Technical Challenges and Solutions for PFAS at Brownfield Sites

March 11, 2020

Troy Conrad, PADEP
Colleen Costello, GHD
Duane Luckenbill, Eurofins
Brie Sterling, PADEP

Agenda

- **PFAS Overview** – Troy Conrad, PADEP
- **PFAS Challenges and Solutions for PFAS at Brownfield Sites** – Colleen Costello, GHD
- **PFAS Analysis in Environmental Samples; Current Status and What's to Come-** Duan Luckenbill, Eurofins
- **PFAS Toxicity Overview –** Brie Sterling, PADEP

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Bureau of Environmental Cleanup & Brownfields

PFAS Overview

PA Brownfields Conference
March 11, 2020
Troy Conrad

Tom Wolf, Governor

Patrick McDonnell, Secretary

Background

- Per- and polyflouroakyl substances
- 3,000+ manmade chemicals since 1940's
- Shed water, repel stains and reduce friction
- Fire fighting foam, textiles, paper and food packaging, non-stick cookware and personal care items
- Teflon, Scotchguard, Gore-Tex

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Background

- Persistent and bioaccumulates
- Perflourococtanoic acid (PFOA) and perflourooctane sulfonate (PFOS)
- Blood serum
- Half-life
- High cholesterol, thyroid disorders and increased risk of cancer
- Largely unregulated

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PFAS Action Team

- Executive Order - Sept. 19, 2018
- DEP, DOH, PDA, DCED, DMVA, PennDOT and State Fire Marshal
- Chaired by Secretary McDonnell
- Identify and eliminate sources
- Ensure drinking water is safe

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PFAS Action Team

- Phase out and disposal of AFFF
- Reduce PFAS from commerce
- Open and closed meetings
  - Gather and share information
  - Discuss data gaps
  - Oversight authority

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PFAS Sampling Plan

- Plan is available on DEP website
- 400 samples
  - 360 samples near known or potential sources
  - 40 samples used as control group
- UCMR3…PFOS, PFOA, PFNA, PFHxS, PFHpA & PFBS
- Follow-up action for > PFOA/PFOS 70 ppt

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Toxicology Contract

- Review/evaluate human health effects and toxicity data for PFOA and PFOS
- Prepare final report with <u>recommendation for appropriate MCL</u>
- Work is expected to take one year
- Contract will be extended if needed
- DOH has also hired a toxicologist

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Remediation Standards

- EPA Maximum Contaminant Level (MCL) or Lifetime Health of Level (HAL) = Act 2 Statewide Health Standard
- Combined EPA Lifetime HAL / Act 2 standard for PFOA/PFOS is 70 ng/L
- Proposing soil and/or groundwater Medium Specific Concentrations for PFOA/PFOS and PFBS

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Challenges

- Still in use
- Occurrence data
- Analytical methods
- Laboratory capability
- Toxicity information
- Standards
- Treatment & disposal options

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PFAS
Considerations and Challenges

Colleen Costello, PG | GHD

Ryan Thomas, PhD | GHD

March 11, 2020

Agenda for Today

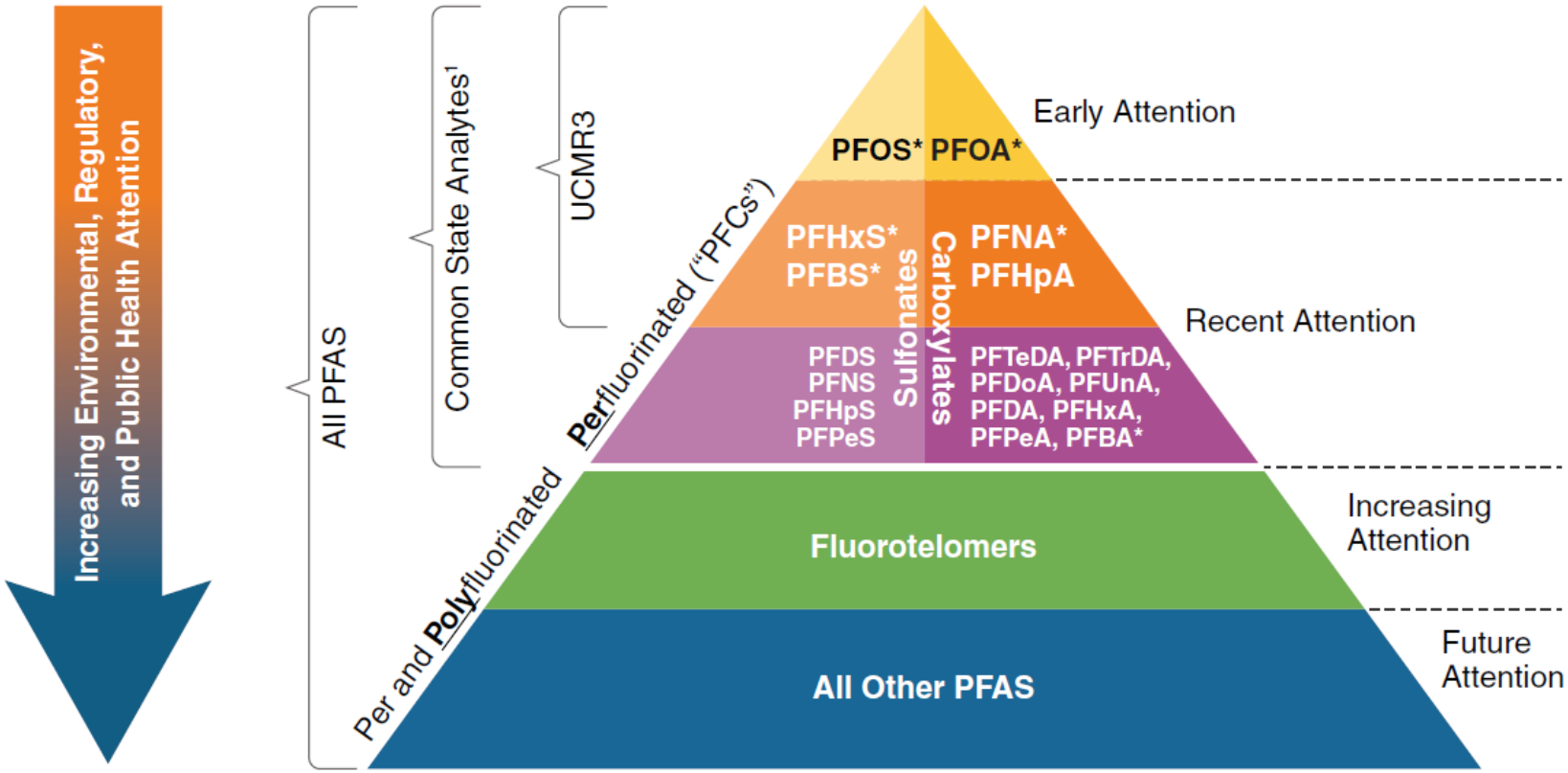
PFAS Pathways

Sampling Challenges

Treatment Challenges

PFAS Pathways

Emerging Awareness

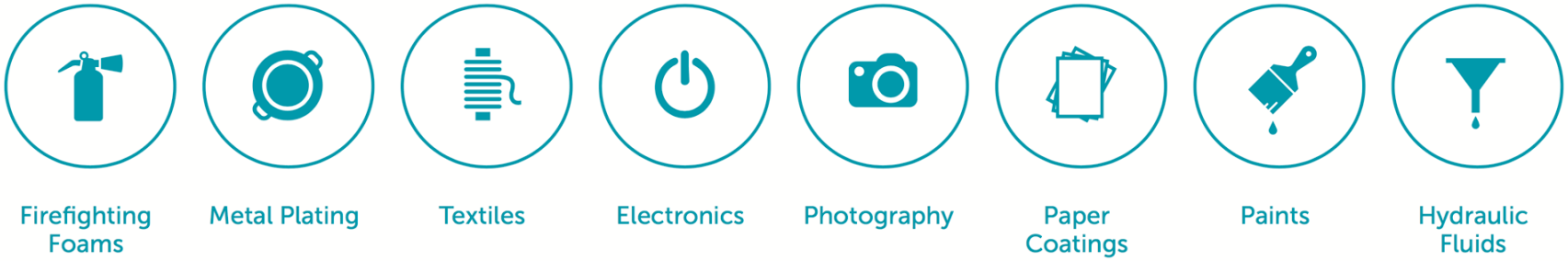


*Common regulatory criteria or health advisories
[1]Sum of informal poll (NJ, NH, MN)

Thematic and not proportional.
Bottom of triangle indicates additional number of compounds; not a greater quantity by mass, concentration, or frequency of detection.

