

Occurrence, Removal, and Destruction
of
Per- and Poly-fluoroalkyl Substances
(PFAS)

Madjid Mohseni, PhD, PEng
Department of Chemical and Biological Engineering
RESEAU Centre For Mobilizing Innovation



13th Annual Science Advisory Board for Contaminated Sites Workshop
September 27, 2023
Vancouver, BC



Water

US drinking water contamination with 'forever chemicals' far worse than scientists thought

The Intercept

EUROPEAN COUNTRIES ANNOUNCE PLAN TO PHASE OUT TOXIC PFAS CHEMICALS BY 2030

A strategy report submitted to the European Commission maps out a comprehensive attack on PFAS chemicals, which have contaminated water around the world.

Sharon Lerner
December 19 2019, 9:48 a.m.

Study by U of T, international researchers finds potentially harmful 'forever chemicals' in makeup: CBC



PFAS chemical found in chocolate cake

US FDA scientists present unpublished data on PFAS in food
by *Britt E. Erickson*
June 7, 2019 | A version of this story appeared in **Volume 97, Issue 23**



Credit: Shutterstock

PFAS are in face masks. Should you be concerned?



Cloth and disposable face masks are viewed as part of packages handed out to small businesses in July 2020 in Orlando, Fla. Photo: M. Eberhack via AP

Firefighting Foam & PFAS: What You Need to Know

by Micah Dickinson | Feb 16, 2022 | Fire Protection Solutions, Oil and Gas Fire Safety | 0 comments



Toxic PFAS chemicals used in packaging can end up in food, study finds

Compostable packaging is popular for environmental reasons, but it can be treated with 'forever chemicals' linked to health problems



"A PERFECT FILM. RIVETING, POWERFUL AND IMPORTANT"
OBSERVER

A FILM BY TODD HAYNES

MARK RUFFALO ANNE HATHAWAY TIM ROBBINS
BILL CAMP VICTOR GARBER AND BILL PULLMAN

DARK WATERS

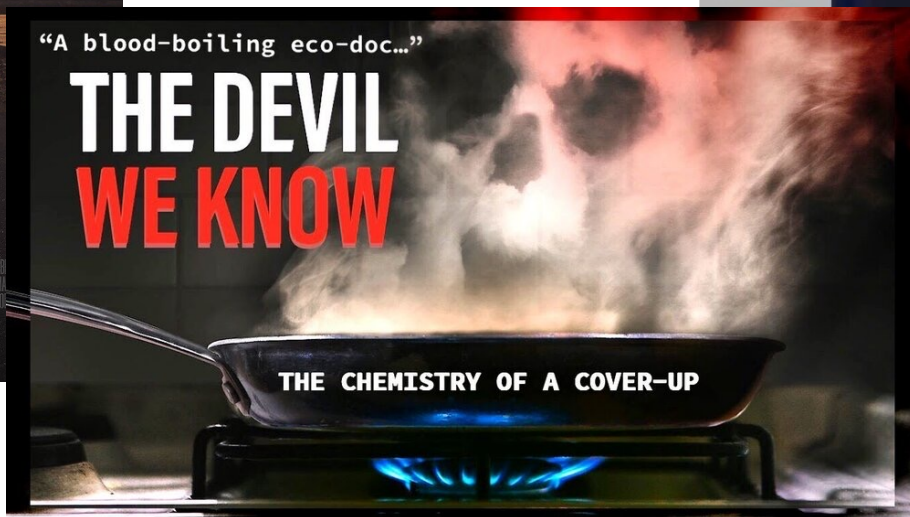
ONE OF THE DEADLIEST COVER-UPS
IN AMERICAN HISTORY



PARTICIPANT presents a WILL HILL/KILLER CONTENT production a TODD HAYNES film "DARK WATERS" MARK RUFFALO ANNE HATHAWAY TIM ROBBINS BILL CAMP VICTOR GARBER MAKE WOODINGHAM and
CASTING BY LAURA ROSENTHAL COSTUME DESIGNER RANDALL PROSTER EXECUTIVE PRODUCERS MARCELO ZAROVIS DESIGNER CHRISTOPHER PETERSON PRODUCED BY AFONSO BUNICALVES AND PRODUCED BY DANAHIL DE ACHILLES WRITTEN BY EDUARDO LACOMBA
DIRECTED BY TODD HAYNES PRODUCED BY JEFF SKOLL JONATHAN KING ROBERT KESSLER MACRAE SLEED PRODUCED BY MARK RUFFALO CHRISTINE WACHON PAMELA KOFFLER PRODUCED BY MARIO CORREA AND MATTHEW MICHAEL BARNHART PRODUCED BY
eOne VILLAGE CINEMA IN CINEMAS SOON © 2019 ENTERTAINMENT WEEKLY CO., LLC

John Oliver on protecting against 'forever chemicals': 'It shouldn't just be on us as individuals'

The Last Week Tonight host digs into contamination by non-biodegradable 'forever chemicals' in household wares and corporate cover-up of its health effects



What are PFAS?

