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# Per- and Polyfluoroalkyl Substances (PFAS) in Water – An Overview of WRF's Initiatives

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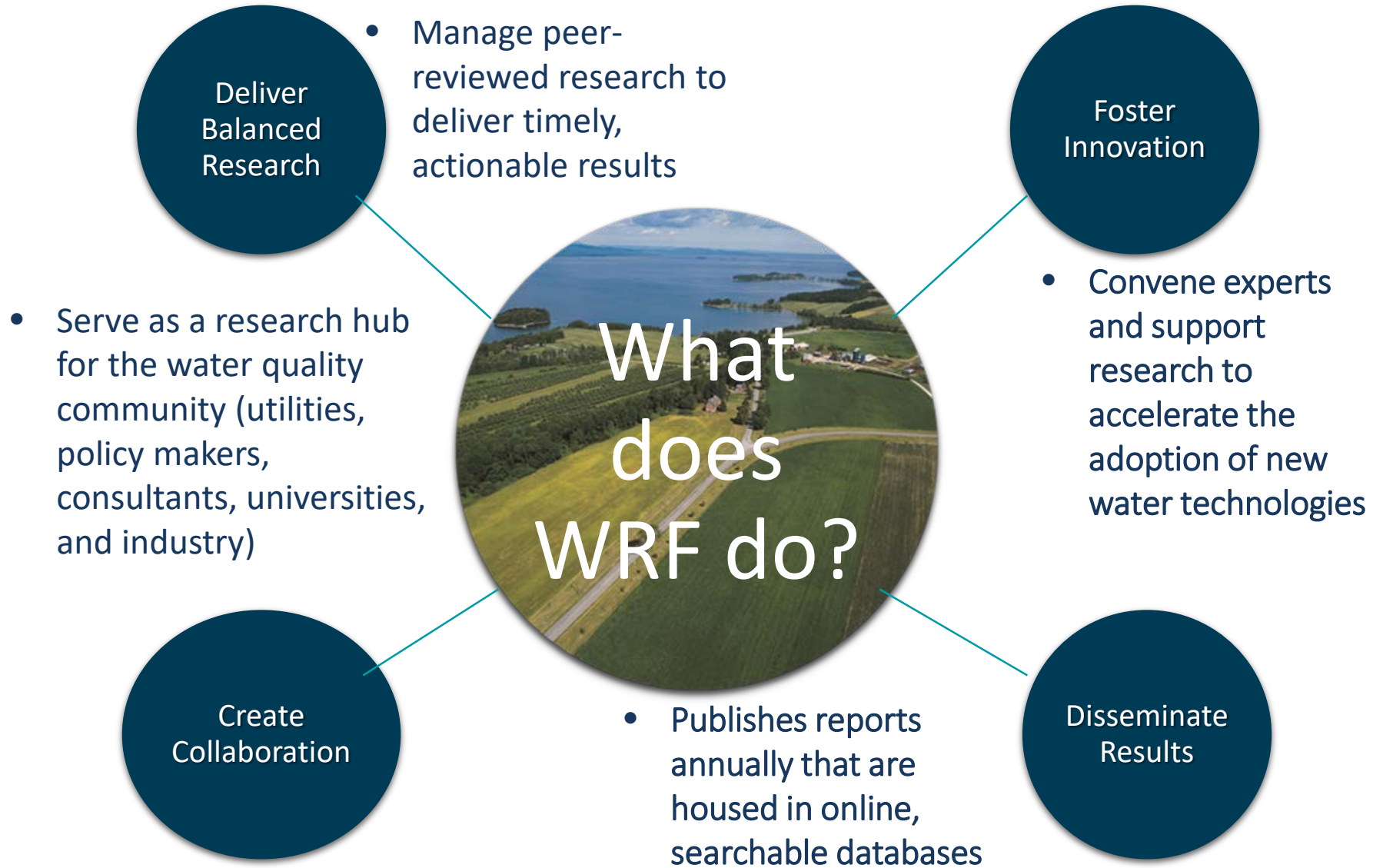
Government Affairs Seminar

February 21, 2019



# Presentation Outline

- WRF 101
- PFAS Background
  - Regs
  - Occurrence
  - treatment
- WRF Research and Resources
- Conclusions
- Parting Thoughts