SOURCE: ITRC's History of Use of Per- and Polyfluoroalkyl Substances (PFAS) – Fact Sheet

Where do PFAS come from?



PFAS exposure may:
Affect development in children
Lower pregnancy chance
Interfere with hormones
Increase cholesterol levels
Affect immune system
Increase risk of cancer

SOURCE: CDC/ATSDR PFAS Health Effects; http://evocra.com.au

Sources from Manufacturing

Manufacture of **military vehicles, RVs, construction equipment**

Chrome plating historically used PFOS as a fume suppressant

Manufacture of **fluorinated pesticides/ herbicides**

Potential for products or precursors to degrade to PFAS

Manufacture, testing, or use of **firefighting pumps and equipment**

Landfill leachate & WWTP effluent

Airports

Use of fire fighting foams for emergencies and training

Firefighting training facilities

Use of fire fighting foams

Potential Exposure Pathway

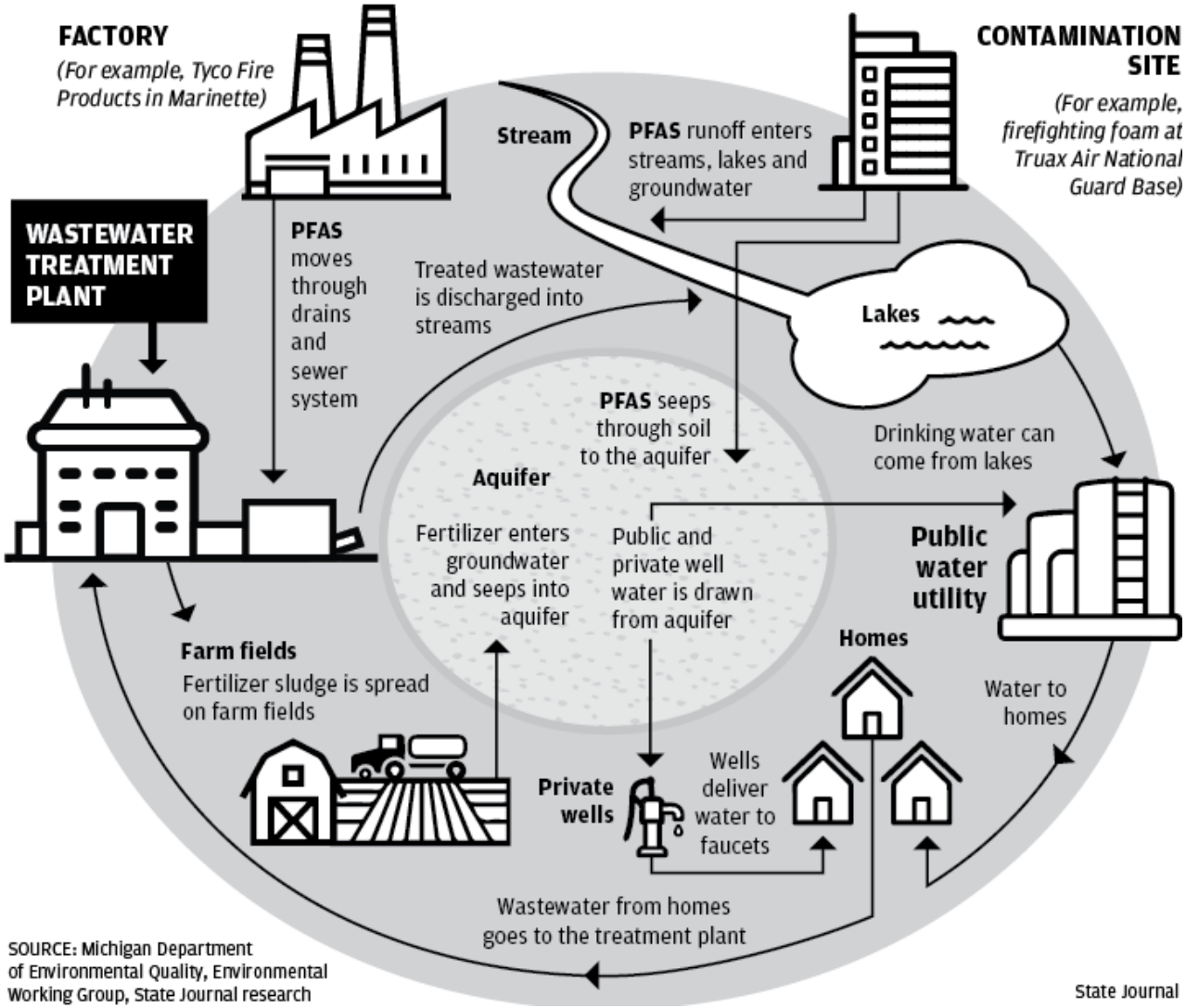
SOURCE: www.atsdr.cdc.gov/pfas

Commercial and Consumer Products Containing PFAS:

- paper and packaging
- clothing and carpets
- outdoor textiles and sporting equipment
- ski and snowboard waxes
- non-stick cookware
- cleaning agents and fabric softeners
- polishes and waxes, and latex paints
- pesticides and herbicides
- hydraulic fluids
- windshield wipers
- paints, varnishes, dyes, and inks
- adhesives
- medical products
- personal care products (for example, shampoo, hair conditioners, sunscreen, cosmetics, toothpaste, dental floss)

SOURCE: ITRC – History and Use of PFAS Fact Sheet 2017

PFAS Potential Pathways to Water Sources



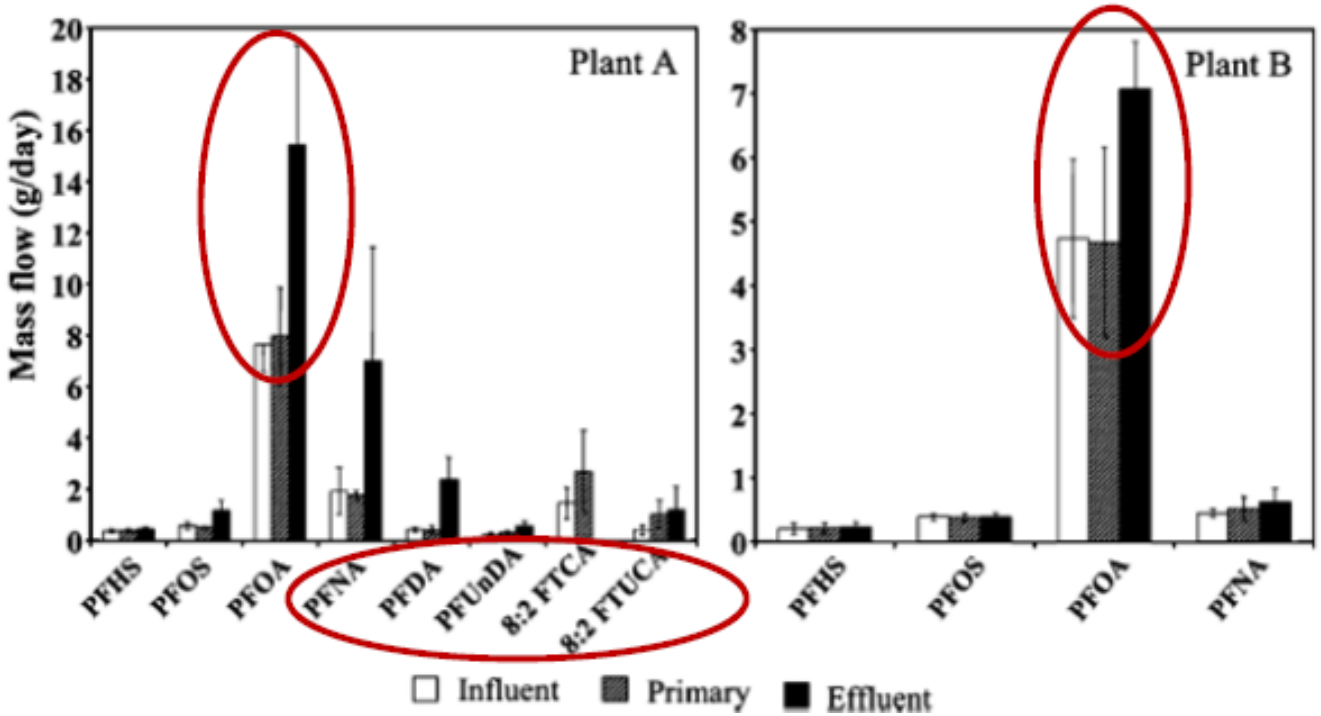
SOURCE: Michigan Department of Environmental Quality, Environmental Working Group, State Journal research