Perfluorooctanoic acid (PFOA)

Functional group
(hydrophilic)

Strong C-F bonds
(hydrophobic)

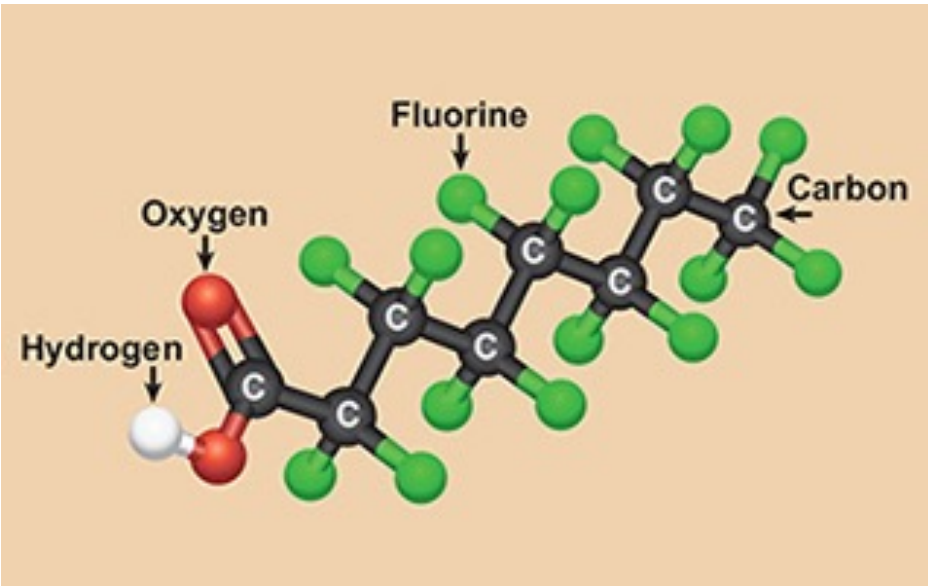


Image: NIEHS.nih.gov

Thermal Stability



Hydrophobic &
Lipophobic
properties

Surfactant
Properties

Chemical Resistance



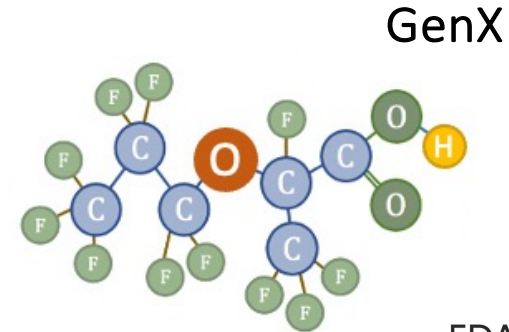
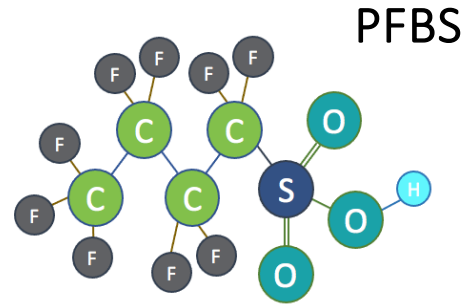
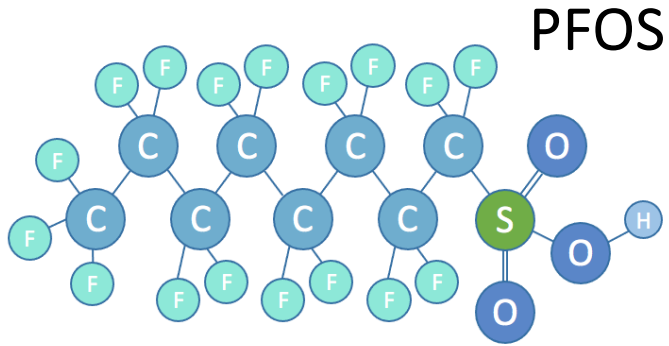
Water solubility
and mobility in
groundwater

Recalcitrance in
environment

What are PFAS?

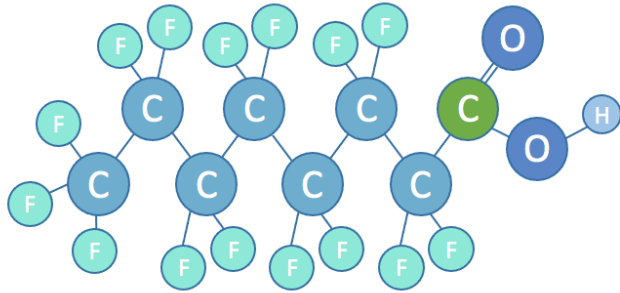
Long-chain

>12000 forms

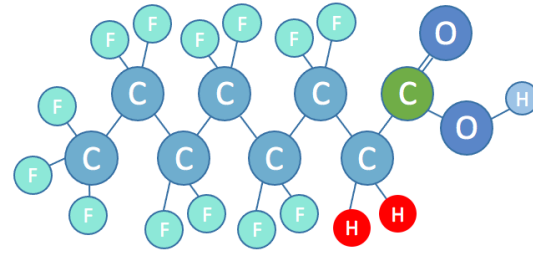


Transition

PFOA



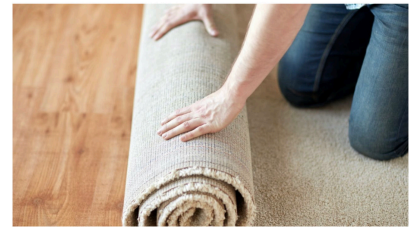
6:2 FTCA



FDA Studies: 'Short-chain' PFAS Chemicals More Toxic Than Previously Thought

By David Andrews Ph.D. (EWG)

