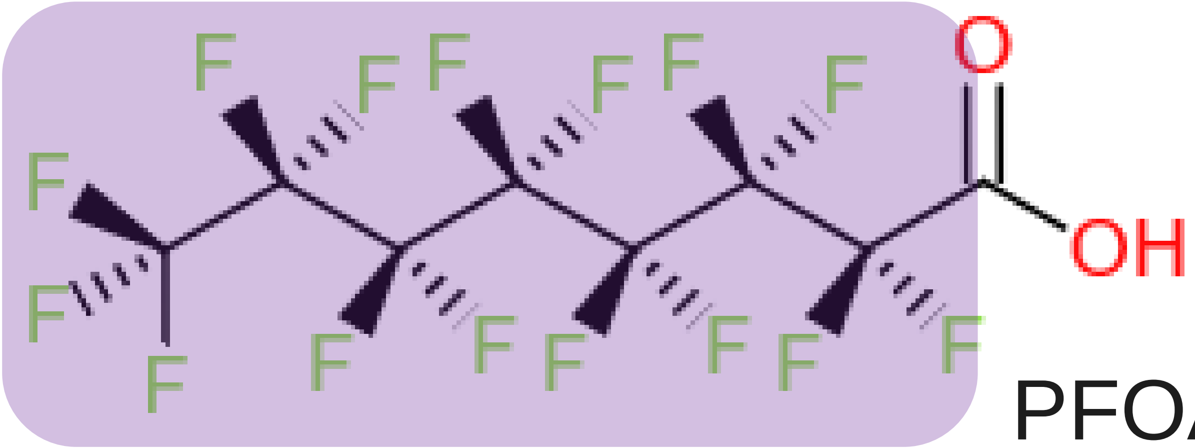
Fluorotelomer alcohol, 8:2 FTOH



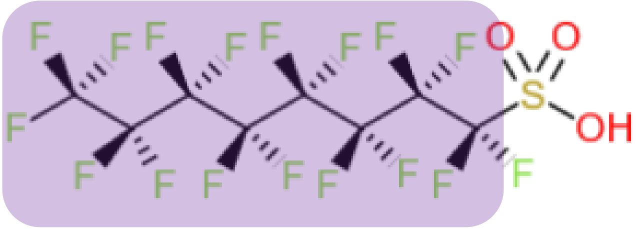
Fluorotelomer Sulfonamido Betaines



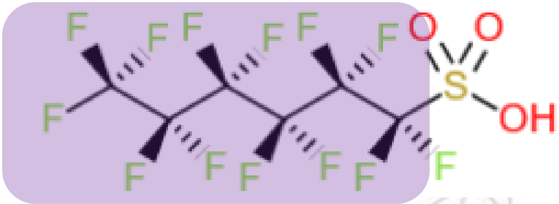
Perfluoroalkyl Sulfonamido Amines



PFOA

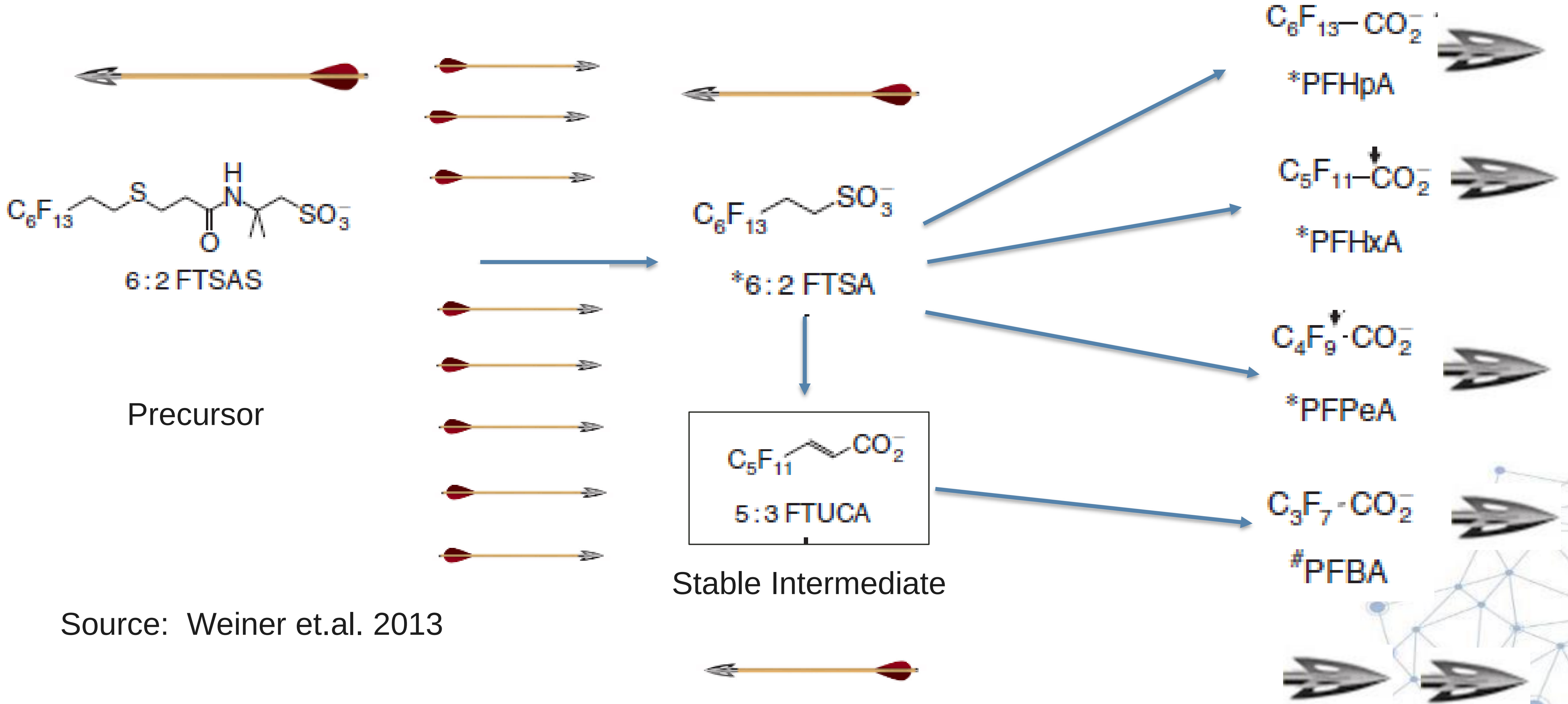


PFOS



PFHxS

Fluorotelomer Foam



Source: Weiner et.al. 2013

Breakdown products of the C6 FT Foam: short-chain PFCAs

PFASs in Landfill Leachate

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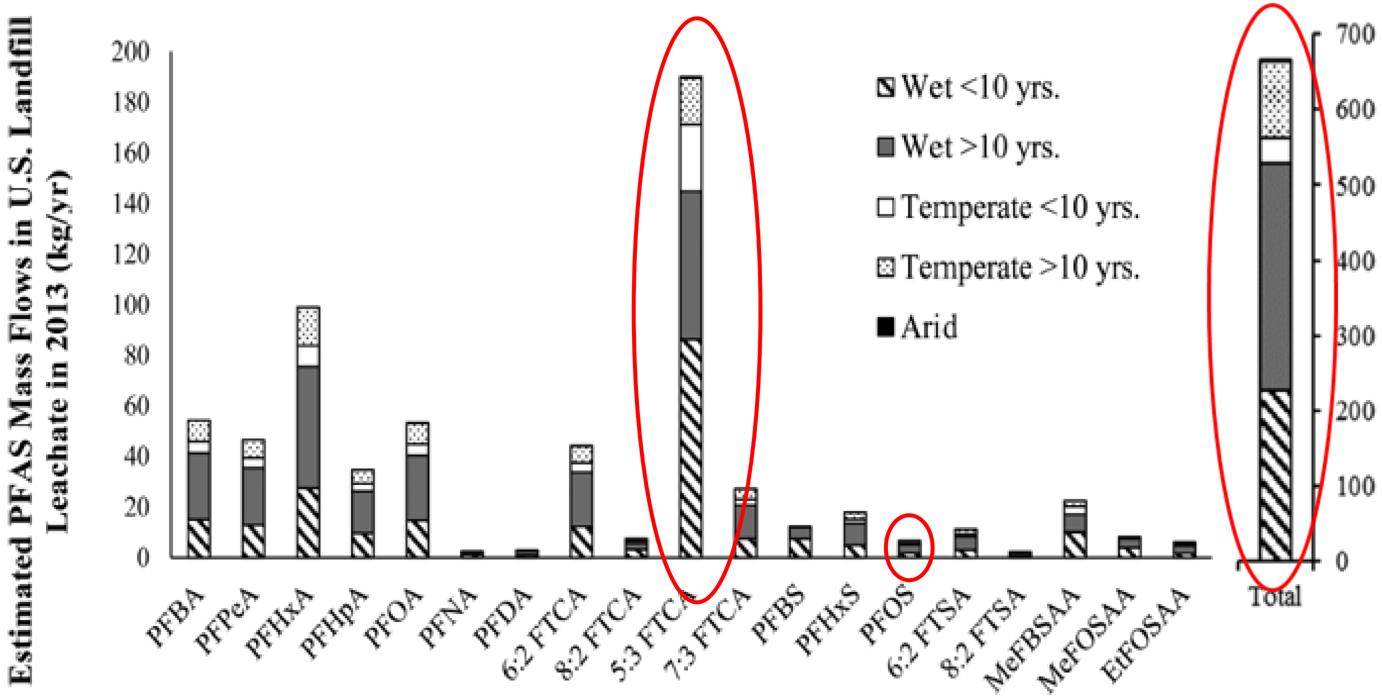
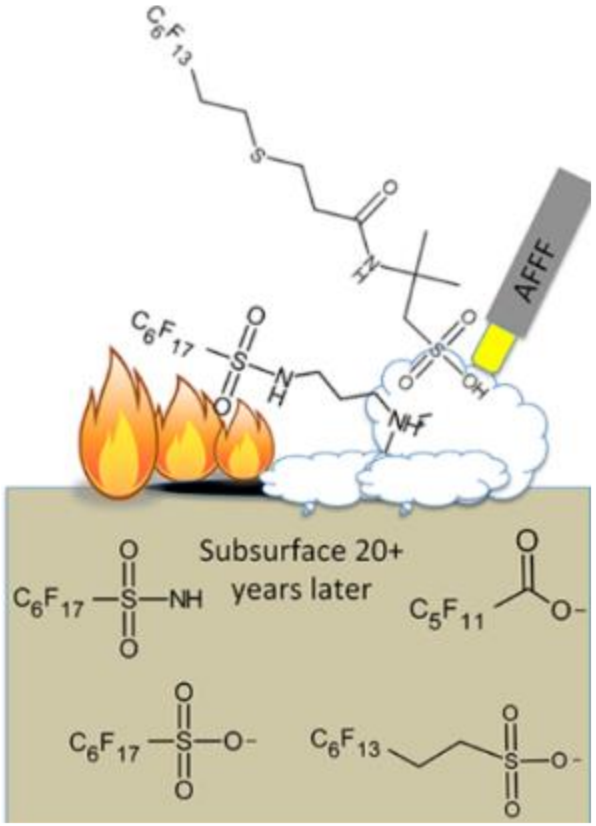
The elephant in the room: potential biopersistence of short-chain PFAS



Environ. Sci. Technol., 2017, 51 (4), pp 2197–2205

Digest AFFF precursors and measure the hidden mass: TOP Assay

- Microbes slowly make simpler PFAA's (e.g. PFOS / PFOA) from PFAS (PFAA precursors) over 20+ years
- Need to determine precursor concentrations as they will form PFAAs