State Journal

PFAS in Wastewater

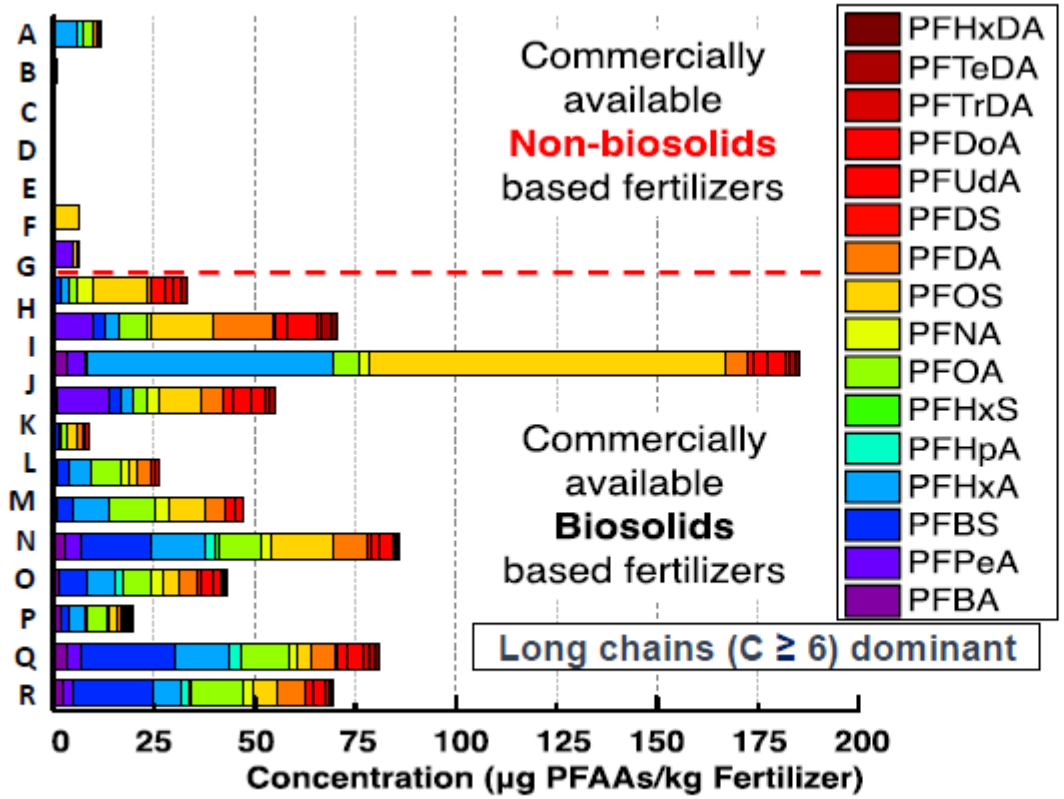
PFAAs: Effluent >> Influent

Biotransformation of precursors during aerobic wastewater treatment



SOURCE: Schultz et al. (2006) Environ. Sci. & Technology 40(5)

PFAS in Commercial Fertilizers



*PFAA concentration in < 2mm fraction (36-80%) normalized to total mass (assumes PFAA is negligible in the fraction > 2 mm)

Fertilizer	Description
A	Food and yard compost
B	Compost with untreated wood products
C	Manure compost
D	Manure and peat compost
E	Mushroom compost
F	Mushroom compost
G	Peat/compost based growing mix
H	Heat-dried granular biosolids
I	Heat-dried granular biosolids
J	Heat-dried granular biosolids
K	Heat-dried granular biosolids
L	Heat-dried granular biosolids
M	Biosolids blended with maple sawdust and aged bark
N	Composted biosolids with woodchips
O	Composted biosolids with woodchips
P	Composted biosolids with municipal solid waste
Q	Composted biosolids with residential yard trimmings
R	Composted biosolids with plant materials

SOURCE: Lazcano et al., Manuscript in preparation

Sampling Challenges

Sampling Challenges

- PFAS are ubiquitous
- Can be on samplers clothing, gloves, sampling equipment
- Waterproof field note books
- Glass bottles can cause loss of analyte
- Water for blanks (must be certified-PFAS free)

Sampling Challenges

Prohibited Items	Acceptable Items
Field Equipment	
Teflon® containing materials (tubing, bladders, o-rings, caps)	High-density polyethylene (HDPE) materials
Low density polyethylene (LDPE) materials	Acetate Liners
	Silicon Tubing
Waterproof field books	Loose paper (non-waterproof)
Plastic clipboards, binders, or spiral hard cover notebooks	Metal field clipboards or with Masonite
Post-It Notes®, Sharpies®	Ball point pens
Chemical (blue) ice packs	Regular ice
Field Clothing and PPE	
New cotton clothing or synthetic water resistant, waterproof, or stain-treated clothing, clothing containing Gore-Tex™	Well-laundered clothing made of natural fibers (preferable cotton) washed at least 6 times since purchase
Clothing laundered using fabric softener	No fabric softener
Boots containing Gore-Tex™	Boots made with polyurethane and PVC (PVC over boots over leather steel-toe safety boots are acceptable*)
Tyvek®	Powder-free nitrile gloves
No cosmetics, moisturizers, hand cream, or other related products as part of personal cleaning/showering routine on the morning of sampling	**Sunscreens** - Alba Organics Natural Sunscreen, Yes To Cucumbers, Aubrey Organics, Jason Natural Sun Block, Kiss my face, Baby sunscreens that are "free" or "natural" **Insect Repellents** - Jason Natural Quit Bugging Me, Repel Lemon Eucalyptus Insect repellant, Herbal Armor, California Baby Natural Bug Spray, BabyGanics **Sunscreen and insect repellant -** Avon Skin So Soft Bug Guard Plus – SPF 30 Lotion

Treatment Challenges

Evaluation of Treatment Technologies

<10%	10-90%	>90%

INCREASING SIZE

	AER	COAG/DAF	COAG/ FLOC/SED/ G- or M-FIL	MnO_4, O_3, ClO_2, Cl_2, CLM, UV	AIX	GAC	NF	RO
PFBA	*	*						
PFPeA								
PFBS								
PFHxA								
PFHpA								
PFHxS								
PFOA								
PFNA					*	*		
FOSA						*		*
PFOS								
PFDA					*	*		
N-MeFOSAA	*				*	*	*	
N-EtFOSAA					*	*	*	

*Treatment performance is assumed based on PFAA size/charge and/or known removal data of shorter or longer chain homologues

SOURCE: Dickenson and Higgins (2016) Water Research Foundation "Treatment Mitigation Strategies for Poly- and Perfluoroalkyl Substances"

Ion Exchange

- Dual removal mechanism
  - PFOS/PFOA negatively charged at the pH of typical natural water
  - Hydrophobic end of PFAS can adsorb to hydrophobic surface of resin
- Co-contaminants
  - Ionic contaminants will compete for IX sites
  - Organics can foul resin and require pretreatment
- Single use disposed through landfilling or incineration
- Regenerable
  - Typically done on site
  - Must dispose of regenerant solution
- Full scale systems in place in the last year or so
- Technology providers
  - Purolite
  - Evoqua
    - Dow resin developed for perchlorate

Activated Carbon

- Treatment systems for PFAS operating for 15+ years
- PFOS removal capacity greater than PFOA
- No conversion of precursors to PFAS
- Considerations
  - Organic concentrations can be 10-100x PFAS and drive carbon usage
  - Adsorption media can be thermally reactivated to destroy PFAS
  - Each supplier has ~3 locations for incineration
  - Some studies show reduced effectiveness with regenerated GAC
  - Uncertain if regenerated GAC could be used for drinking water treatment
- Technology Providers
  - Calgon
  - Evoqua