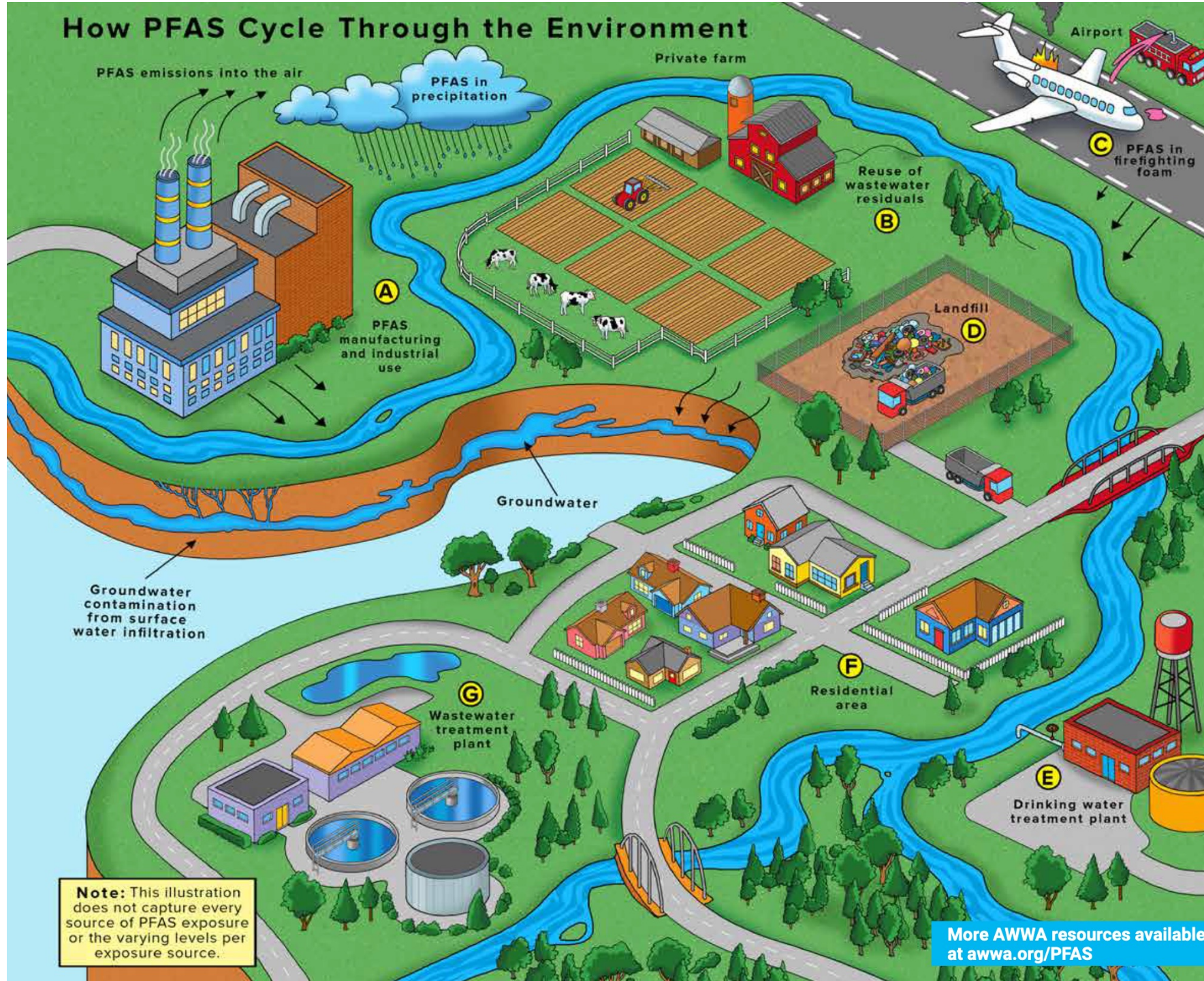
MARCH 9, 2020



PFAS Applications



How PFAS Cycle Through the Environment

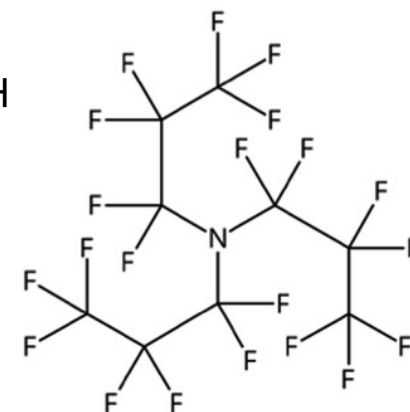
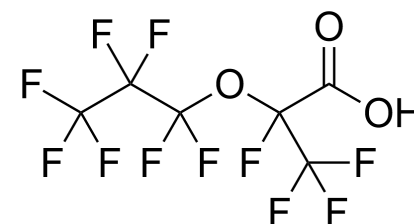
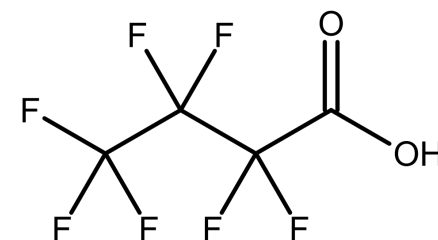
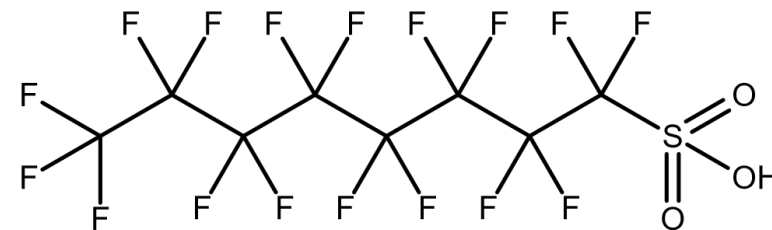


Note: This illustration does not capture every source of PFAS exposure or the varying levels per exposure source.