# Evolution of The Water Research Foundation



2016



2018

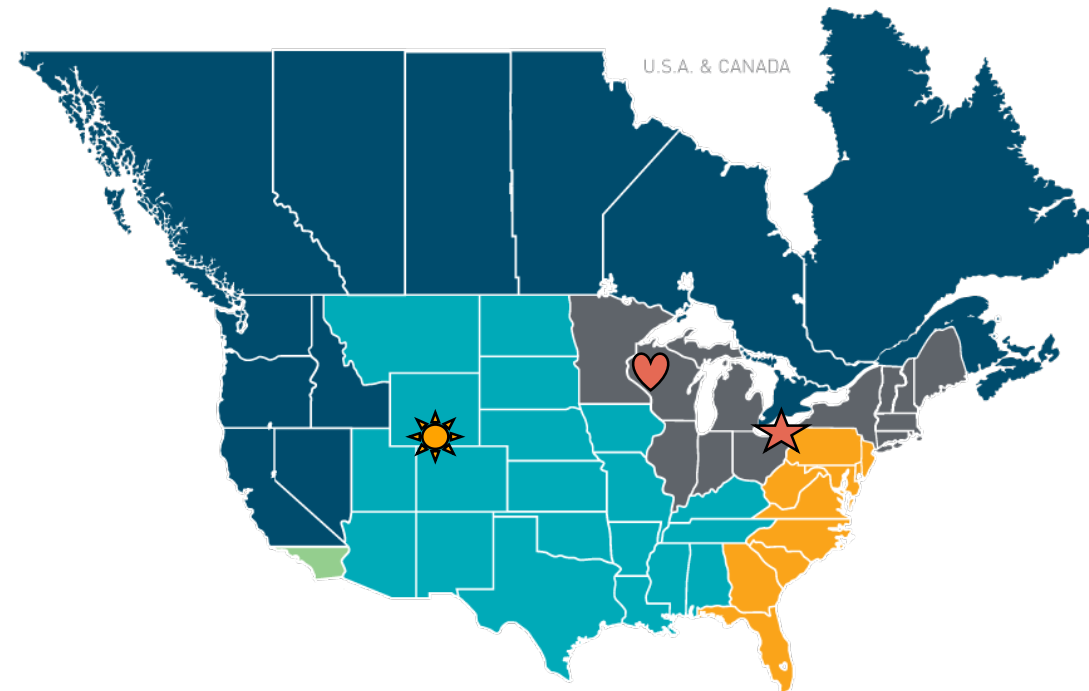
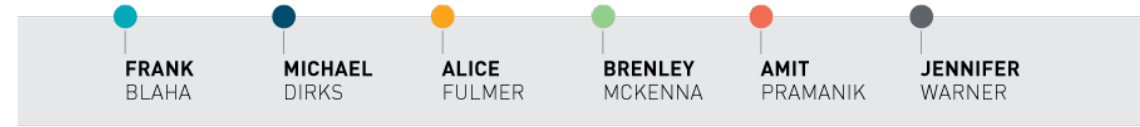


- Represents the evolution of water research
  - 2,300 research studies
  - \$700M integrated research portfolio
  - 1,200 subscribers

# Regional Liaison Service Areas

## Services Provided:

- Quarterly Regional Updates
- In-person Meetings
- Regional, topical workshops
- Guidance navigating resources and research



# PFAS in the Headlines

**THE U.S. MILITARY IS SPENDING MILLIONS TO REPLACE TOXIC FIREFIGHTING FOAM WITH TOXIC**

Fish advisories issued for Michigan lakes, river impacted by PFAS contamination

Updated Mar 16; Posted Mar 15



**Clarendon, Vt., Businesses React To Contaminated Water Notice From State**



Contaminant found in drinking water of 11 properties near landfill



**Washington could ban cancer-causing chemicals used to fight fires**

Drinking water in three Colorado cities contaminated with toxic chemicals above EPA limits

80,000 people south of Colorado Springs being warned of high levels of PFCS in water

# PFAS in the Headlines

## Federal budget bill includes \$10M for PFAS health study, \$85M for cleanup

By Kyle Bagenstose



Posted Mar 22, 2018 at 1:51 PM  
Updated Mar 23, 2018 at 12:15 PM



The bill could fund a nationwide health study that would include residents of Bucks and Montgomery counties who were exposed to PFAS in drinking water.