Incineration of PFAS

- Limited scientific literature
- Fluorinated byproducts may be formed when incinerating PFOS (Yamada & Taylor 2003)
  - At 600°C, incineration of PFOS-contaminated material resulted in many byproducts
  - At higher temperatures (750°C and 900°C), these byproducts were not observed
- Current best practice disposal routes for spent PFAS adsorption media are incineration at temperatures >1000°C

Case Study PFAS Impacted Groundwater

- Target parameters initially phosphorus, iron, and oil and grease
- Permanent treatment system design completed 2017/2018
- Monitoring to better define design basis
- Focus on PFAS in Michigan
- PFAS detected, original design scrapped
- Continue discharging to the potw
- Design for a direct discharge

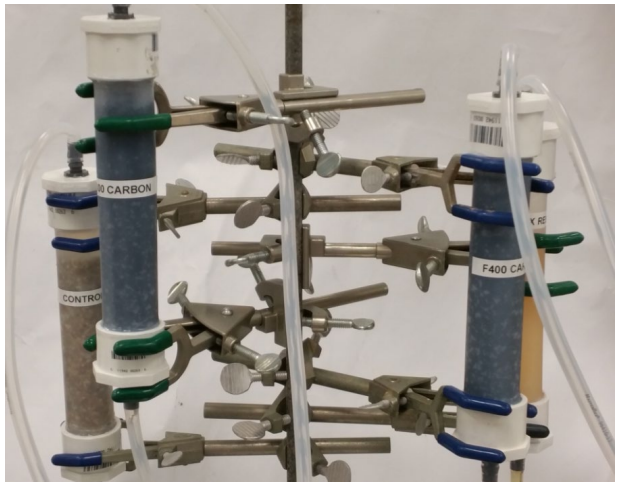
Case Study Groundwater Characterization

Parameters	Units	Max	Avg	% Detected	Potential Limits	
					POTW	Surface Water
Phosphorus	ug/L	160	107	39%	15,000	30/ 1,000
PFOA	ng/L	38	31	100%	No limit (currently)	420
PFOS	ng/L	390	383	100%		11
Ammonia-N	mg/L	1.4	1.0	61%	No limit	
BOD	mg/L	5	3.5	44%		
Calcium	mg/L	140	121	61%		
COD	mg/L	133	84	89%		
Ferrous Iron	mg/L	2.3	1.7	22%		
TOC	mg/L	18	17.3	100%		
TSS	mg/L	11	6.5	67%		

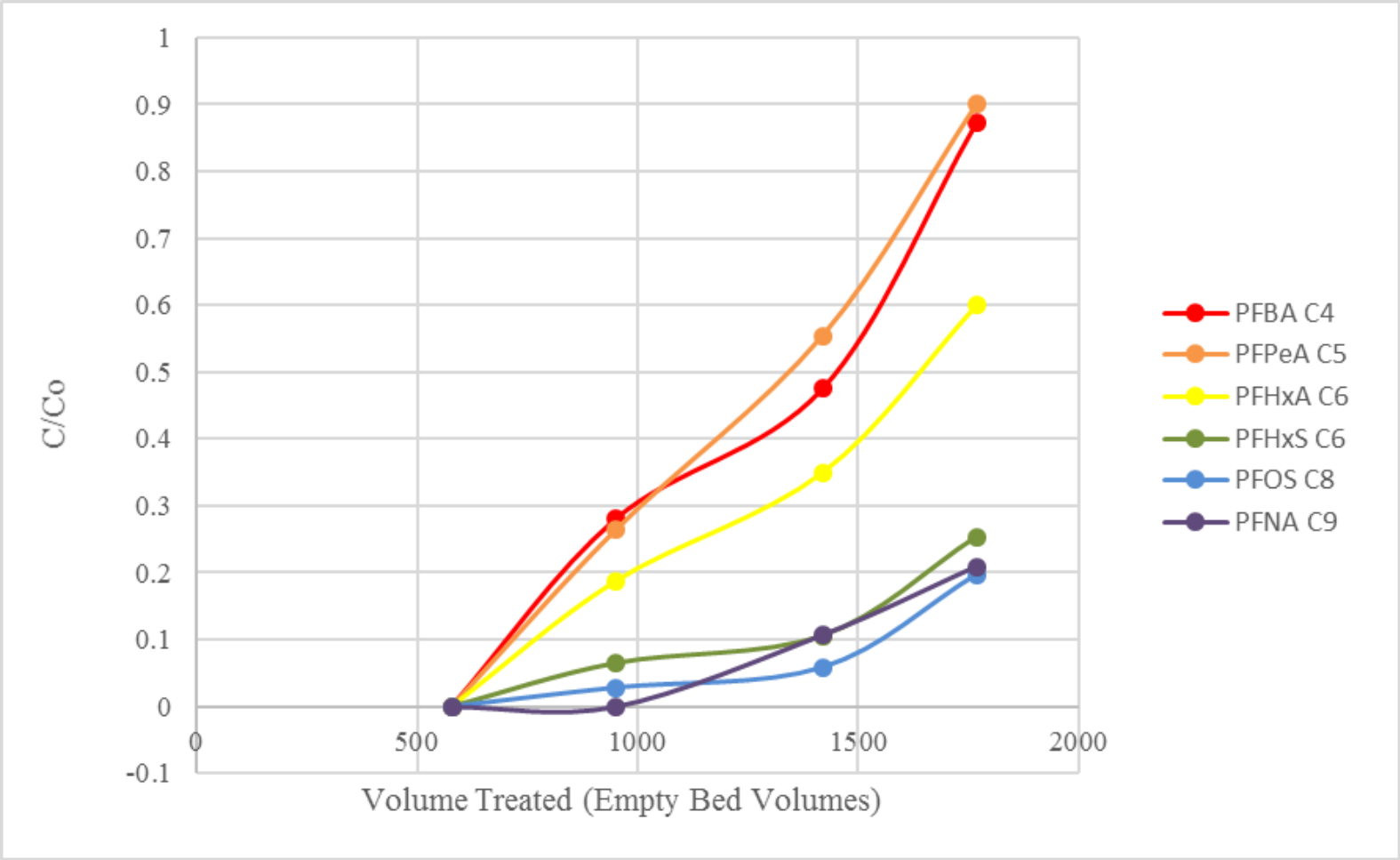
Technology Evaluation

Bench Testing Conducted:

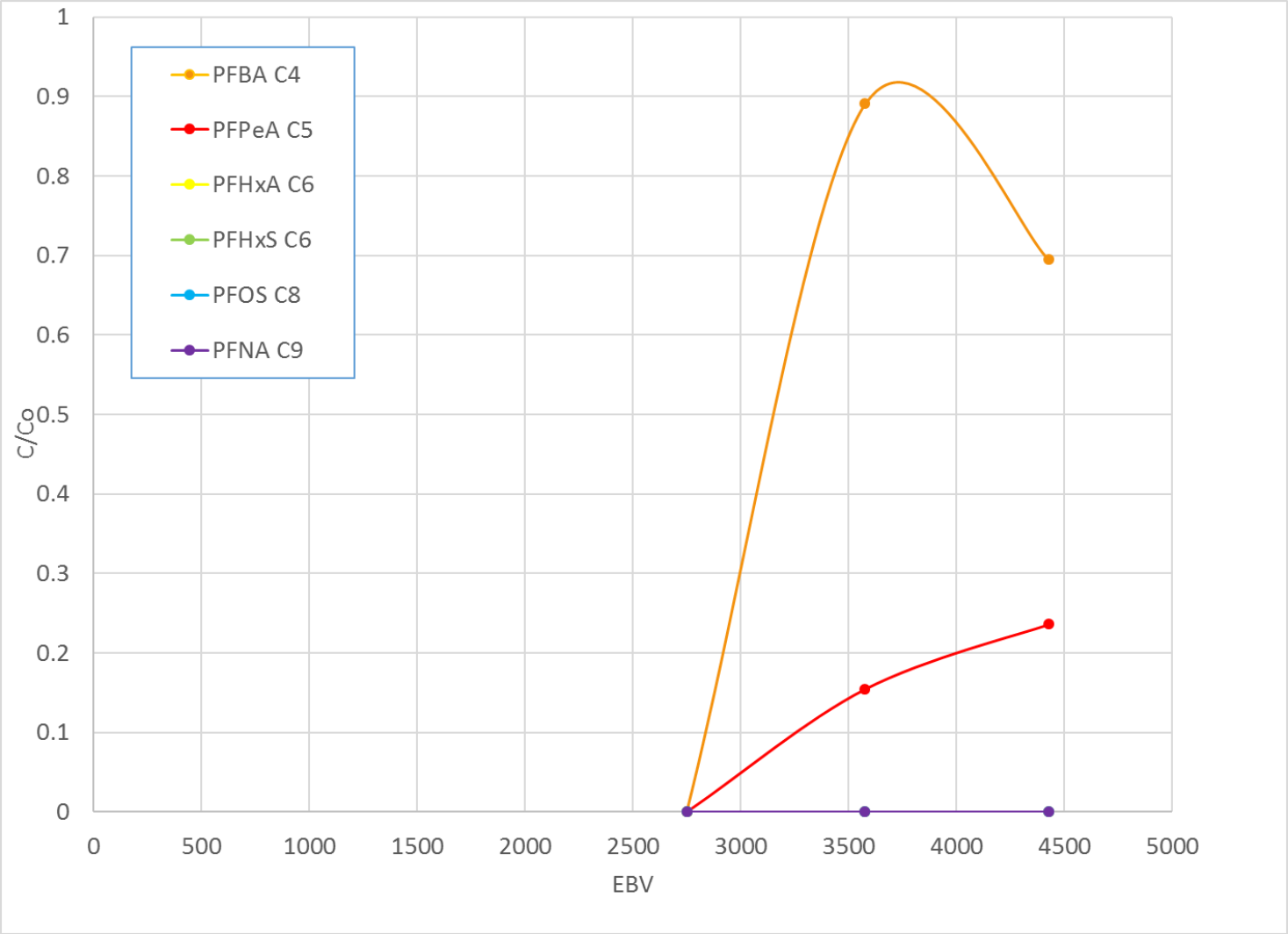
- Granular Activated Carbon (GAC)
- Anion Exchange (AIX)
- Adsorbents
- Alkaline Ozonation



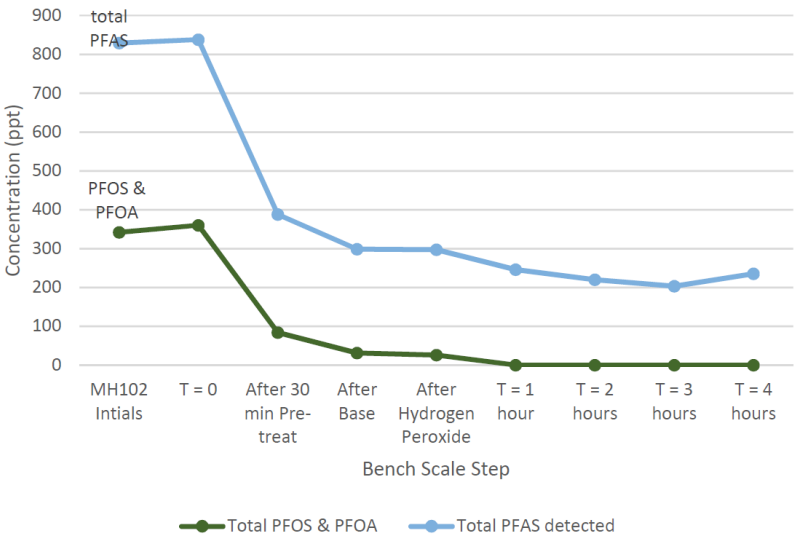
Granular Activated Carbon Results

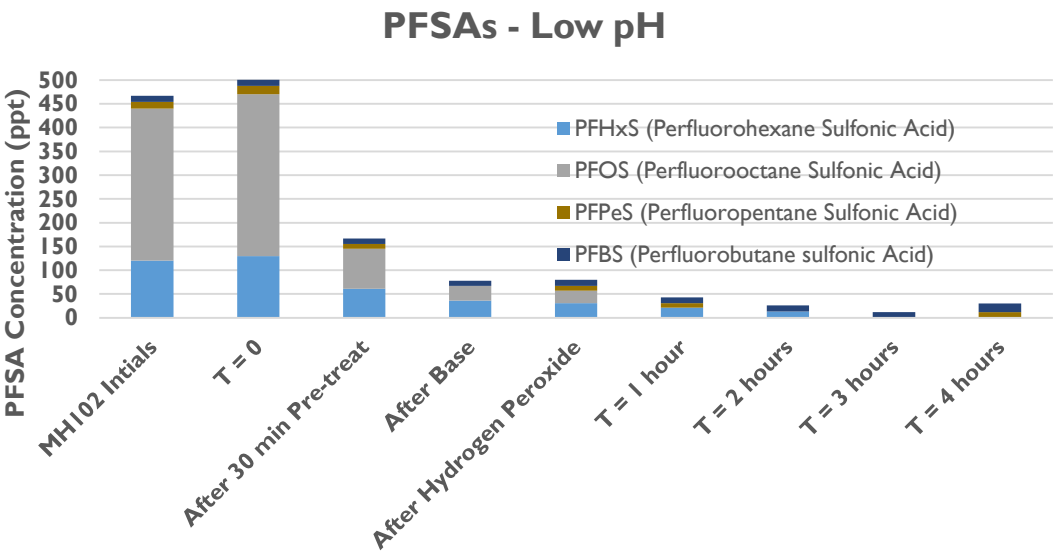


Anion Exchange Results



Alkaline Ozonation Results





Thomas, Jenkins, Landale, Trigger et al., 2020 Remediation Journal (submitted).

Developing Technologies

- Reverse Osmosis or Nanofiltration
  - Bench/pilot studies, limited full scale installations
  - Concentrating the PFAS and other constituents
  - Would require further treatment or solidification/stabilization
- Adsorbents
  - Rembind© - Mixture of Powdered Activated Carbon, kaolinite and amorphous aluminum hydroxide
  - Zeolite/clay adsorption
  - Many other under development
- Advanced oxidation/Advanced reduction
- Electrochemical oxidation
- Plasma

Questions

Ryan Thomas, PhD | ryan.thomas@ghd.com

eurofins | Lancaster Laboratories Environmental



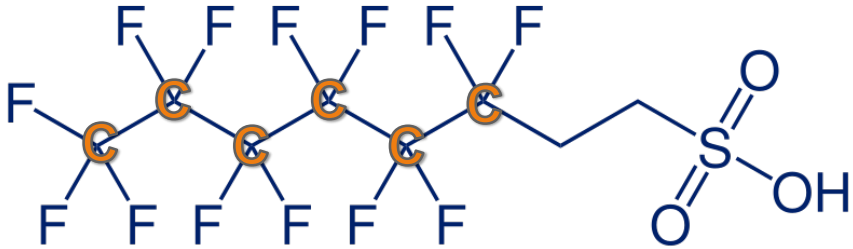
PFAS Analysis in Environmental Samples; Current Status and What's to Come

Duane Luckenbill, Technical Director
Charles Neslund, Scientific Officer
Eurofins Lancaster Laboratories Environmental, LLC

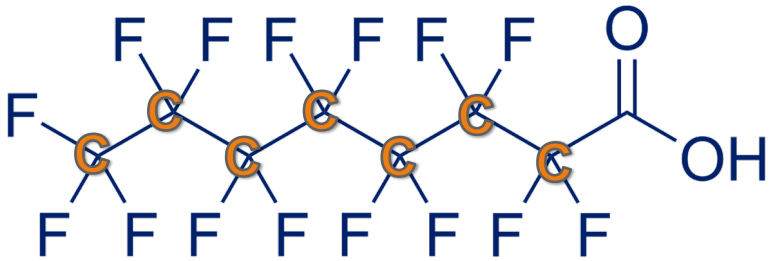
Per- and Polyfluorinated Alkyl Substances