- Too many PFAS compounds and precursors –so very expensive analysis
- Oxidative digest **stoichiometrically** converts PFAA precursors to PFAA's
- TOP assay indirectly measures total precursors as a result of increased PFAAs formed after oxidation vs before.

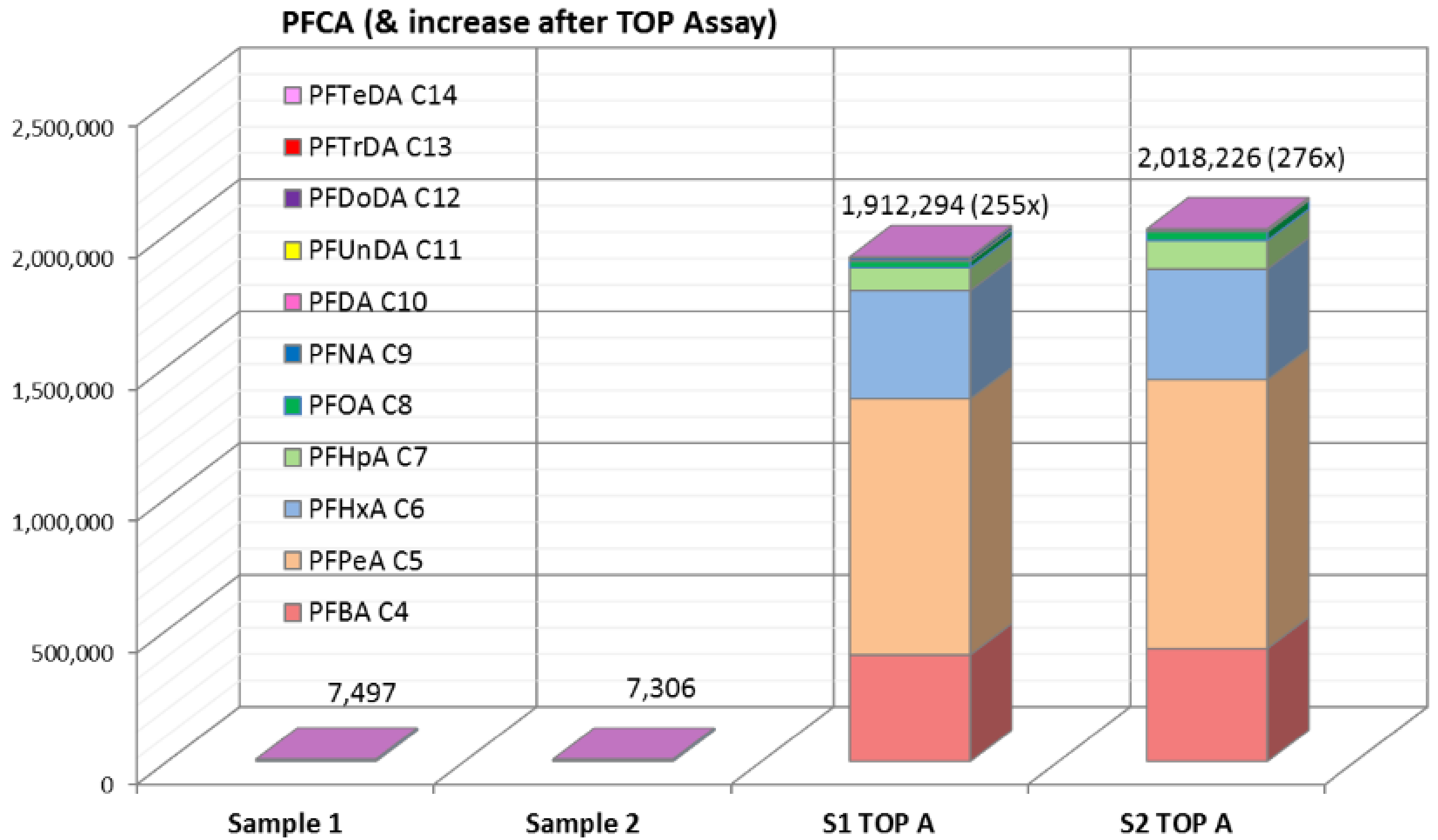


Persistence of Perfluoroalkyl Acid Precursors in AFFF-Impacted Groundwater and Soil

Erika F. Houtz,[†] Christopher P. Higgins,[‡] Jennifer A. Field,[§] and David L. Sedlak[†,*]

Analytical tools fail to measure the hidden PFAS precursor mass, the TOP assay solves this

TOP Assay Applied to Surface Water from Recent C6 Fluorotelomer Foam Loss



Data Courtesy of Nigel Holmes Queensland DEHP

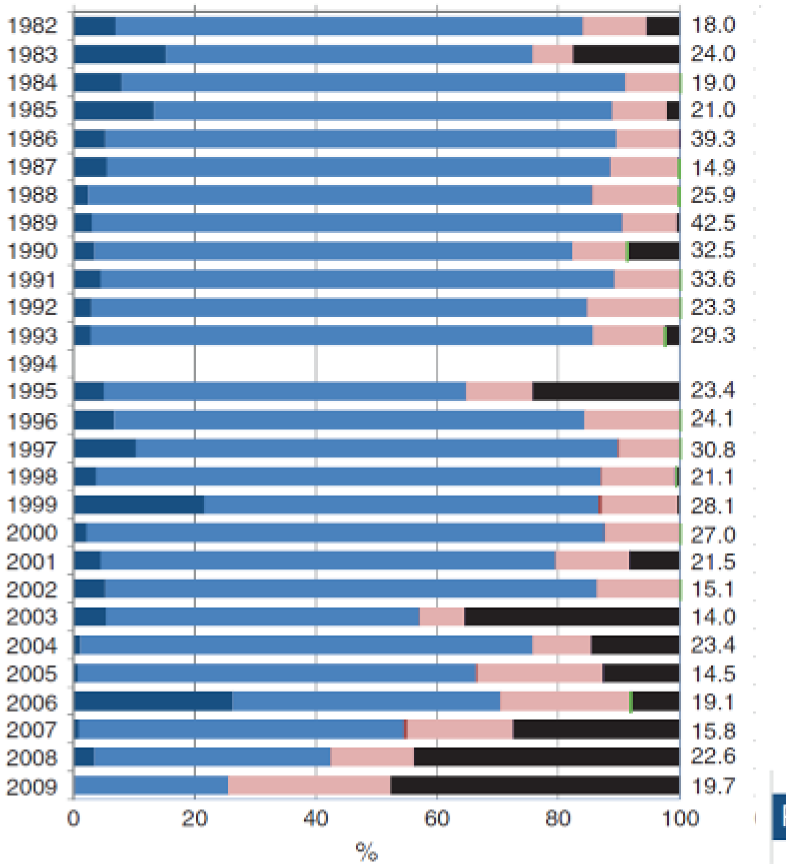
Chemical “Whack a Mole”

CSIRO PUBLISHING

Environ. Chem. 2016, 13, 102–110

Are humans exposed to increasing amounts of unidentified organofluorine?