More AWWA resources available at awwa.org/PFAS

What PFAS Matter? “All PFAS”?

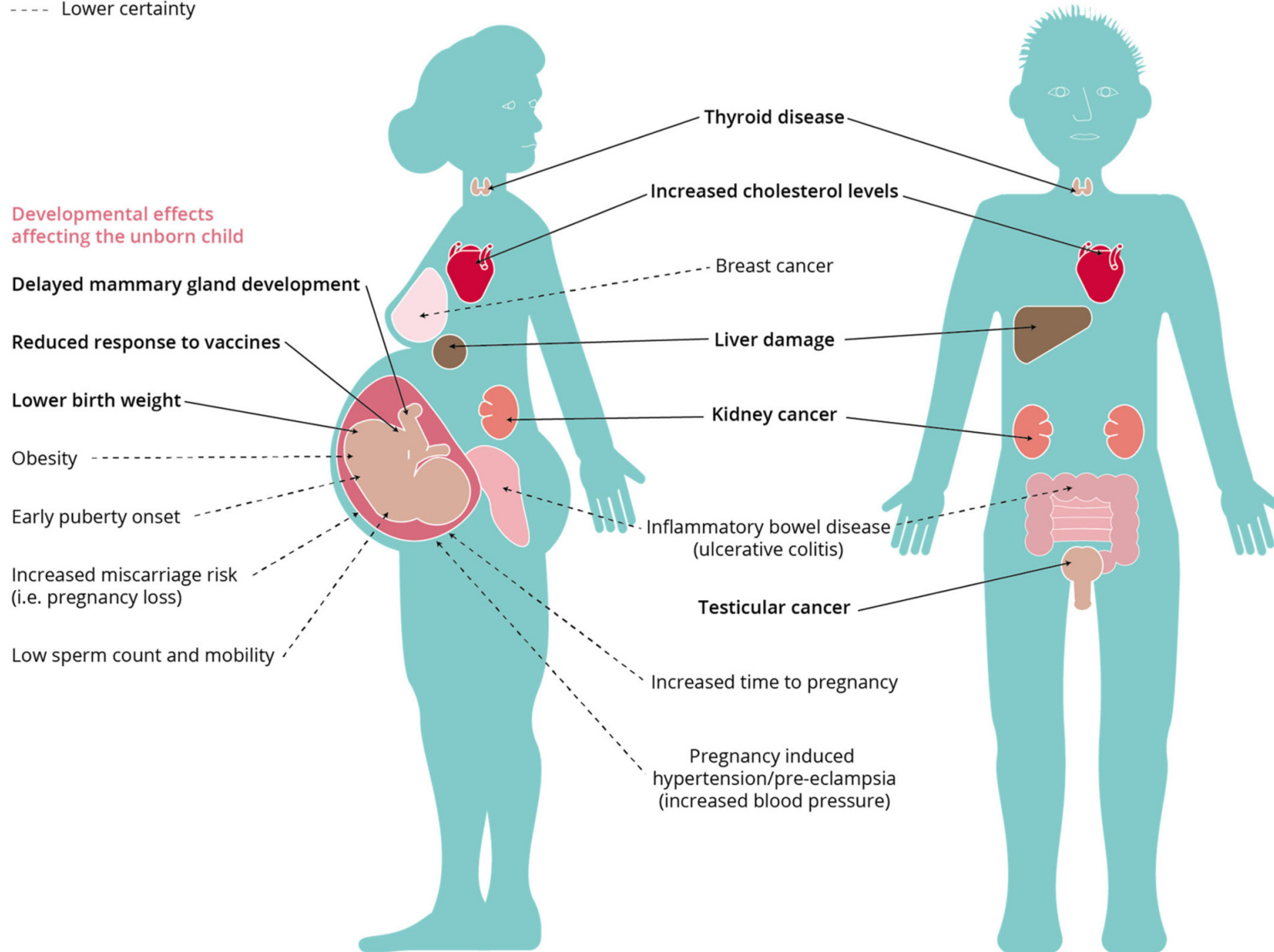
PFAS List	#
EPA’s Contaminant Candidate List 5	10,239
Actually in industry /commercial products today	~ 600
Academic Lab’s analyte list	~ 440
Commercial labs – environmental samples analyte list	~ 30 - 70
Standardized method for water	40
Toxicity value (human health)	~ 8