- Per- and Polyfluorinated Alkyl Substances (PFAS)
  - Have been in use since the late 1940's, early 1950's
- Perfluorinated – all carbons in the chain are fully bonded to fluorine, forming a strong bond that is challenging to break
- Polyfluorinated – not all carbons in the chain are only bonded to fluorine



6:2 Fluorotelomer sulfonate (6:2 FTS)



Perfluorooctanoic acid (PFOA)

The General Classes of Per- and Polyfluoroalkyl Substances (PFAS)



PFAS

- Non-polymer
  - Perfluorinated
    - PFAAs
      - PFCAs
      - PFSAs
    - FASAs
  - Polyfluorinated
    - FTSAs
    - FTCAs
    - FTOHs
    - FASEs
    - FASAAs
- Polymer
  - Fluoropolymers
  - Perfluoropolyethers (PFPE)
  - Side-chain fluorinated polymers

Perfluoroalkyl acids
- Carboxylates
- Sulfonates

Fluorotelomers:
- Sulfonates
- Carboxylates
- Alcohols

Source: ITRC Naming Conventions and Physical Chemical Properties fact sheet

Current Methods - EPA 537.1 (2018)



- Matrix
  - Potable Water
- 14 +4 Compounds – Prescriptive
- Added in the 4 “replacement” compounds
  - GenX
  - Adona
  - F53b (major and minor)
- Styrene divinylbenzene solid phase extraction cartridge for the compounds listed
- Internal Standard quantitation
- Most other aspects of method are the same as 537 ver 1.1 (2009)
- Like 537 ver 1.1, intended for DW with low TSS and low TDS

PFAS Replacement Compounds



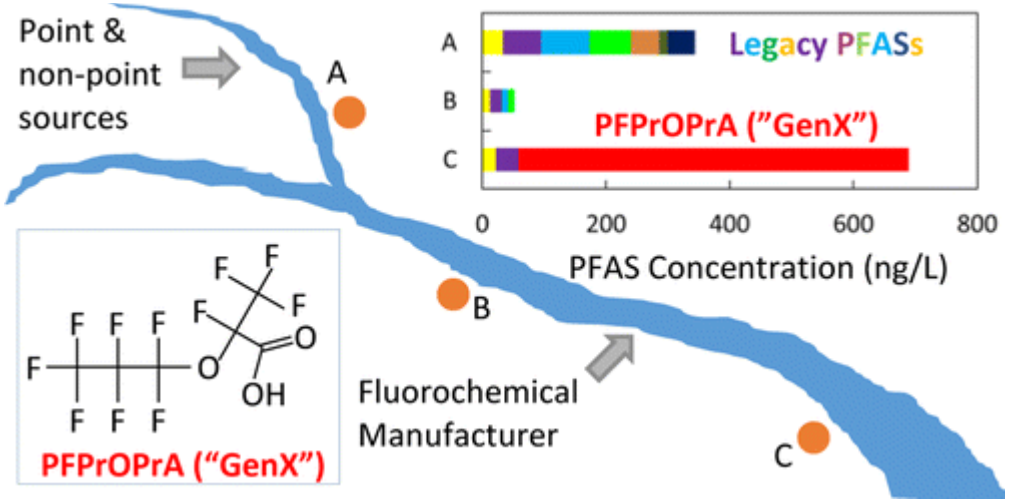
Environmental Science & Technology Letters

Letter

pubs.acs.org/journal/estlcu

Legacy and Emerging Perfluoroalkyl Substances Are Important Drinking Water Contaminants in the Cape Fear River Watershed of North Carolina

Mei Sun,[*,†,‡] Elisa Arevalo,[‡] Mark Strynar,[§] Andrew Lindstrom,[§] Michael Richardson,[∥] Ben Kearns,[∥] Adam Pickett,[⊥] Chris Smith,[#] and Detlef R. U. Knappe[‡]



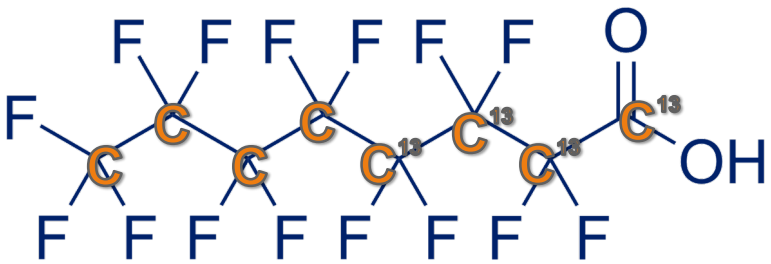
Current Methods – PFAS by Isotope Dilution



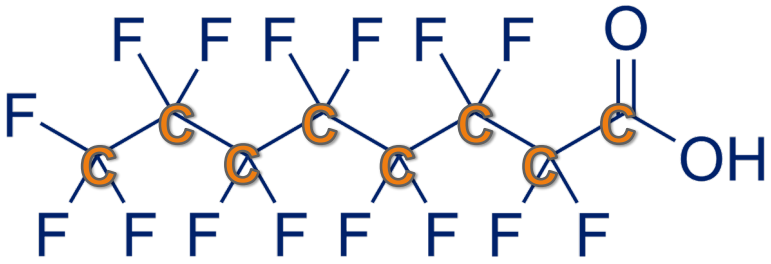
- Matrices
  - Potable water
  - Nonpotable water
  - Soil/sediment
  - Tissue/biota
  - Dust wipes
  - Landfill leachate
  - AFFF Formulations
- 36 Compounds
- Solid Phase Extraction/Cleanup using weak anion exchange
- Isotope Dilution quantitation
  - 25 isotopically labeled internal standards
- Injection Standards for monitoring instrument vs extraction performance
- Advantages
  - Isotope Dilution offers the highest degree of quantitative accuracy and precision
  - Broadest list of compounds and widest range of matrices
  - Lowest reporting limits across matrices
  - Used for TOP Assay

Isotope Dilution





C13-PFOA
Spiked into Sample prior to Extraction



PFOA
Target Analytical Compound

Per- and Polyfluorinated Compounds



Perfluorobutanoic acid
Perfluoropentanoic acid
Perfluorohexanoic acid
Perfluoroheptanoic acid
Perfluorooctanoic acid
Perfluorononanoic acid
Perfluorodecanoic acid
Perfluoroundecanoic acid
Perfluorododecanoic acid
Perfluorotridecanoic acid
Perfluorotetradecanoic acid
Perfluorohexadecanoic acid
Perfluorooctadecanoic acid
N-methylperfluoro-1-octanesulfonamidoacetic acid
N-ethylperfluoro-1-octanesulfonamidoacetic acid
2-(N-methylperfluoro-1-octanesulfamido)-ethanol
2-(N-ethylperfluoro-1-octanesulfamido)-ethanol

Perfluorobutanesulfonate
Perfluoropentanesulfonate
Perfluorohexanesulfonate
Perfluoroheptanesulfonate
Perfluorooctanesulfonate
Perfluorononanesulfonate
Perfluorodecanesulfonate
Perfluorododecanesulfonate
Perfluorooctanesulfonamide
Methylperfluoro-1-octanesulfonamide
Ethylperfluoro-1-octanesulfonamide
4:2 Fluorotelomer sulfonate
6:2 Fluorotelomer sulfonate
8:2 Fluorotelomer sulfonate
10:2 Fluorotelomer sulfonate
HFPO-DA (GenX)
ADONA
F53b (major and minor)

EPA 537.1 list

Compound Lists



Compound	Full List of 36	DW List	DOD List of 24	NY List of 21	UCMR List of 6	MI List of 24	NH List of 9	TX List of 16
PFHxA	X	X	X	X		X	X	X
PFHpA	X	X	X	X	X	X	X	X
PFOA	X	X	X	X	X	X	X	X
PFNA	X	X	X	X	X	X	X	X
PFDA	X	X	X	X		X		X
PFUnDA	X	X	X	X		X		X
PFDoDA	X	X	X	X		X		X
PFTrDA	X	X	X	X		X		X
PFTeDA	X	X	X	X		X		X
PFBS	X	X	X	X	X	X	X	X
PFHxS	X	X	X	X	X	X	X	X
PFOS	X	X	X	X	X	X	X	X
NMeFOSAA	X	X	X	X		X		
NEtFOSAA	X	X	X	X		X		
4:2-FTS	X		X			X		
6:2-FTS	X		X	X		X		
8:2-FTS	X		X	X		X		
10:2-FTS	X							
PFPeS	X		X			X		
PFHpS	X		X	X		X		
PFNS	X		X			X		
PFDS	X		X	X		X		X
PFDoS	X							
PFOSA	X		X	X		X		X
PFHxDA	X							
PFODA	X							
PFBA	X		X	X		X	X	X
PFPeA	X		X	X		X	X	X
NMEPFOSAE	X							
NMEPFOSA	X							
NEtPFOSAE	X							
NEtPFOSA	X							
GenX (HFPODA)	X	X						
NaDona	X	X						
9Cl-PF3ONSA	X	X						
11Cl-PF3OUdS	X	X						