## Michigan bill proposes nation's lowest PFAS limit in drinking water



# What are PFAS?

- **Per- and poly**fluoroalkyl substances (PFAS) are a class of man-made chemicals
- Carbon-Fluorine bond → shortest and strongest chemical bond in nature
- Persistent, resistant to degradation
- PFAS family → thousands of diverse compounds
- Found globally in people, wildlife and fish

# PFAS Family of Chemicals

## TERMS

PFC = Perfluorinated Compound

PFAS = Perfluoroalkyl or  
Polyfluoroalkyl Substance

PFOA = Perfluorooctanoic Acid  
 $C_8HF_{15}O_2$

PFOS = Perfluorooctane Sulfonate  
 $C_8HF_{17}O_3S$

GenX =  $C_6H_4F_{11}NO_3$

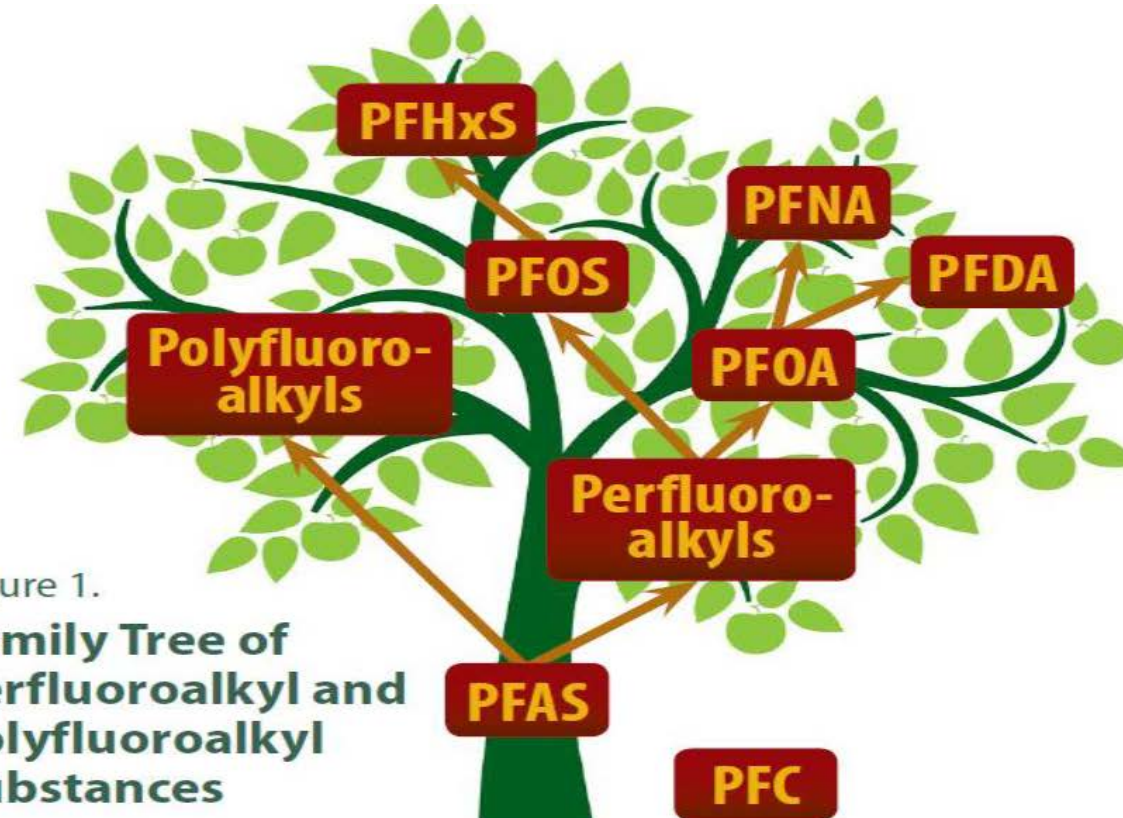
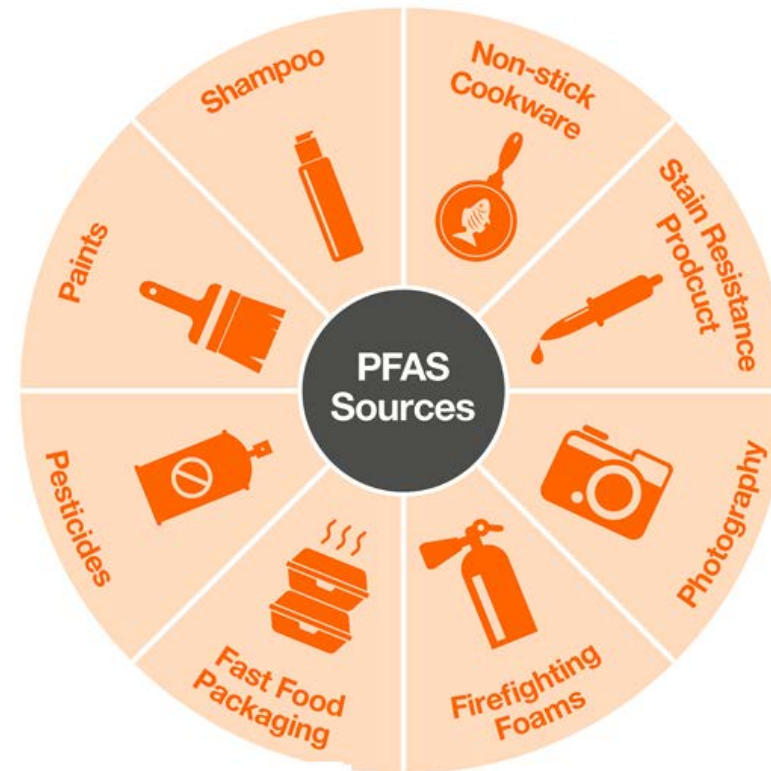