Effects of PFAS on Human Health

— High certainty

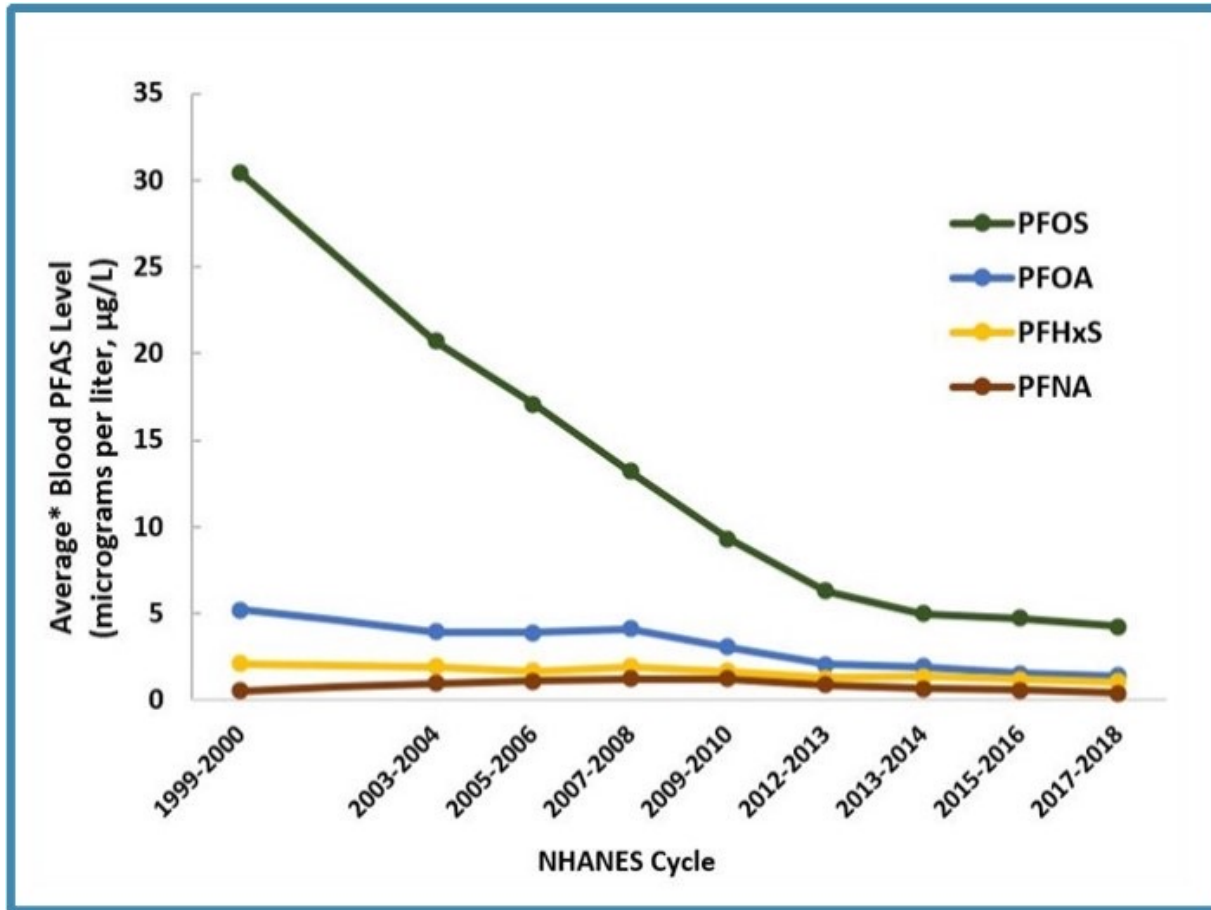
- - - Lower certainty



- Immune function
- Thyroid function/disease
- Liver disease/cancer
- Metabolic Dysfunction
- Kidney disease/cancer
- Repro & Developmental Outcomes