Future Methods



1600 Series/SW-846 Method 8328

- Uses SPE for extraction of non-potable water samples
- Solvent extraction for solids, biosolids and tissues
- Isotope dilution so recovery correction for analyte concentrations
- List of 28 compounds, performance based
- Would be DoD QSM Version 5.3 Table B-15 compliant
- Sensitivity to <10 ng/l
- Single lab validation to be submitted to OW for publication as 1600 series method
- Publication by OW should result in OLEM's publication as SW-846 method

New/Additional Drinking Water Method



EPA Method 533

- New drinking water method
- SPE but designed to accommodate short chain acids (WAX)
- Employs isotope dilution so recovery correction for analyte concentrations
- List of compounds is 14 of 18 from 537.1 plus short chain acids and several precursor compounds
- Method published December 19, 2019 without any public comment period
- States still working through listing in their accreditation tables

Draft Method



SW-846 Method 8327

- variation of ASTM 7979-17
- Direct aqueous injection after dilution with methanol (no SPE)
- Intended for non-potable waters
- External standard calibration
- List of 24 compounds, performance based
- Documented issues with 6:2 Fluorotelomer sulfonate
- Sensitivity of 10 ng/l – 50 ng/l
- Has been referred to as a screening method (although that is not intent
- Draft released summer 2019, public comments in by 8/23/19
- Final version not yet released

Advisory Limits



- EPA Office of Water established Health Advisory Levels
  PFOS = 70 ng/l PFOA = 70 ng/l
- Minnesota regulatory action limits
  PFOS = 15 ng/l PFBS = 2000 ng/l PFHxS = 47 ng/l
  PFOA = 35 ng/l PFBA = 7000 ng/l

- New Jersey MCL** and proposed MCLs
  PFOS = 13 ng/l PFNA = 13 ng/l **(MCL)
  PFOA = 14 ng/l

- Massachusetts and Vermont Enforcement Standard
  PFOA/PFOS/PFHxS/PFHpA/PFNA = 20 ng/l

- North Carolina Health Advisory
  GenX = 140 ng/l
- Connecticut
  PFOA/PFOS/PFHxS/PFHpA/PFNA = 70 ng/l

Proposed Limits



- New Hampshire

  PFOA = 12 ng/l PFOS = 15 ng/l
  PFHxS = 18 ng/l PFNA = 11 ng/l

  Surface water criteria coming in January of 2020

- Michigan

  PFOA = 8 ng/l PFOS = 16 ng/l
  PFHxS = 51 ng/l PFNA = 6 ng/l
  PFBS = 420 ng/l GenX = 370 ng/l
  PFHxA = 400,000 ng/l

  Surface water criteria in place

- Vermont

  Requiring survey of all drinking water supplies in state by 12/1/19

  Surface water criteria by January 2021

Data Evaluation



In absence of an accepted EPA method, QSM 5.3 has detailed and relatively prescriptive criteria for the analysis of PFAS compounds.

- Calibration
- Order and concentration of CCVs
- Prescription for clean-up of samples
- Sensitivity monitoring and checks
- LCS control limits
- Retention time criteria added
- Mass calibration is different
- > 1% solid may need filtering
- Criteria for ion transitions and their ratios
- Use of internal standard removed
- IDAs controlled by their area response
- Inline SPE is acceptable

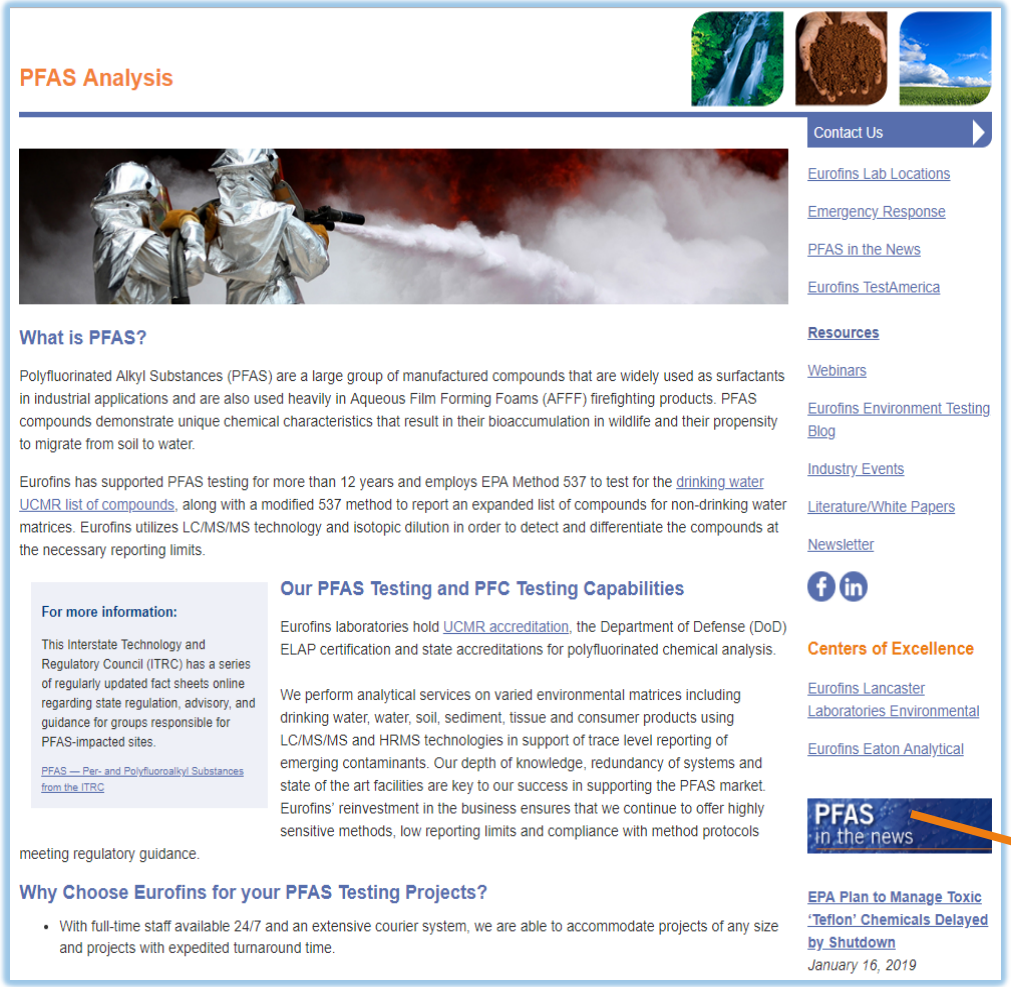
Future Methods - Other



Other EPA Initiatives

- Air method
- TOP Assay
- Total Organic Fluorine (TOF)
- Non-Targeted Analysis

Advisory Limits



PFAS Analysis

Contact Us

Eurofins Lab Locations

Emergency Response

PFAS in the News

Eurofins TestAmerica

Resources

Webinars

Eurofins Environment Testing Blog

Industry Events

Literature/White Papers

Newsletter

What is PFAS?

Polyfluorinated Alkyl Substances (PFAS) are a large group of manufactured compounds that are widely used as surfactants in industrial applications and are also used heavily in Aqueous Film Forming Foams (AFFF) firefighting products. PFAS compounds demonstrate unique chemical characteristics that result in their bioaccumulation in wildlife and their propensity to migrate from soil to water.

Eurofins has supported PFAS testing for more than 12 years and employs EPA Method 537 to test for the drinking water UCMR list of compounds, along with a modified 537 method to report an expanded list of compounds for non-drinking water matrices. Eurofins utilizes LC/MS/MS technology and isotopic dilution in order to detect and differentiate the compounds at the necessary reporting limits.