Leo W. Y. Yeung[A] *and Scott A. Mabury*[A,B]



Science News *from research organizations*

Novel PFAS comprise 24% of those measured in blood of Wilmington, N.C. residents

Date: July 22, 2020

Source: North Carolina State University

Summary: Researchers detected novel per- and polyfluoroalkyl substances (PFAS) called "fluoroethers" in blood from residents of Wilmington, North Carolina. The fluoroethers represented 24% of the total PFAS detected in the blood of Wilmington residents and appear to leave the body faster than legacy PFAS.

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FULL STORY

In a new paper detailing findings from North Carolina State University's GenX Exposure Study, researchers detected novel per- and polyfluoroalkyl substances (PFAS) called "fluoroethers" in blood from residents of Wilmington, North Carolina. The fluoroethers -- Nafion byproduct 2, PFO4DA and PFO5DoA -- represented 24% of the total PFAS detected in the blood of Wilmington residents and appear to leave the body faster than legacy PFAS. These are the first measurements of these chemicals in humans.

Exposure from one PFAS replaced by another

Next Generation PFASs

United States Environmental Protection Agency

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Science Inventory

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Assessing Generated In Vitro Toxicokinetic Data of Per- and Polyfluoroalkyl Substances (PFAS) with In Vitro-In Vivo Extrapolation (IVIVE)

Citation:

Smeltz, M., D. Crizer, Larry - RTP McMillan, G. Patlewicz, M. Devito, AND B. Wetmore. Assessing Generated In Vitro Toxicokinetic Data of Per- and Polyfluoroalkyl Substances (PFAS) with In Vitro-In Vivo Extrapolation (IVIVE). North Carolina Society of Toxicology Annual Fall Meeting, RTP, NC, September 21 - 23, 2020. https://doi.org/10.23645/epacomptox.13203011

Contact

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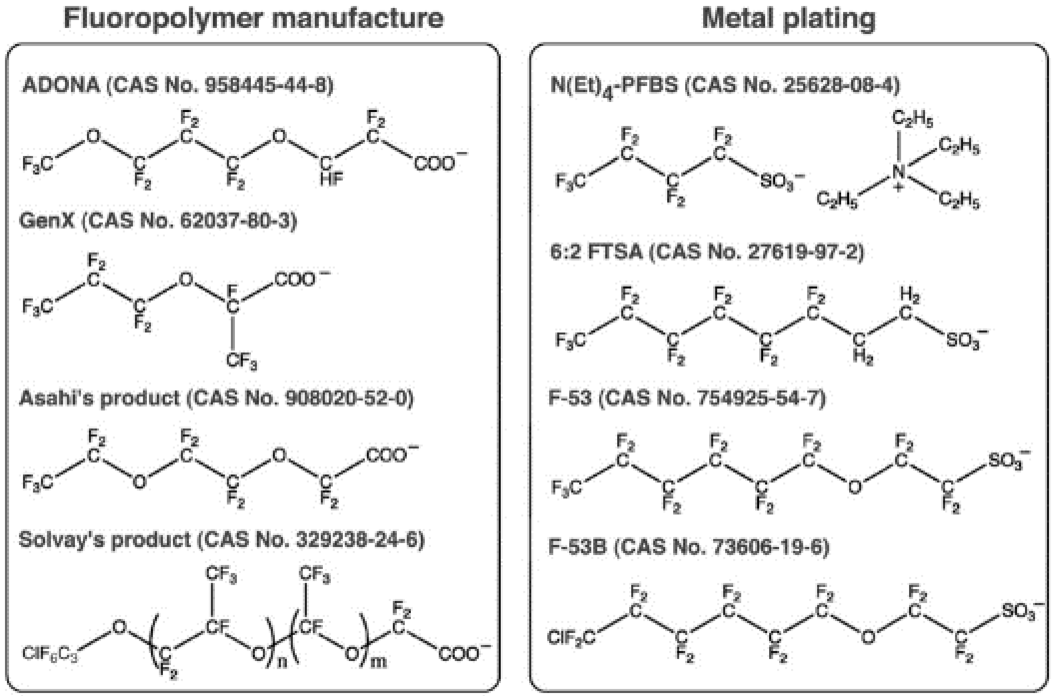
Impact/Purpose:

This presentation will be given at the annual Fall meeting for the North Carolina chapter of the Society of Toxicology and is focused on utilizing in vitro toxicokinetic assays with PFAS. This meeting is being held virtually over three separate days in September 2020. Plasma protein binding for more than 50 PFAS was determined by ultracentrifugation. Hepatic clearance data from collaborators at NTP was also included to then perform IVIVE to predict systemic concentrations. Future work will examine toxicokinetic differences based on functional group and may help inform risk-based chemical safety assessment.

Fluorinated alternatives to long-chain perfluoroalkyl carboxylic acids (PFCAs), perfluoroalkane sulfonic acids (PFSAs) and their potential precursors

Zhanyun Wang [a], Ian T. Cousins [b], Martin Scheringer [a,*], Konrad Hungerbühler [a]

[a] Institute for Chemical and Bioengineering, ETH Zurich, Wolfgang-Pauli-Strasse 10, CH-8093 Zurich, Switzerland
[b] Department of Applied Environmental Science (ITM), Stockholm University, SE-10691 Stockholm, Sweden



PBT Applicability?

- For drinking water quality, PBT-based regulations are only marginally effective
- PBT aimed to protect food chain, not drinking water?
- In contrast, persistent and mobile organic compounds (PMOCs) are more of a concern for water quality because, like PCBs, they can persist in the environment, but they are not removed from water by sorption processes due to their high polarity and thus excellent water solubility
- Therefore, they may end up in drinking water, posing a potential risk to human health
- Umweltbundesamt (UBA) suggesting alternative assessment frameworks:
  - PMT **P**ersistent **M**obile **T**oxic
  - vPvM very **P**ersistent and very **M**obile as potential Substances of Very High Concern


Environmental Science & Technology

Mind the Gap: Persistent and Mobile Organic Compounds—Water Contaminants That Slip Through

Thorsten Reemtsma, Urs Berger, Hans Peter H. Arp, Hervé Gallard, Thomas P. Knepper, Michael Neumann, José Benito Quintana, and Pim de Voogt

German environment agency updates criteria for 'mobile' chemicals in water

Now includes vPvM category

19 October 2017 / Ecotoxicology, Europe, PBT/vPvB

Germany's federal environment agency (UBA) has updated its proposal for implementing criteria to identify persistent, mobile and toxic (PMT) substances, following comments from EU member states and industry. The revised document now includes a very persistent, very mobile (vPvM) category.

The agency first published its proposal to introduce a PMT classification for substances in drinking and ground water in May. The aim is for such compounds to qualify for inclusion on the REACH candidate list. The agency also hopes that chemical manufacturers and downstream users will adopt its proposed criteria and assessment procedure, to identify PM/PMT substances during product development.

Short chain replacement PFAS more mobile so more potential to impact drinking water

Concerns over short chain PFAS - Overview

Persistent

- Based on read-across from long chain PFAS
- Long-range transport and findings in remote areas

Mobility and Exposure of Organisms

- Potential to contaminate drinking water resources
- Difficult to be removed from water
- Binding to proteins
- Non-negligible half-lives in organisms
- Enrichment in plants

Toxic

- No indications of ecotoxicity
- Toxicity in humans to be assessed
- Potential endocrine disruptor

https://www.umweltbundesamt.de/sites/default/files/medien/421/dokumente/01_uba_eisentrager_pmt.pdf

Regulation of PFHxA

- EU proposal to limit the use of PFHxA related substances (precursors) – December 2019;
- Rationale:
  - *“Fulfils the P-criterion and vP-criterion”*
  - “*Mobility and long range transport potential*” and “*unpredictable and irreversible adverse effects on the environment or human health over time*”
- Exemptions (5 years) are in place for certain uses:
  - Hard chrome plating;
  - Photographic coatings;
  - Firefighting foams – **Emergency use only**
  - There is **no exemption** for testing (unless all releases contained) or training with fire fighting foams.