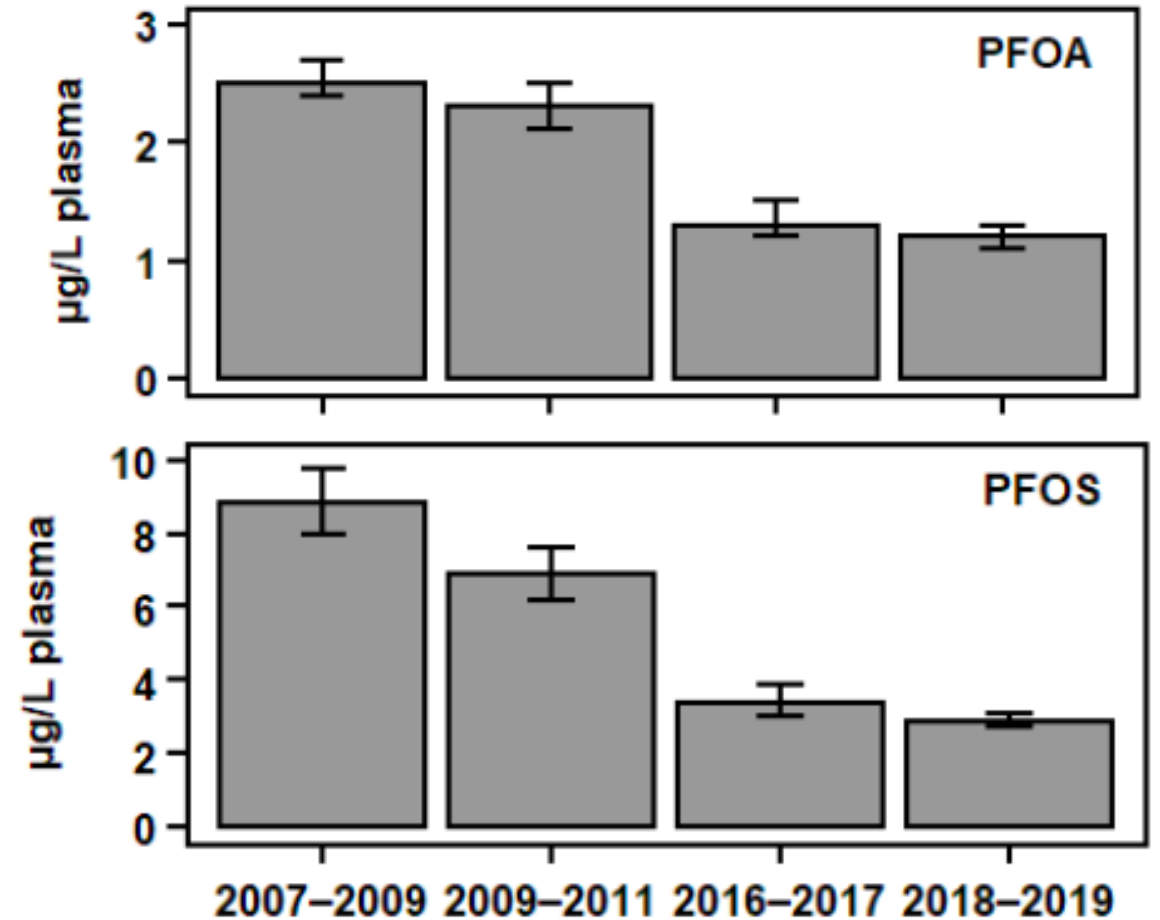
PFAS in People

Blood Levels of the most common PFAS in people in the US



Source: U.S. CDC and Prevention

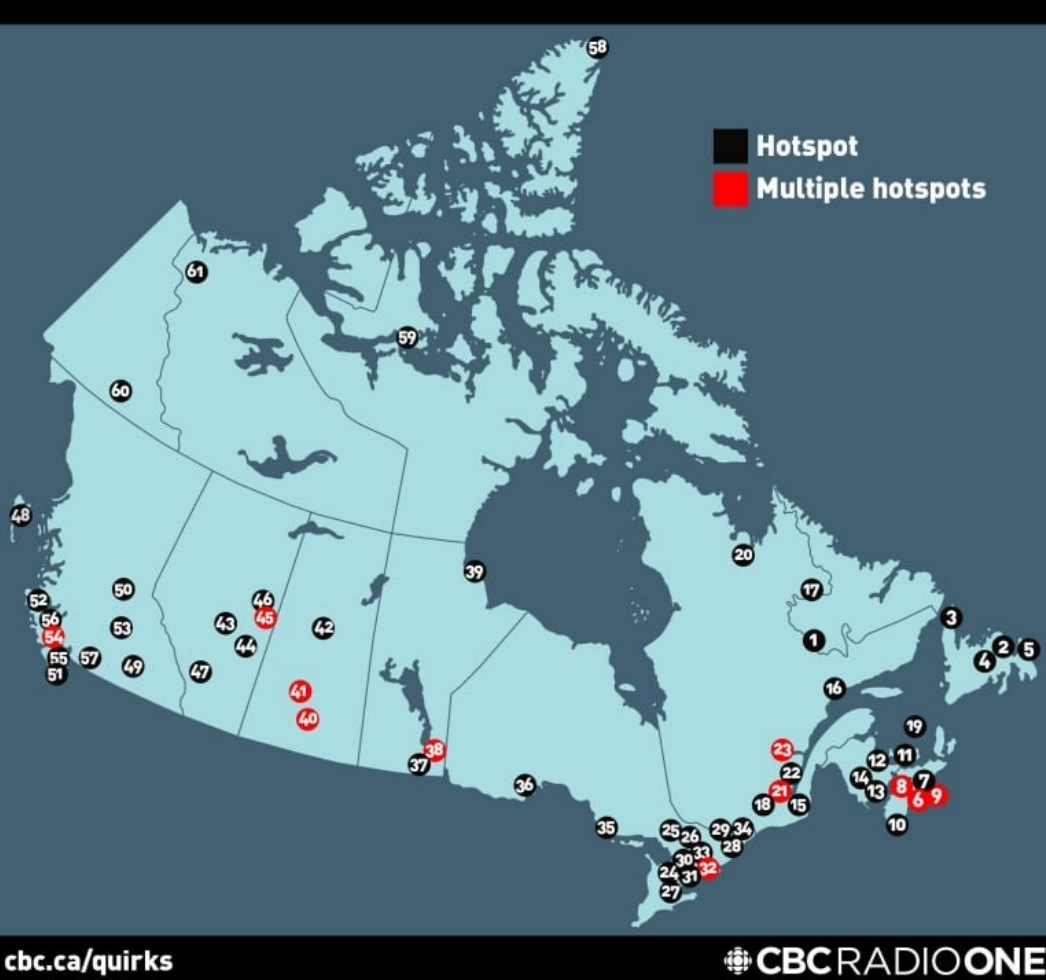
Blood Levels of the PFOA and PFOS in people in Canada