Figure 1.  
**Family Tree of  
Perfluoroalkyl and  
Polyfluoroalkyl  
Substances**

Source: [https://www.atsdr.cdc.gov/docs/17\\_278160-A\\_PFAS-FamilyTree-508.pdf](https://www.atsdr.cdc.gov/docs/17_278160-A_PFAS-FamilyTree-508.pdf)

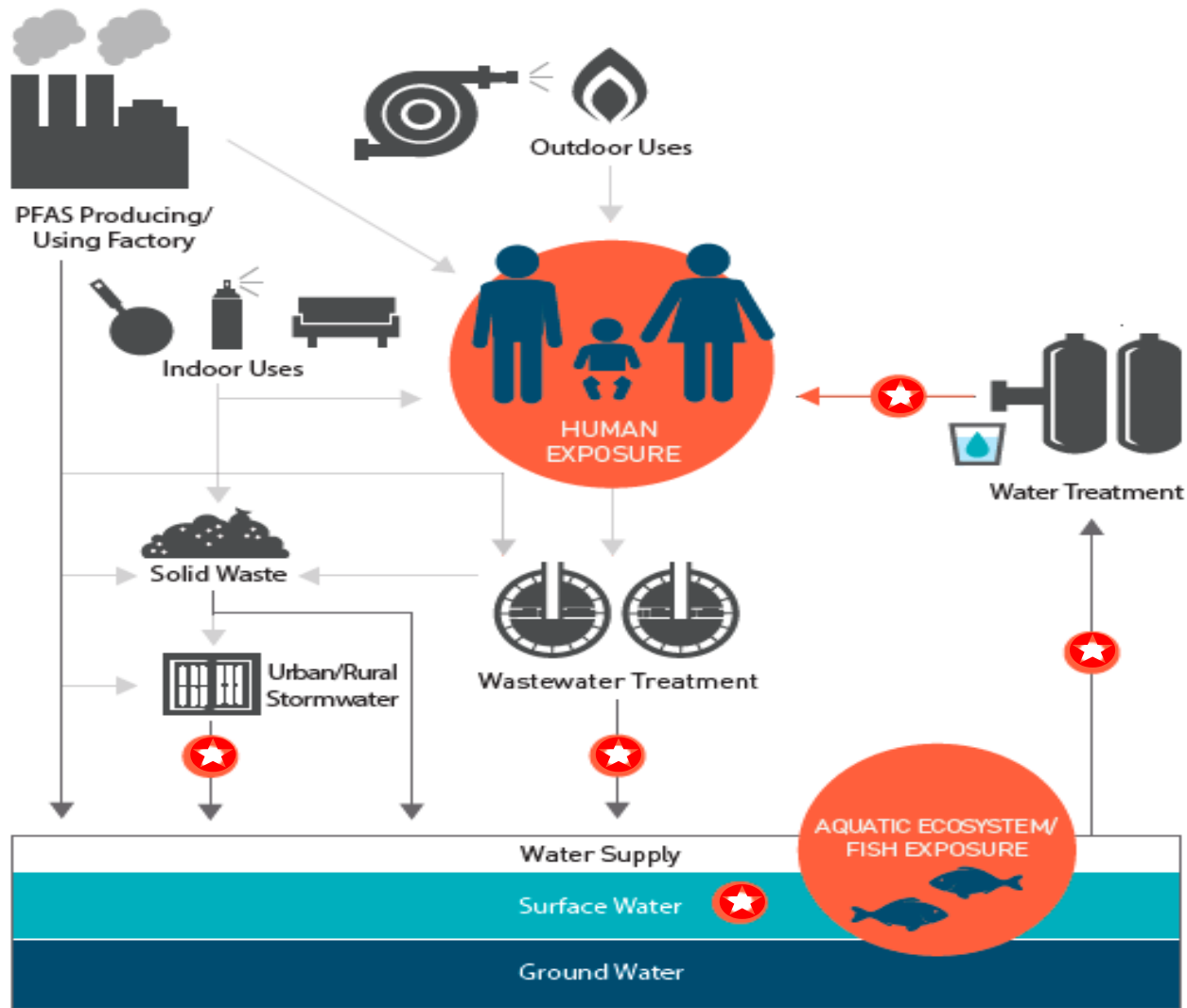
# Uses of PFAS

- Commercial and consumer products containing PFAS were first introduced in the 1950s
- PFAS have been used for many years to make products that resist heat, stains, grease and water