For more information:

This Interstate Technology and Regulatory Council (ITRC) has a series of regularly updated fact sheets online regarding state regulation, advisory, and guidance for groups responsible for PFAS-impacted sites.

PFAS — Per- and Polyfluoroalkyl Substances from the ITRC

Our PFAS Testing and PFC Testing Capabilities

Eurofins laboratories hold UCMR accreditation, the Department of Defense (DoD) ELAP certification and state accreditations for polyfluorinated chemical analysis.

We perform analytical services on varied environmental matrices including drinking water, water, soil, sediment, tissue and consumer products using LC/MS/MS and HRMS technologies in support of trace level reporting of emerging contaminants. Our depth of knowledge, redundancy of systems and state of the art facilities are key to our success in supporting the PFAS market. Eurofins' reinvestment in the business ensures that we continue to offer highly sensitive methods, low reporting limits and compliance with method protocols meeting regulatory guidance.

Why Choose Eurofins for your PFAS Testing Projects?

- With full-time staff available 24/7 and an extensive courier system, we are able to accommodate projects of any size and projects with expedited turnaround time.

Centers of Excellence

Eurofins Lancaster Laboratories Environmental

Eurofins Eaton Analytical

PFAS in the news

EPA Plan to Manage Toxic 'Teflon' Chemicals Delayed by Shutdown

January 16, 2019

- Eurofins keeps an up-to-date newsfeed regarding all things PFAS at: EurofinsUS.com/PFAS
- Interstate Technology Regulatory Council (ITRC) keeps an updated listing of pending advisories, regulation, and guidance: ITRC Table 4-1

(https://pfas-1.itrcweb.org)

Eurofins Capacity



- Isolated PFAS laboratory
- 6 dedicated systems over multiple shifts
- Data meets or exceeds all EPA Public Health Advisory limits and state drinking water guidance

Eurofins Capacity



- Capacity
  - ELLE
  - EEA (Monrovia and South Bend)
  - ETA facilities (West Sacramento, Denver, Burlington)
- Technical Expertise
- Analytical offerings
  - drinking water method 537
  - Isotope dilution method (NPW, solids, tissue)
  - DoD compliant isotope dilution
  - Replacement compounds (GenX, Adona)
  - TOP Assay

Questions



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Bureau of Environmental Cleanup & Brownfields

PFAS Toxicity Overview

PA Brownfields Conference

March 11, 2020

Brie Sterling

Tom Wolf, Governor

Patrick McDonnell, Secretary

Health Effects of PFOA and/or PFOS

- Animal
  - ❑ Liver effects
  - ❑ Immunological effects
  - ❑ Developmental effects
  - ❑ Endocrine effects (thyroid)
  - ❑ Reproductive effects
  - ❑ Hematological (blood) effects
  - ❑ Neurobehavioral effects
  - ❑ Tumors (liver, testicular*, pancreatic*)

*PFOA ONLY

- Human (possible links)
  - ❑ Liver effects (serum enzymes/bilirubin, cholesterol)
  - ❑ Immunological effects (decreased vaccination response, asthma)
  - ❑ Developmental effects (birth weight)
  - ❑ Endocrine effects (thyroid disease)
  - ❑ Reproductive effects (decreased fertility)
  - ❑ Cardiovascular effects (pregnancy induced hypertension)
  - ❑ Cancer* (testicular, kidney)

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Health Effects of PFOA and/or PFOS

Serum half-life	PFBS (C4)	PFHxS (C6)	PFOS (C8)	PFBA (C4)	PFHxA (C5)	PFOA (C8)	PFNA (C9)
Mouse	NA	26-29 days	34-40 days	2.9-13 hours	~1 hour	17-19 days	26-69 days
Humans	26 days*	4.7-7.4 years	3.4-7.4 years	3-3.6* days	32 days*	2.3-4.6 years	2.5-12 years

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Toxicology of Other PFAS

- Information for small number of other PFAS in peer-reviewed literature, National Toxicological Program studies; chemical registration information (REACH dossiers, TSCA submittals); and EPAs CompTox program files

- Most focus on PFCAs and PFSAs, the perfluoroalkyl acid “families” to which PFOA and PFOS belong, also GenX. Some information on ADONA, fluorotelomer alcohols

- Long-chain PFAAs appear to have generally similar effects in animal studies (developmental, immune, liver, etc.)

- Animal data for short-chain PFAAs also show effects similar to long-chain although at higher doses

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	# of Carbons	Liver	Developmental	Reproductive	Immune	Hematologic	Thyroid	Neurobehavioral	Tumors
Perfluoroalkyl Carboxylates									
PFBA	4	■	■	■	□	■	■	□	□
PFPeA	5	□	□	□	□	□	□	□	□
PFHxA	6	■	■	■	□	■	■	□	□ (Negative)
PFHpA	7	■	□	□	□	□	□	□	□
PFOA	8	■	■	■	■	■	■	■	■
PFNA	9	■	■	■	■	■	■	□	□
PFDA	10	■	■	■	■	■	■	■	□
PFUnA	11	■	■	□	■	□	□	□	□
PFDoA	12	■	■	■	■	■	□	■	□
Perfluoroalkyl Sulfonates									
PFBS	4	■	■	■	■	■	■	□	□
PFHxS	6	■	■	□	□	■	■	■	□
PFOS	8	■	■	■	■	■	■	■	■
Per- & Polyfluoroalkyl Ether Replacements									
ADONA	6	■	■	□	□	■	□	□	□
HFPO-DA GenX	6	■	■	■	■	■	■	□	■

■ Effect reported in one or more laboratory animal study

□ Effect was evaluated but not found, or effect has not been evaluated

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Carcinogenic Potential of PFAS

- PFOA
  - IARC - “Possibly carcinogenic to humans” (Group 2B)
  - USEPA - “Suggestive evidence of carcinogenic potential in humans” Oral cancer slope factor (SF) for PFOA of 0.07 $(mg/kg\text{-}day)^{-1}$
- PFOS
  - USEPA – “Suggestive evidence of carcinogenic potential in humans”. Data insufficient for quantitative assessment
- GenX
  - USEPA (draft) – “Suggestive evidence of carcinogenic potential in humans”. Data insufficient for quantitative assessment
- PFHxA
  - Did not induce tumors in male or female rats (Klaunig et al., 2015)

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Example Toxicity Values (Noncancer)

Chemical	Type	Value (ng/kg-day)	Source	Notes
PFOA	Oral RfD	20	USEPA 2016 (May)	Mice: developmental - reduced ossification, accelerated puberty
	Oral RfD	0.45	OEHHA 2019 (August)	Mice: hepatic mitochondrial membrane potential changes and increased apoptosis and oxidative DNA damage
	Oral MRL	3	ATSDR 2018 (June) DRAFT	Mice: altered activity and skeletal alterations in offspring
PFOS	Oral RfD	20	USEPA 2016 (May)	Rat: reduced pup body weight
	Oral RfD	1.8	OEHHA 2019 (August)	Mice: decreased plaque forming cell response
	Oral MRL	2	ATSDR 2018 (June) DRAFT	Rat: delayed eye opening, decreased pup body weight, UF immune effects
PFNA	Oral RfD	0.74	NJDEP 2015 (June)	Mice: increased maternal liver weight
	Oral MRL	3	ATSDR 2018 (June) DRAFT	Mice: decreased offspring body weight and developmental delays
PFHxS	Oral MRL	20	ATSDR 2018 (June) DRAFT	Rat: thyroid follicular cell damage

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Comparison: PFOA and PFOS

Source	*Noncancer toxicity values for human health risk assessment (ng/kg body weight*day)*			
	PFOA	*Basis*	*PFOS*	*Basis*
USEPA (2016)	20	Delayed bone development and accelerated male puberty in mice (following developmental exposure)	20	Reduced growth of offspring (following developmental exposure)
ATSDR (2018) DRAFT	3	Behavioral and skeletal effects in mice (following developmental exposure) USEPA reviewed but did not select the study on behavioral effects; skeletal effects data published after USEPA analysis	2	Used same study as USEPA as the main basis Added a 10X uncertainty factor to protect for immunotoxicity

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Questions?

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