Source: Health Canada

PFAS Occurrence in Canada

PFAS HOTSPOTS IN CANADA

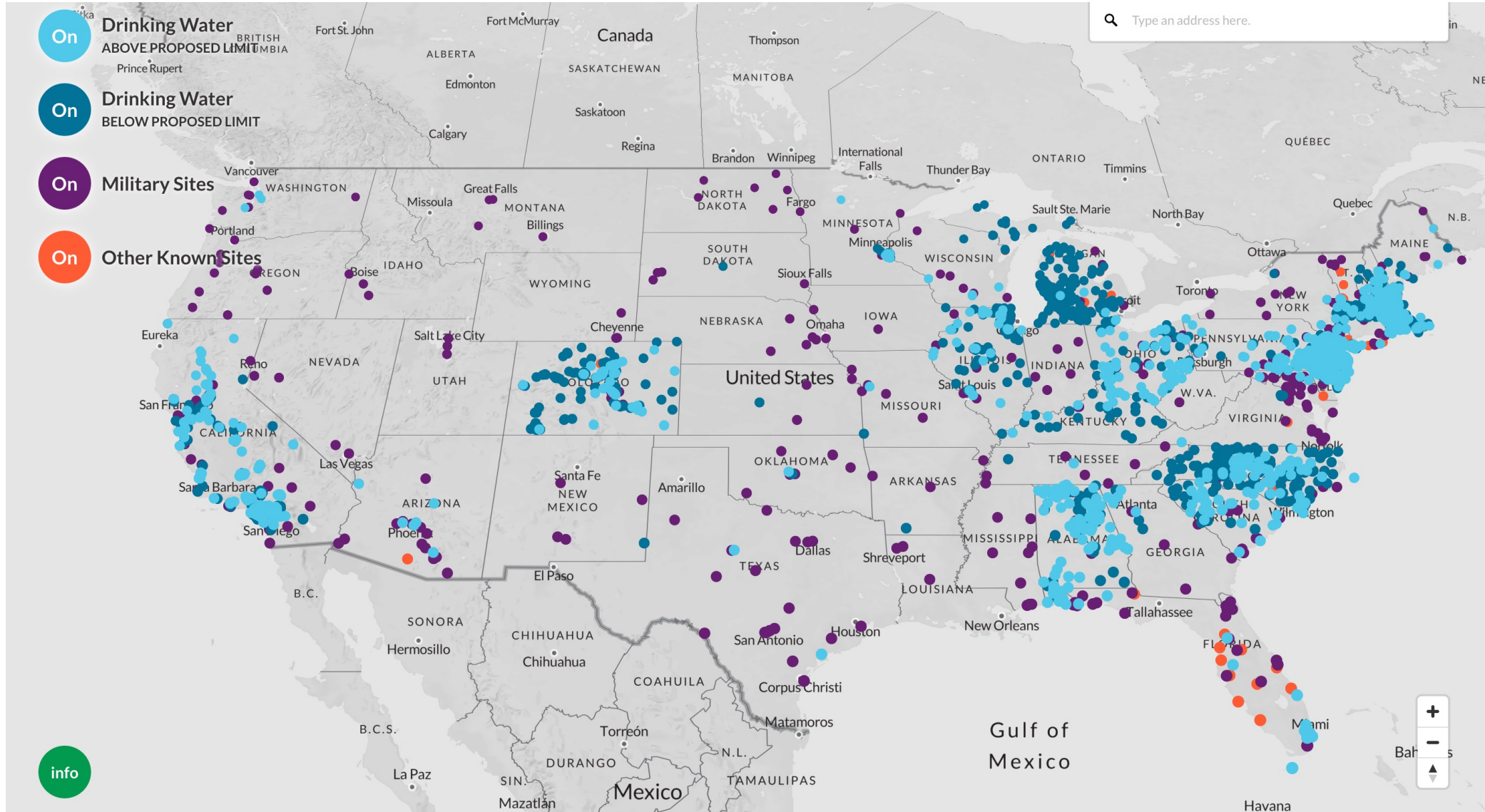


The Federal Contaminated Sites Inventory shows over 100 sites with confirmed or suspected PFAS contamination

- Non-federal PFAS contaminated sites also exist

Many PFAS-impacted federal contaminated sites are located in areas where there is reliance on local resources

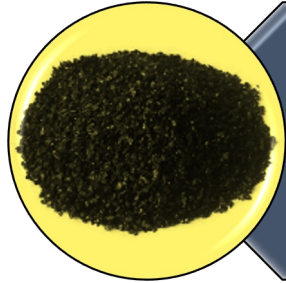
PFAS Occurrence in the USA



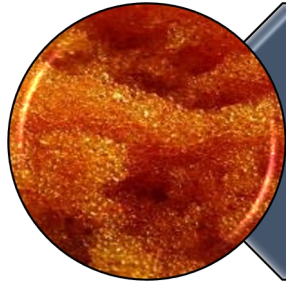
Source: Environmental Working Group (www.ewg.org)

PFAS Removal

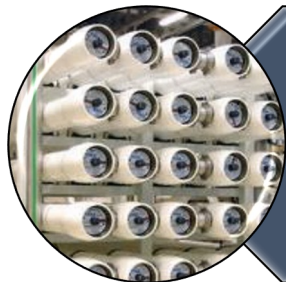
Current readily implementable removal methods



Granular Activated Carbon
(GAC)



Anion Exchange (AIX)



High Pressure Membranes
(nanofiltration & RO)

PFAS Removal from Water

Factors affecting adsorptive techniques (GAC or AIX)

PFAS Structure:

- Chain length
- Functional group
- Branch or linear structure
- Ether oxygen
- Perfluorinated vs polyfluorinated