ANNEX XV RESTRICTION REPORT

PROPOSAL FOR A RESTRICTION

ECHA
EUROPEAN CHEMICALS AGENCY

SUBSTANCE NAMES:
Undecafluorohexanoic acid (PFHxA), its salts and related substances

- Exemptions (12 year) are in place for Class B firefighting foams used to protect storage tanks with a surface area **above** 500m^2
- Military users exempted – Requirement that during training foam contained and disposed of safely
- The EU considers the restriction practical as it is affordable, implementable, and manageable

Potential Locations of PFAS Point Source Contamination

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- Primary Manufacturing (e.g. for PTFE)
- Product manufacturing: carpets, paints, paper coating, leather tanneries, metal plating, textiles
- Fire Training Sites: Airports, Civil, Defence, Petrochemical, Rail Yards
- Sites of hydrocarbon fires, since late 1960's e.g. Buncefield
- Car wash/wax, dry cleaners, ash pits
- Sprinkler systems -warehouses, aircraft hangars, car workshops, pharmaceutical plants
- Wastewater treatment plants – biosolid waste
- Landfills

Soils / Concrete are Long Lasting Sources of PFASs

- The unsaturated zones continue to be a source of PFASs to the groundwater after **18 years** (FTA-1) and **20 years** (infiltration beds) of inactivity.
- Some precursors are mobile at this field site
- Results indicate that shorter chain length PFAAs are more mobile than PFOS both vertically and horizontally.
- Significant long PFOS retained at the surface (top 0.5 cm) of 12 cm concrete core
- Long term leaching of PFOS from concrete surfaces is an ongoing issue with potential for impacted run off and surface water impacts for >80 years


Journal of Hazardous Materials

Perfluoroalkyl substances in a firefighting training ground (FTG), distribution and potential future release

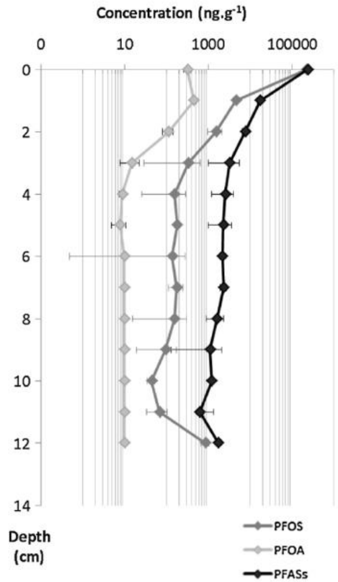
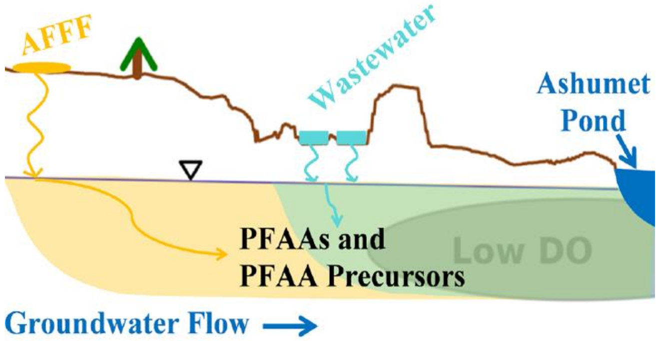


Fig. 3. Vertical profile contamination (ng g^{-1}) of PFOS, PFOA and $\sum$PFASs in the concrete at site #14 close to the out flow pipe. The concentration is an average of the two core profiles and the error bars represent the standard variation between these two values. More compounds are presented in Supplementary material S3(b).

Geochemical and Hydrologic Factors Controlling Subsurface Transport of Poly- and Perfluoroalkyl Substances, Cape Cod, Massachusetts

Andrea K. Weber, Larry B. Barber, Denis R. LeBlanc, Elsie M. Sunderland, and Chad D. Vecitis



Worldwide Distribution of Novel Perfluoroether Carboxylic and Sulfonic Acids in Surface Water

Yitao Pan,[†,‡,⊥] Hongxia Zhang,[†,⊥] Qianqian Cui,[†] Nan Sheng,[†] Leo W. Y. Yeung,[§] Yan Sun,[‖] Yong Guo,[‖] and Jiayin Dai[*,†]

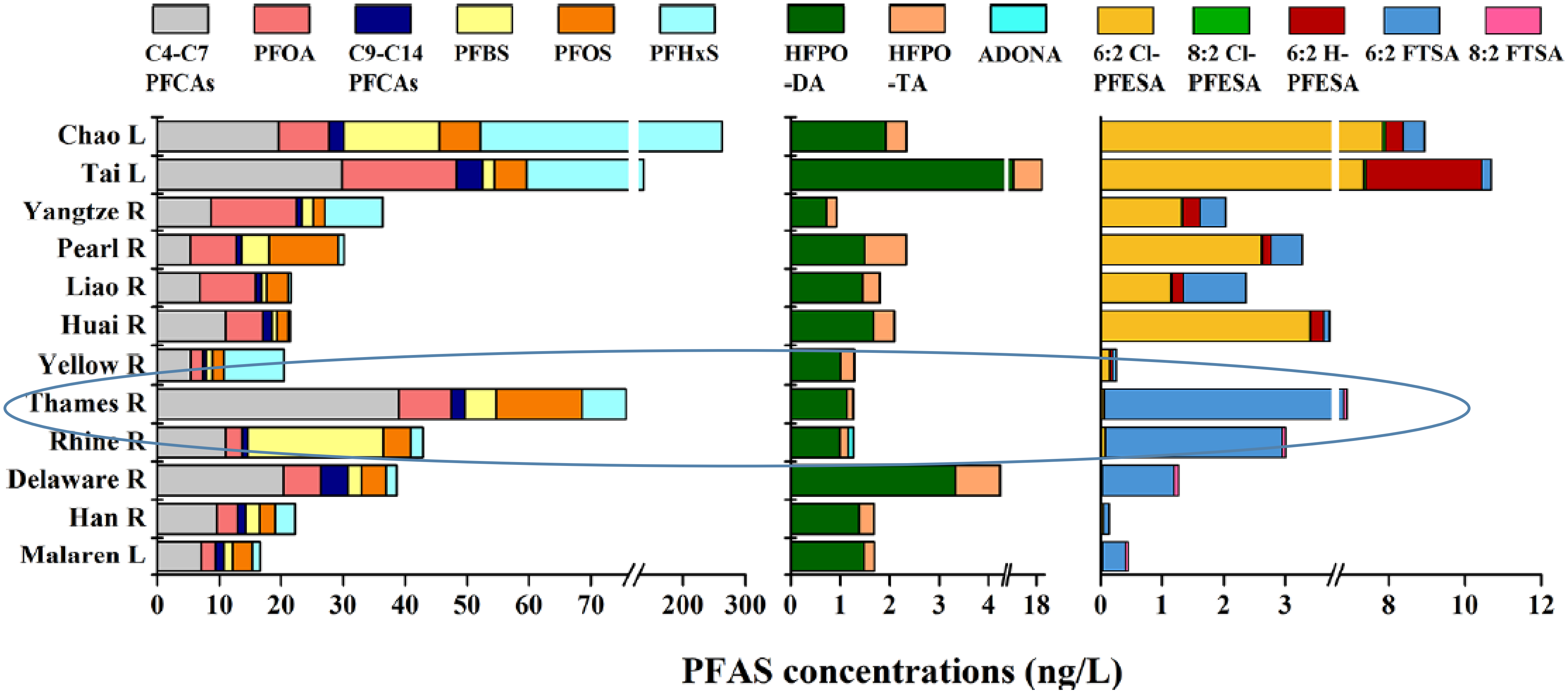
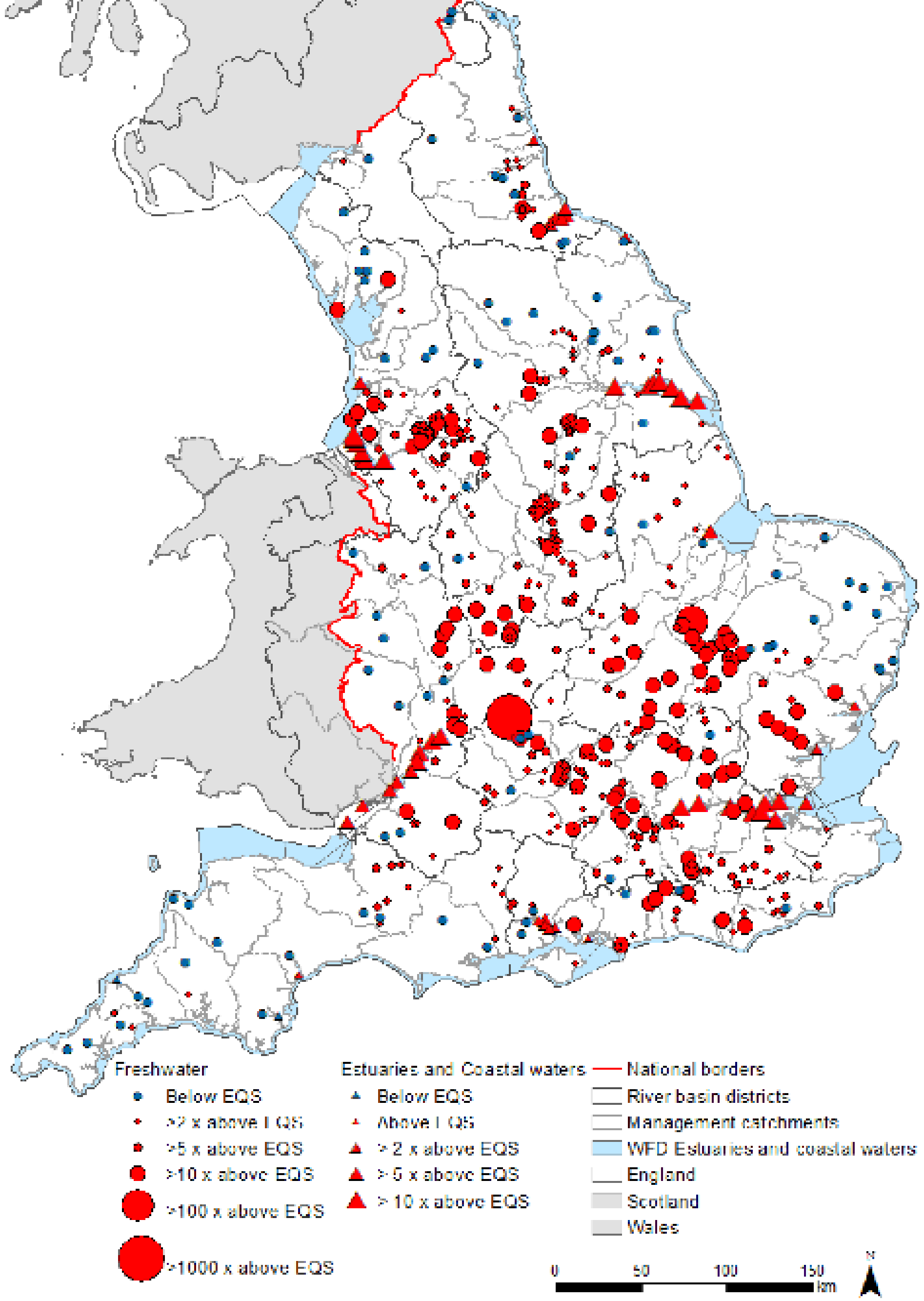
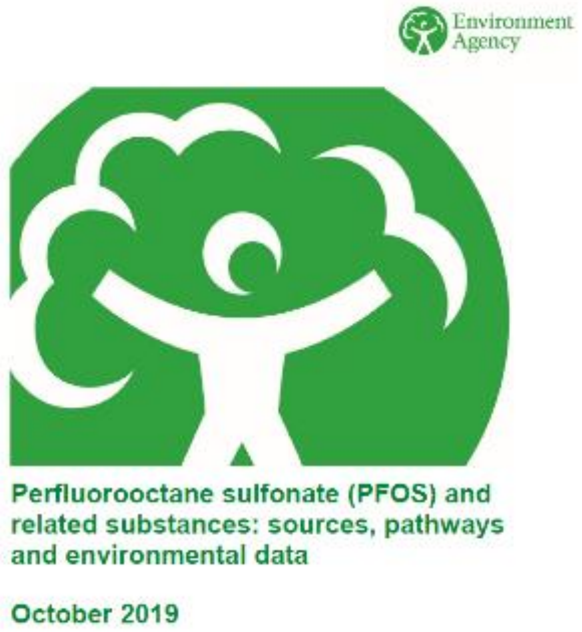