<http://www.defence.gov.au>

# Human Exposure to PFAS



# Biomonitoring NHANES PFAS Data

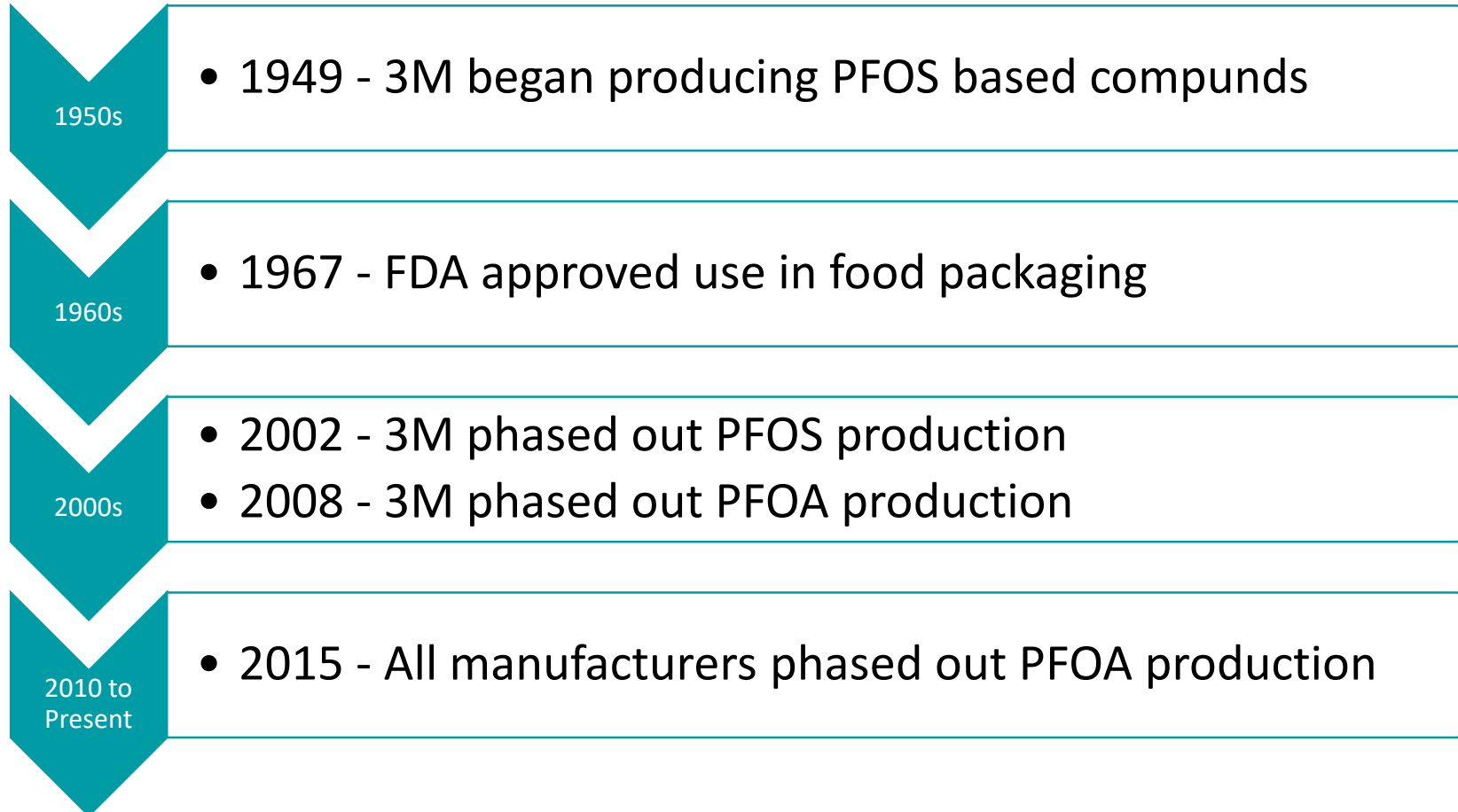
PFAS in serum		99-00*	03-04 -----11-12	13-14
Short-alkyl chain	PFBS		X	X
	PFHpA	X	X	X
Long-alkyl chain	PFHxS	X	X	X
	PFOS	X	X	X <sup>a</sup>
	PFOA	X	X	X <sup>a</sup>
	PFNA	X	X	X
	PFDA	X	X	X
	PFUnDA	X	X	X
	PFDODA	X	X	X
	FOSA	X	X	
	EtFOSAA	X	X	
	MeFOSAA	X	X	X

\*No serum available in 2001-2

<sup>a</sup>Measured as isomers



# History of PFAS



# Potential Health Effects – Further Research Needed

- Animals
  - Increased liver weight (critical effect)
  - Spleen, thymus, and developmental
  - Cancer—liver, testis, pancreas
- Humans
  - Possible changes in growth, learning and behavior
  - Decreased fertility
  - Increased cholesterol
  - Immune effects
  - Cancer—kidney, bladder, testicular, prostate

# Regulations

- No Federal Regulations *but* EPA released Action Plan

- Health Advisories

***EPA Provisional Health Advisory, 2009***

*Short-term* adverse health effects

PFOS: 200 ppt, PFOA: 400 ppt

***EPA Health Advisory, 2016***

*Long-term* adverse health effects

PFOS: 70 ppt, PFOA: 70 ppt, PFOS + PFOA: 70 ppt

“EPA's health advisories are **non-enforceable and non-regulatory** and provide technical information to states agencies and other public health officials on health effects, analytical methodologies, and treatment technologies associated with drinking water contamination.”

# Proposed Or Established PFAS Standards/ Guidelines

State	Compound	Level (ppt)
<b>Connecticut</b>	Sum of PFOA, PFOS, PFNA, PFHxS, PFHpA	70
<b>Maine</b>	Sum of PFOA and PFOS	70
<b>Minnesota</b>	PFOA	35
	PFOS	27
	PFHxS	27
<b>New Hampshire</b>	Sum of PFOA and PFOS	70
<b>New Jersey</b>	PFNA	13
	PFOA	14
<b>North Carolina</b>	GenX	140
<b>Vermont</b>	Sum of PFOA and PFOS	20
<b>West Virginia</b>	Sum of PFOA and PFOS	70