Figure 2. Mean concentrations (ng/L) of legacy PFASs (PFCAs and PFSAs) and fluorinated alternatives (PFECAs, PFESAs, and FTSAs) in the studied rivers and lakes: Chao Lake (n = 13), Tai Lake (n = 15), Yangtze River (n = 35), Pearl River (n = 13), Liao River (n = 6), Huai River (n = 9), Yellow River (n = 15), Thames River (n = 6), Rhine River (n = 20), Delaware River (n = 12), Han River (n = 6), and Mälaren Lake (n = 10).

PFOS EQS Exceedances





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Principle Exposure Route –Drinking Water

2016

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- Occurrence Data
- Reporting Requirements
- UCMR 5

Third Unregulated Contaminant Monitoring Rule

The 1996 Safe Drinking Water Act (SDWA) amendments require that once every five years EPA issue a new list of no more than 30 unregulated contaminants to be monitored by public water systems (PWSs).

The third Unregulated Contaminant Monitoring Rule (UCMR 3) was published on May 2, 2012. UCMR 3 required monitoring for 30 contaminants (28 chemicals and two viruses) between 2013 and 2015 using analytical methods developed by EPA, consensus organizations or both. This monitoring provides a basis for future regulatory actions to protect public health.

- Federal Register Notice: Final Revisions to the UCMR 3 for Public Water Systems, May 2, 2012
- UCMR 3 Basic Information Fact Sheet
- EPA Approved Laboratories for UCMR 3

Six Perfluorinated Compounds

Contaminant	CAS Registry Number[1]	Minimum Reporting Level	Sampling Points[2]	Analytical Methods
perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.04 µg/L	EPTDS	EPA 537 Rev 1.1
perfluorooctanoic acid (PFOA)	335-67-1	0.02 µg/L	EPTDS	EPA 537 Rev 1.1
perfluorononanoic acid (PFNA)	375-95-1	0.02 µg/L	EPTDS	EPA 537 Rev 1.1
perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.03 µg/L	EPTDS	EPA 537 Rev 1.1
perfluoroheptanoic acid (PFHpA)	375-85-9	0.01 µg/L	EPTDS	EPA 537 Rev 1.1
perfluorobutanesulfonic acid (PFBS)	375-73-5	0.09 µg/L	EPTDS	EPA 537 Rev 1.1

EPA examines 29 PFAS

2021

EPA United States Environmental Protection Agency

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- Reporting Requirements
- **UCMR 5**

Fifth Unregulated Contaminant Monitoring Rule

The Safe Drinking Water Act (SDWA) requires that once every five years EPA issue a new list of unregulated contaminants to be monitored by public water systems (PWSs).

The proposed fifth Unregulated Contaminant Monitoring Rule (UCMR 5) was published on March 11, 2021. UCMR 5, as proposed, would require sample collection for 30 chemical contaminants between 2023 and 2025 using analytical methods developed by EPA and consensus organizations. This proposed action would provide EPA, states, and communities with scientifically valid data on the national occurrence of these contaminants in drinking water. The proposed UCMR 5 would provide new data that is critically needed to improve EPA's understanding of the frequency that 29 PFAS are found in the nation's drinking water systems and at what levels. EPA will accept public comment on the proposed UCMR 5 for 60 days, following publication in the Federal Register. EPA will also hold a virtual stakeholder meeting twice during the public comment period.

- 40 CFR (Code of Federal Regulations, Title 40) Part 141: Proposal - Revisions to the Unregulated Contaminant Monitoring Rule (UCMR 5) for Public Water Systems and Announcement of a Public Meeting (PDF) (27 pp, 440 K, About PDF)
- Press Release: EPA Takes Action to Address PFAS in Drinking Water
- UCMR 5 Fact Sheet
- Public Stakeholder Meeting (Webinar): April 6 and 7, 2021

Table 2. Contaminants, Minimum Reporting Levels, Sampling Locations, and Analytical Methods