# PFAS Analysis

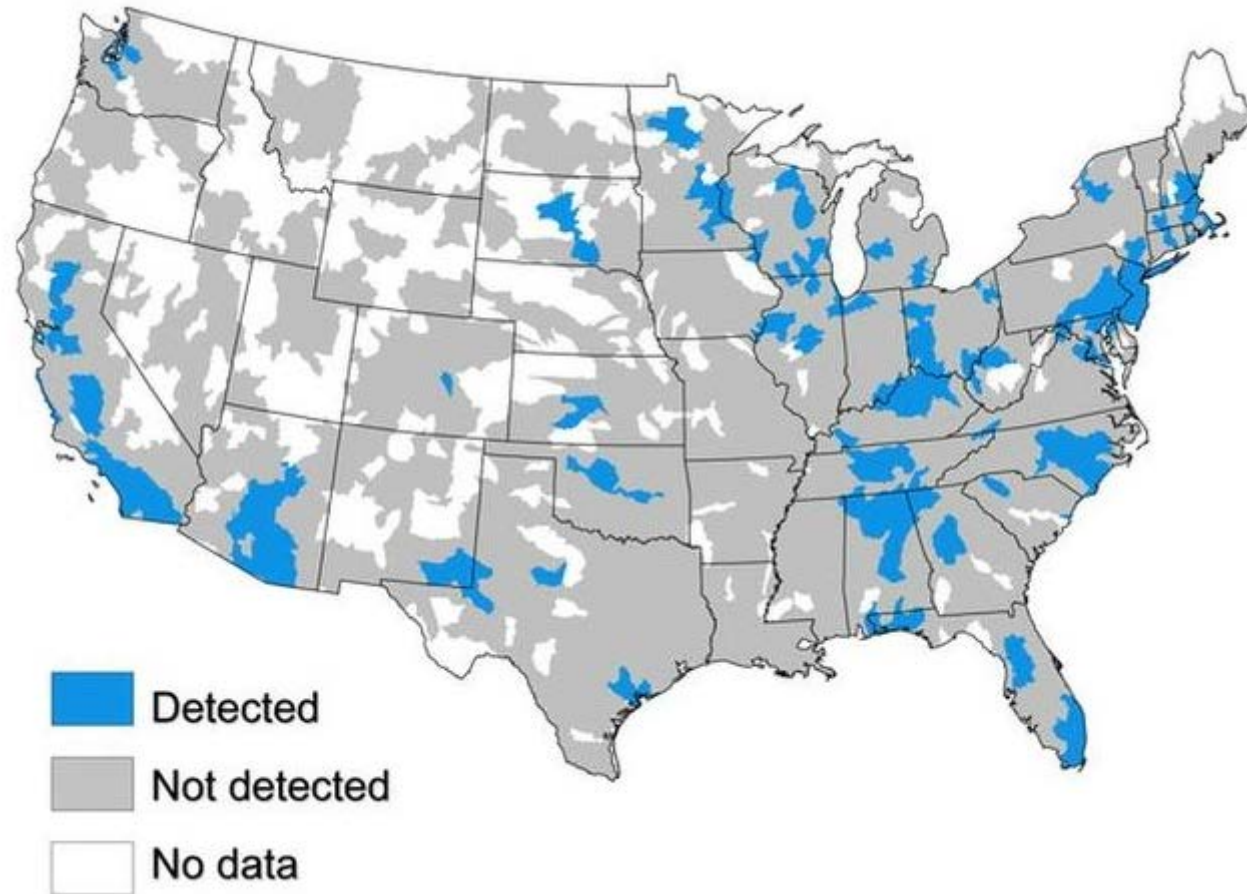
- EPA Method 537
- Perfluorinated alkyl acids
- Drinking water
- SPE, LC/MSMS
- 250mL sample
- MRLs < 1ng/L vs UCMR MRLs
- New EPA method coming

Table 2. PFASs detected by EPA Method 537 and UCMR3

PFAS	UCMR (Y/N)	EPA HA Conc (µg/L)	UCMR MRL (µg/L)	UCMR PWSs > MRL	UCMR PWSs > Ref Conc	% PWSs > Ref Conc	Max Conc (µg/L) <sup>1</sup>
PFHxA	N						
PFHpA	Y		0.01	82			0.09
PFOA	Y	0.07	0.02	107	11	0.2	0.35
PFNA	Y		0.02	14			0.06
PFDA	N						
PFUnA	N						
PFDoA	N						
PFBS	Y		0.09	6			0.37
PFHxS	Y		0.03	54			0.73
PFOS	Y	0.07	0.04	91	44	0.9	1.8
<i>N</i> -MeFOSAA	N						
<i>N</i> -EtFOSA A	N						

<sup>1</sup>Based on UCMR data available as of January 2016

# PFAS Occurrence



Source: Hu XC et al., Environmental Science & Technology Letters



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# PFAS Research and Resources