Twenty-nine Per- and Polyfluoroalkyl Substances

Contaminant	Chemical Abstract Service Registry Number (CASRN)	Minimum Reporting Level	Sample Point Location[1]	Analytical Methods
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS)	763051-92-9	0.005 µg/L	EPTDS	EPA Method 533
9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	0.002 µg/L	EPTDS	EPA Method 533
4,8-dioxa-3H-perfluorononanoic acid (ADONA)[2]	919005-14-4	0.003 µg/L	EPTDS	EPA Method 533
hexafluoropropylene oxide dimer acid (HFPO-DA)	13252-13-6	0.005 µg/L	EPTDS	EPA Method 533
nonafluoro-3,6-dioxaheptanoic acid (NFDHA)	151772-58-6	0.02 µg/L	EPTDS	EPA Method 533
perfluorobutanoic acid (PFBA)	375-22-4	0.005 µg/L	EPTDS	EPA Method 533
perfluorobutanesulfonic acid (PFBS)	375-73-5	0.003 µg/L	EPTDS	EPA Method 533
1H,1H, 2H, 2H-perfluorodecane sulfonic acid (8:2FTS)	39108-34-4	0.005 µg/L	EPTDS	EPA Method 533
perfluorodecanoic acid (PFDA)	335-76-2	0.003 µg/L	EPTDS	EPA Method 533
perfluorododecanoic acid (PFDoA)	307-55-1	0.003 µg/L	EPTDS	EPA Method 533
perfluoro(2-ethoxyethane)sulfonic acid (PFEESA)	113507-82-7	0.003 µg/L	EPTDS	EPA Method 533
perfluoroheptanesulfonic acid (PFHpS)	375-92-8	0.003 µg/L	EPTDS	EPA Method 533
perfluoroheptanoic acid (PFHpA)	375-85-9	0.003 µg/L	EPTDS	EPA Method 533
1H,1H, 2H, 2H-perfluorohexane sulfonic acid (4:2FTS)	757124-72-4	0.003 µg/L	EPTDS	EPA Method 533
perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.003 µg/L	EPTDS	EPA Method 533
perfluorohexanoic acid (PFHxA)	307-24-4	0.003 µg/L	EPTDS	EPA Method 533
perfluoro-3-methoxypropanoic acid (PFMPA)	377-73-1	0.004 µg/L	EPTDS	EPA Method 533
perfluoro-4-methoxybutanoic acid (PFMBA)	863090-89-5	0.003 µg/L	EPTDS	EPA Method 533
perfluorononanoic acid (PFNA)	375-95-1	0.004 µg/L	EPTDS	EPA Method 533
1H,1H, 2H, 2H-perfluorooctane sulfonic acid (6:2FTS)	27619-97-2	0.005 µg/L	EPTDS	EPA Method 533
perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.004 µg/L	EPTDS	EPA Method 533
perfluorooctanoic acid (PFOA)	335-67-1	0.004 µg/L	EPTDS	EPA Method 533
perfluoropentanoic acid (PFPeA)	2706-90-3	0.003 µg/L	EPTDS	EPA Method 533
perfluoropentanesulfonic acid (PFPeS)	2706-91-4	0.004 µg/L	EPTDS	EPA Method 533
Perfluoroundecanoic acid (PFUnA)	2058-94-8	0.002 µg/L	EPTDS	EPA Method 533
N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA)	2991-50-6	0.005 µg/L	EPTDS	EPA Method 537.1
N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA)	2355-31-9	0.006 µg/L	EPTDS	EPA Method 537.1
perfluorotetradecanoic acid (PFTA)	376-06-7	0.008 µg/L	EPTDS	EPA Method 537.1
perfluorotridecanoic acid (PFTrDA)	72629-94-8	0.007 µg/L	EPTDS	EPA Method 537.1

Groundwater Risks to Receptors

Landfill Leachate
Municipal / Domestic WWTP
Industry & Manufacturing
Agricultural Land
Commercial / Domestic Products
Metal Plating
Car Wash/Wax
ASTs –Fuel storage (FFFP / FP)

AFFF / FFFP / FP
Fire training
Incident Response

?

?

?

Diffuse
Ground level impacts and ground/surface water

Source – Pathway – Receptor
High concentration, spill site, route via groundwater to receptor e.g. drinking water well

Grasshopper effect

via widening of source zones

e.g. concentrated plume intercepts crop spray irrigation to make secondary wider source area for more dilute plume

Incineration

- 1,000 to 1,200 °C required to completely degrade PFOS
- Lower temperature incineration of PFASs can produce toxic intermediates (e.g. **perfluoroisobutylene**)
- Not proven effective for liquid wastes, potential for steam expansion i.e. AFFF concentrates –U.S. litigation
- Incinerator ash pits source of PFAS to groundwater
- Potent greenhouse gases (CF_4, C_2F_6 etc.) require 1,400 °C for destruction –above incineration temperatures
- Comprehensive analysis of all gaseous emissions required for any thermal treatment
- Cement kilns one potential solution but several technologies potentially applicable –sonolysis, plasma, electrochemical oxidation, supercritical water etc.

Groundwater Monitoring&Remediation Advances in Remediation Solution

Understanding and Managing the Potential By-Products of PFAS Destruction

by John Horst, Jeffrey McDonough, Ian Ross, and Erika Houtz

DISPOSAL OF AFFF, FFFP AND FP:
CHALLENGES AND EMERGING SOLUTIONS

Ian Ross Ph.D. Arcadis, Leeds, West Yorkshire, UK.

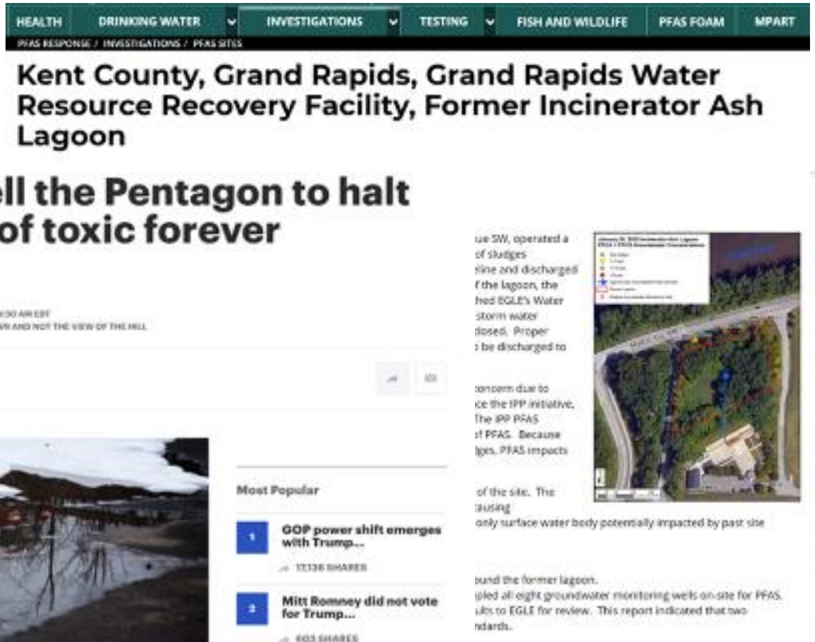
https://earthjustice.org/sites/default/files/files/filed_complaint_-_pfas_incineration_suit.pdf

https://joiff.com/wp-content/uploads/2020/11/Catalyst-Q4-FINAL.pdf

https://www.epa.gov/sites/production/files/2019-09/documents/technical_brief_pfas_incineration_ioaa_approved_final_july_2019.pdf

https://toxnet.nlm.ni.gov/cgi-bin/sis/search/a?dbs+hsdb:@term+@DOCNO+7708

Biosolids as a PFAS Source to Groundwater / Milk



https://thehill.com/opinion/energy-environment/501603-congress-tell-the-pentagon-to-halt-incineration-of-toxic-forever

https://www.michigan.gov/pfasresponse/0,9038,7-365-86511_95645-529272--,00.html

https://www.theguardian.com/us-news/2019/feb/20/new-mexico-contamination-dairy-industry-pollution

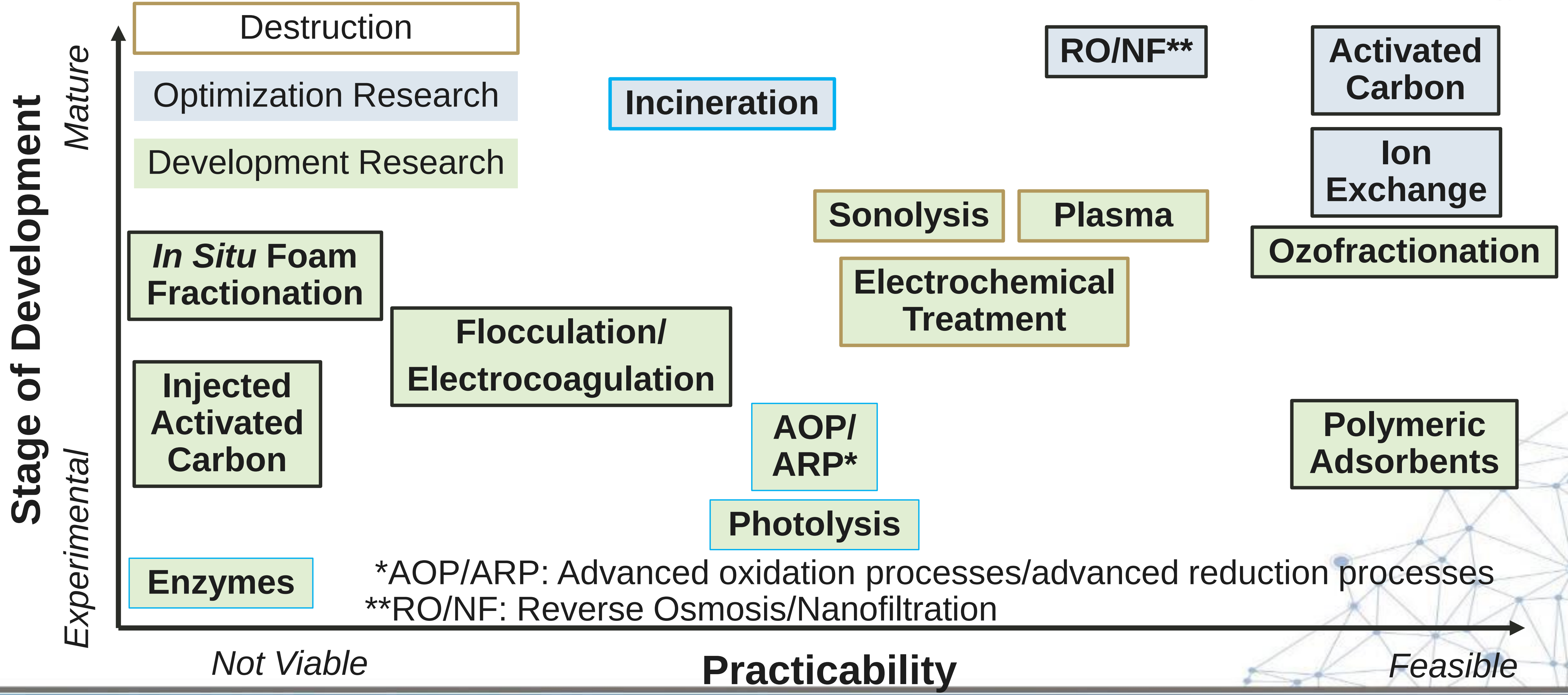
https://www.iatp.org/blog/202007/second-farm-shuttered-due-massive-pfas-contamination-maine-legislators-weigh-easing