# Per- and Polyfluoroalkyl Substances: Background Technical Information



October 2018

[Kenan Ozekin](#) and [Alice Fulmer](#), The Water Research Foundation



## Treatment Mitigation Strategies for Poly- and Perfluoroalkyl Substances

Web Report #4322

Subject Area: Water Quality



## Removal of Perfluoroalkyl Substances by PAC Adsorption and Anion Exchange

Web Report #4344

Subject Area: Water Quality



# PFAS Removal Summary – WRF Project 4322

		Removal <10%	Removal 10-90%	Removal > 90%						
Compound	M.W. (g/mol)	AER	COAG/DAF	COAG/ FLOC/SED/ G- or M- FIL	AIX	GAC	NF	RO	MnO <sub>4</sub> , O <sub>3</sub> ClO <sub>2</sub> , CLM, UV, UV-AOP	
	PFBA	214	assumed	assumed						
	PFPeA	264								
	PFHxA	314								
	PFHpA	364								
	PFOA	414								
	PFNA	464		unknown		assumed	assumed			
	PFDA	514		unknown		assumed	assumed			
	PFBS	300								
	PFHxS	400								
	PFOS	500								
	FOSA	499	unknown	unknown		unknown	assumed	unknown	assumed	unknown
	N-MeFOSAA	571	assumed	unknown		assumed	assumed	assumed		unknown
N-EtFOSAA	585		unknown		assumed	assumed	assumed		unknown <sup>a</sup>	



# Point of Entry / Point of Use

- GAC, AIX, RO can be used in POU/POE devices such as whole house water filtration units or systems installed under sinks or in refrigerators
- Can be effective for PFAS BUT questions remain regarding:
  - Removal efficiency
  - Maintenance (how often to change the media, and responsibility for maintenance if for compliance)
  - Cost
- Raise social justice concerns, since not all can afford

# WRF Focus Area “Management, analysis, removal, fate and transport of per- and polyfluoroalkyl substances (PFAS) in water”

## Objectives:

1. Assess effectiveness of analytical methods
2. Evaluate vulnerability of waters to PFAS, identify sources and hotspots
3. Understand behavior, fate, and transport of PFAS in treatment and environment
4. Evaluate treatment for removing PFAS and reliability of technologies
5. Develop risk communication strategies

# Multi-Year Research Agenda

In Contracting: Investigation of Treatment Alternatives for Short-Chain PFAS

## Future Years:

- Development of An Analytical Procedure For Total PFAS Measurement In Drinking Water, Natural Water, And Wastewater
- Interlaboratory Studies of PFAS Methods
- Qualitative Structure Activity Relationships For Predicting Removal of New and Emerging PFAS
- PFAS Residual Handling And Treatment Options

# WRF Project U2R16 “Concept Development of Chemical Treatment Strategy for PFOS-Contaminated Water”

- University of Texas at Austin
- Proof of concept project to determine if advanced oxidation integration (AIR) with chemical reduction using zerovalent iron (Fe) nanoparticles conjugated with common oxidants (FECO) is able to decompose PFOS
- Hypothesis is that AIR strategy has a high potential to decompose PFOS through oxidative decomposition with reductive dehalogenation

# WRF DoD PFAS Project

- **Evaluation and Life Cycle Comparison of Ex-Situ Treatment Technologies for Poly- and Perfluoroalkyl Substances (PFAS) in Groundwater**
- Research Team: Colorado School of Mines (Chris Bellona, Chris Higgins), North Carolina State University (Detlef Knappe), University of Colorado – Boulder (Sherri Cook), CDM Smith (Charles Schaefer)
- Budget \$1,090,000

# WRF DoD Project Objectives

- To compare established & emerging PFAS treatment approaches on a life-cycle assessment (LCA) and costing (LCC) basis
- To provide a framework for selection of effective treatment technologies

# PFAS Conclusions

- PFAS are useful in society, *but* extremely persistent and bioaccumulative
- No Federal Regulations – Health Advisories and different state initiatives – communication challenges
- Conventional treatment ineffective for PFAS
- AIX treatment preferably remove longer-chain PFAS
- RO and NF demonstrate significant removal for all PFAS
- Tradeoffs of replacement compounds – harder to remove from water but less persistent

# Parting Thoughts

- CECs are a moving target, as science evolves
- Multiple routes of exposure
- Emerging → Emerged → Re-emerging
- Regulatory challenges to keep up with new or replacement compounds
- Consider unintended consequences
  - Byproducts, residuals, biosolids, fate and transport, replacement chemicals, GHGs, rate impacts on affordability of water, ...
- Destructive treatment vs removal using media that requires disposal or further treatment
- Scientists need communication training
- *Need more research!*



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