PFAS Treatment Technologies for Water


RESEARCH ARTICLE
WILEY

A review of emerging technologies for remediation of PFASs

Ian Ross | Jeffrey McDonough | Jonathan Miles | Peter Storch | Parvathy Thelakkat Kochunarayanan | Erica Kalve | Jake Hurst | Soumitri S. Dasgupta



*AOP/ARP: Advanced oxidation processes/advanced reduction processes
**RO/NF: Reverse Osmosis/Nanofiltration

PFAS Treatment Technologies for Soil/Sediment

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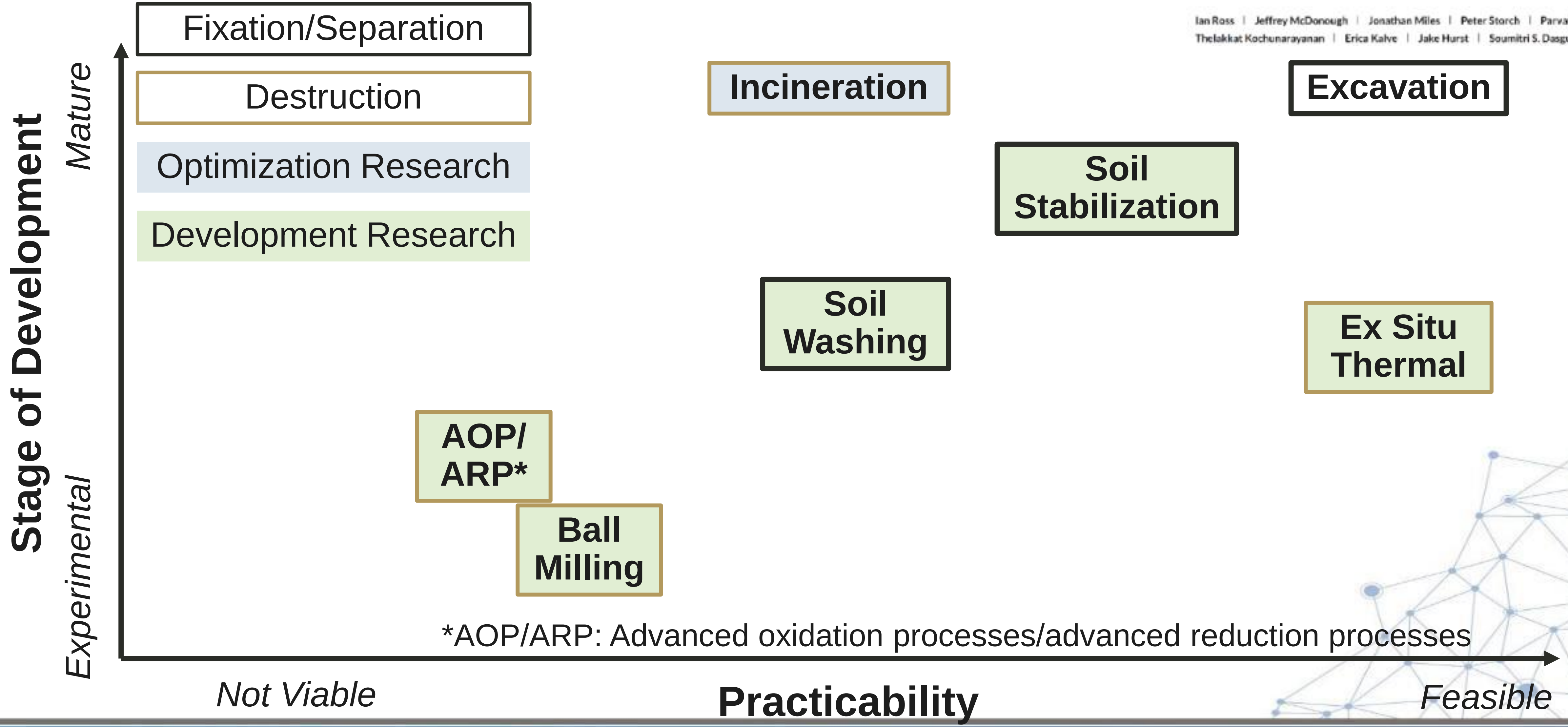
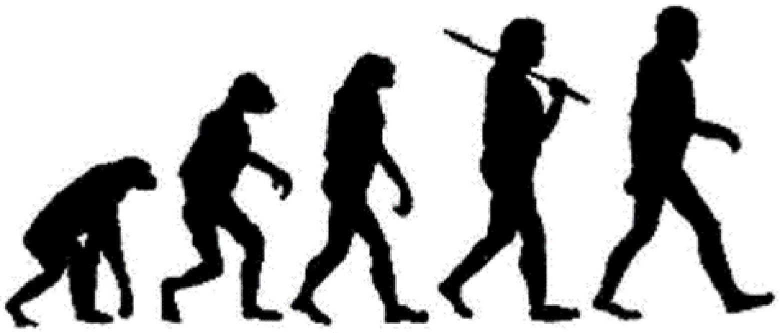


PFAS Foams being Replaced

- C8 (PFOS) generally phased-out, replaced with foams containing C6 and C8 (20% PFOA precursors)
- C6-pure foams with shorter (C6) perfluorinated chains, still contai PFOA and precursors
- C4, C6 PFAS are less bioaccumulative, but extremely persistent and more mobile in aquifer systems vs C8 - more difficult and expensive to treat in water.
- Regulations addressing multiple chain length PFAS (long and short) are evolving globally – PFHxA restrictions coming
- Fluorine free (F3) foams contain no persistent pollutants
- F3 foams pass ICAO tests with highest ratings for extinguishment times and burn-back resistance and are widely available as replacements to AFFF
- Lastfire Independent Large Scale Storage Tank Test Program Results 2018: "*It is not possible to state, for example, that all C6 foams demonstrate better performance than all FF foams and vice versa*"



C8 C6 → F3 Foams

AFFF
FFFP
FP
AR-AFFF
AR-FFF

INTEGRITY
ANGUS FOAMS
JetFoam 1%
Fluorine Free (FF)
Foam Concentrate

GREEN APPLE AWARD WINNER 2016

2014 PRESIDENTIAL GREEN CHEMISTRY CHALLENGE AWARD winner

RE-HEALING FOAM
AUTHENTIC FLUORO-FREE

TETRA TECH

Research Work – Rational Progression - more than 200 tests

Small scale
Simulated tank fire
Critical application rates

LASTFIRE
Large Atmospheric Storage Tank Fires
www.lastfire.org.uk

Phases have included
- Different foams
- Different nozzles
- Different application methods
- Different rates
- Different fuels (including crud
- Different preburns
- Fresh/Salt water

Subsurface tests

Spill fire
Critical application rates

Larger scale
“Real life” Application
NFPA rates

Longer flow
“Real life” Application
NFPA rates

Self expanding foam

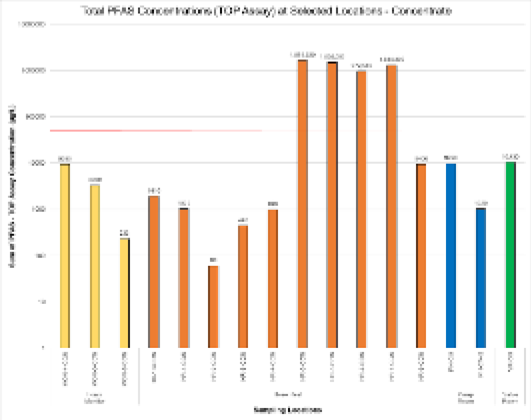
Vapour suppression

Hybrid Medium Expansion

Further obstructed spill fire testing

Decontamination of Fire Suppression Systems

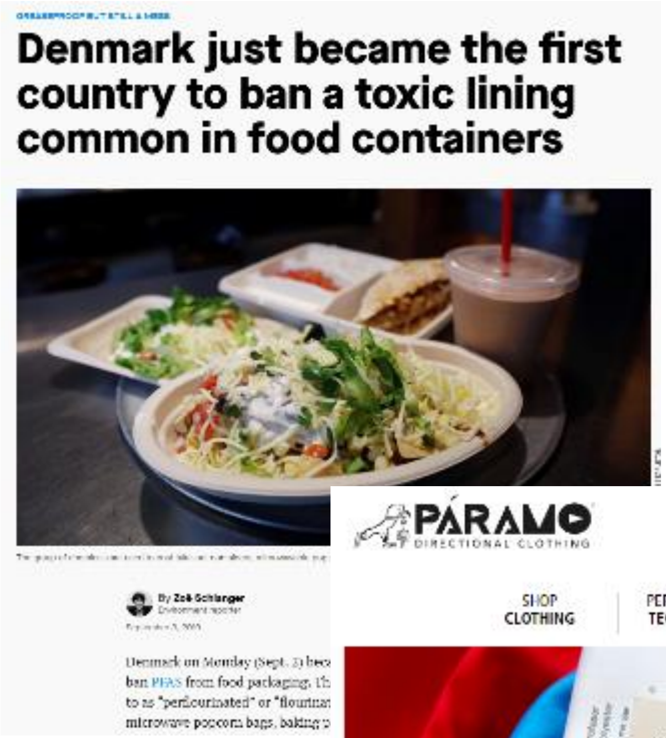
- Fire suppression systems remain significant ongoing source of PFAS to F3 foams
- g/L PFAS appear in F3 foams if suppression system not decontaminated properly
- Fluorosurfactants self assembled on surfaces
- Water flushing not effective
- Requires specialist decontamination
- Solutions developed in UK and used globally

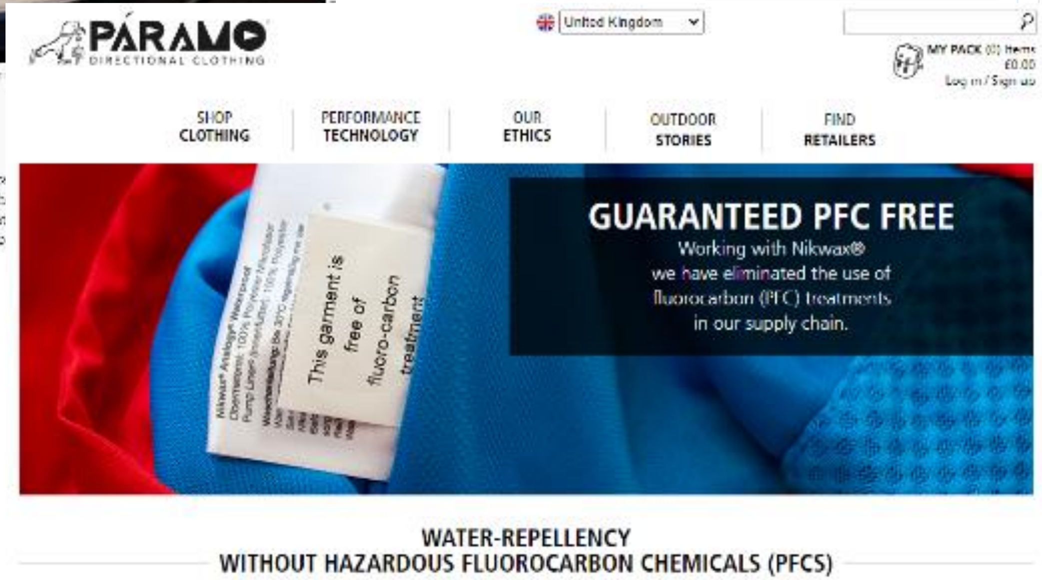


https://joiff.com/wp-content/uploads/2019/04/Jan_2019.pdf

https://joiff.com/wp-content/uploads/2020/05/JOIFF-Catalyst-Q2-Foam-Supplement-13May20.pdf

Transition to Green Chemistry

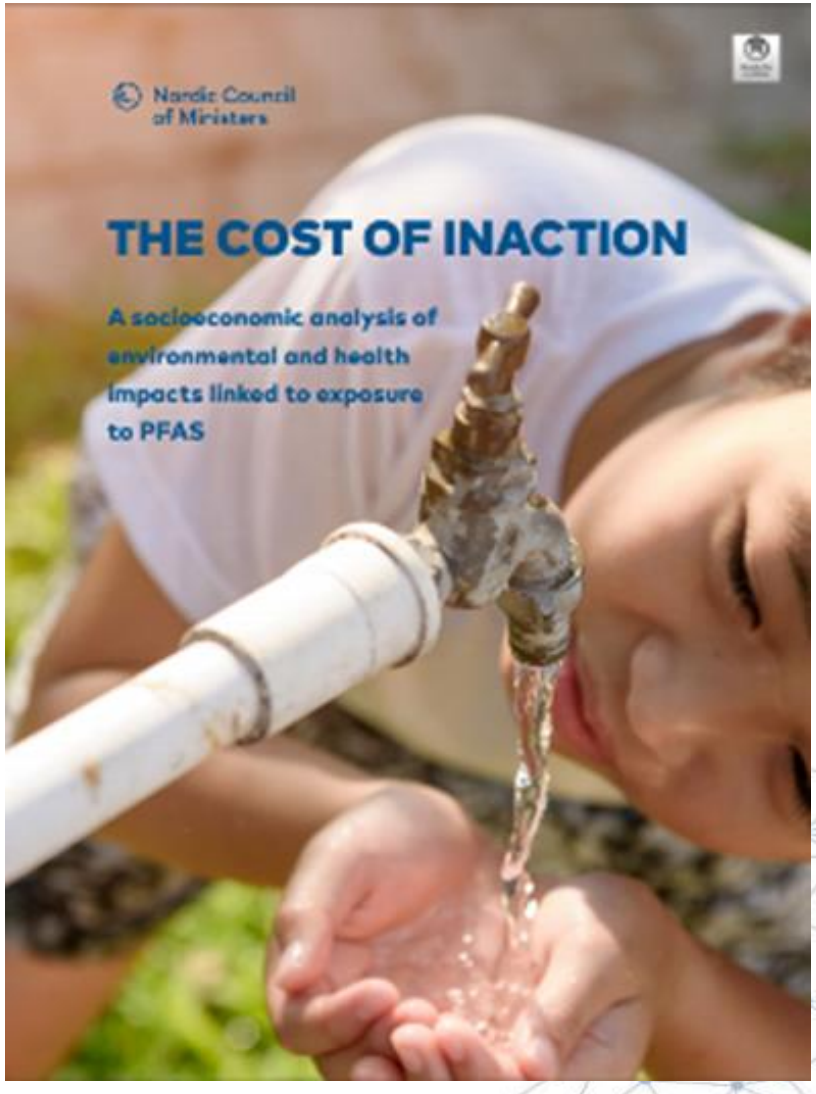




The Cost of Inaction

- Non-health costs, e.g., treatment of contaminated drinking water, are estimated to range between 16.9 and 170.8 billion EUR over the next 20 years. The estimates are based on actual costs of PFAS contamination incurred by communities and industries in the U.S. and Sweden.

- Health-related costs may be even higher. Epidemiological research on PFAS exposures of workers and communities with contaminated drinking water indicates that annual health-related costs range between 52 and 85 billion EUR each year.



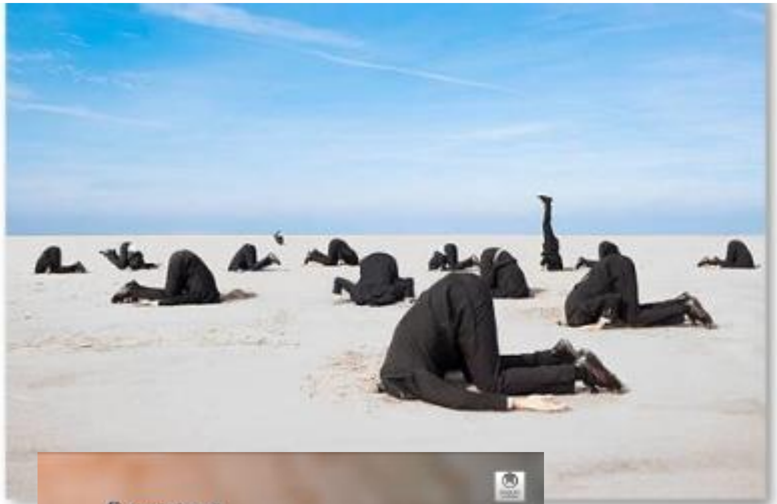
Summary

Challenges

- PFAS diversity - short chains and ethers replacing long chains
- Proprietary precursors form PFAAs
- Uncertain toxicology of broader group of PFAS
- A significant mass of PFASs in source areas can bleed PFASs to form plumes for decades

Solutions

- Total PFAS can be detected –TOP assay
- Rapid In Vitro toxicological screening started
- Evaluation of exposure pathways and development of site specific CSMs essential for PFAS management
- Multiple remediation technologies evolving
- Effective and green substitutions for PFAS often available



PFAS Publications