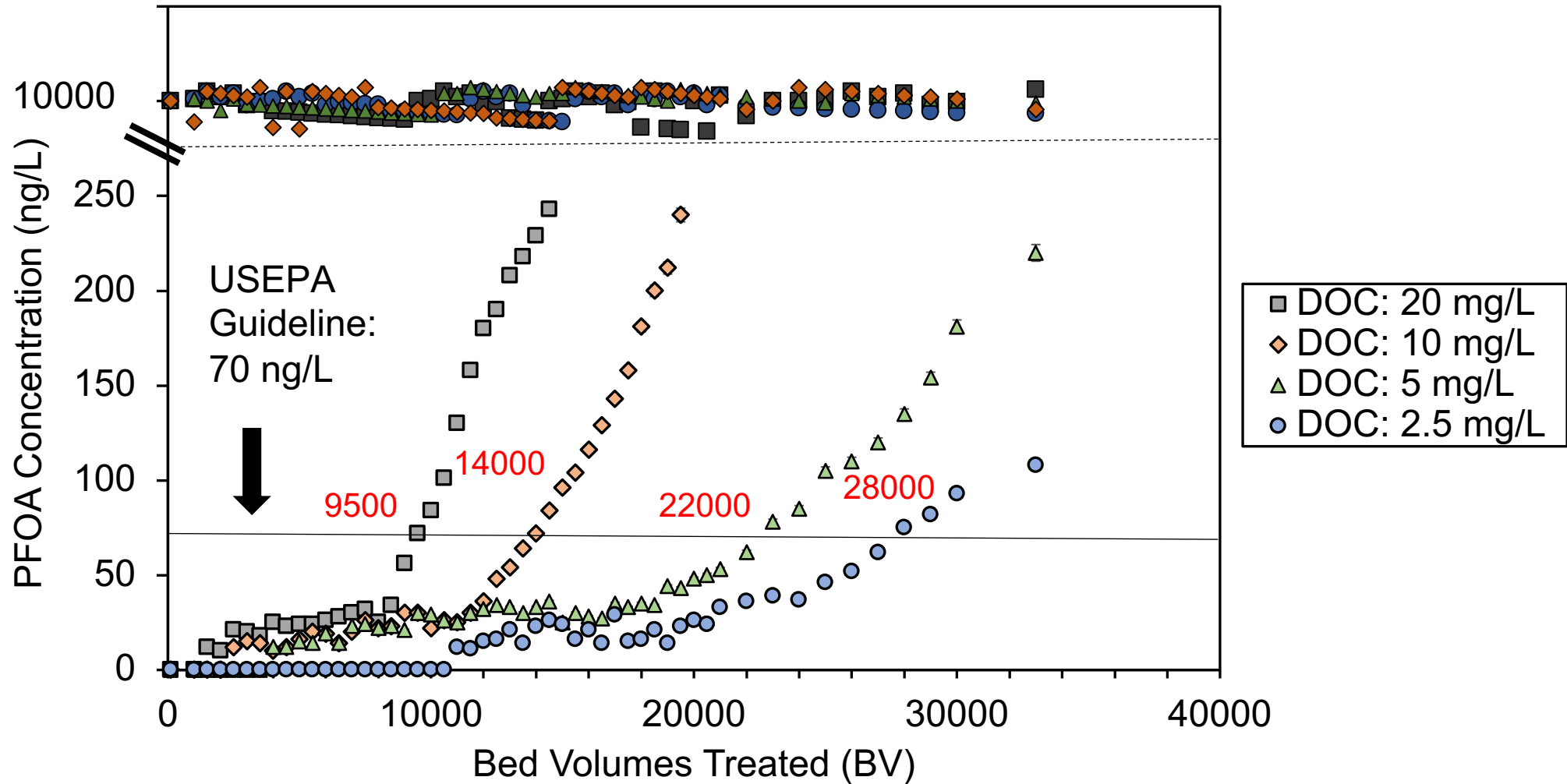
Water Matrix:

- NOM or DOC content
- Inorganic ions (sulphate, nitrate, etc.)

Operating conditions:

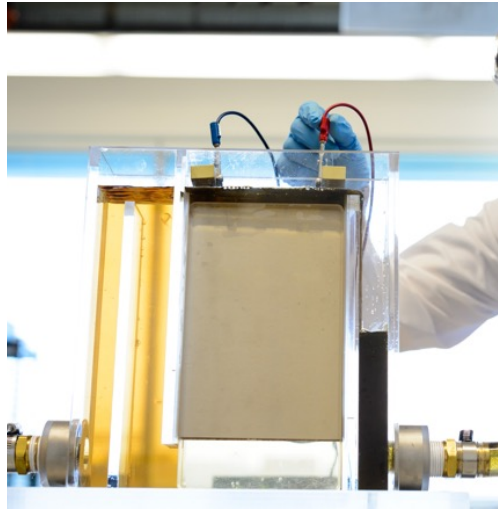
- pH
- Temperature

PFOA Removal (with AIX)

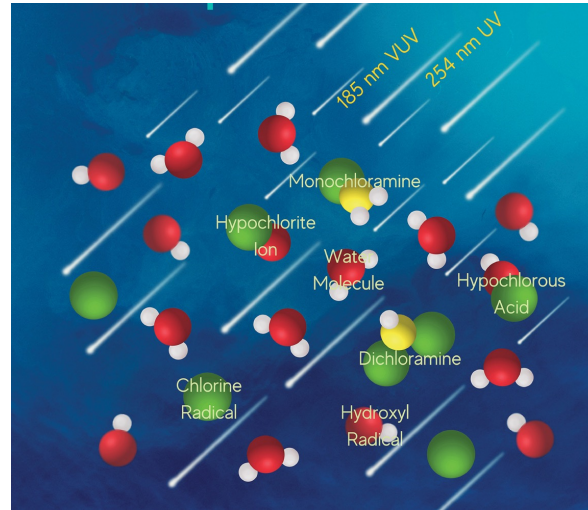


Breakthrough in DI water at > 150,000 BV

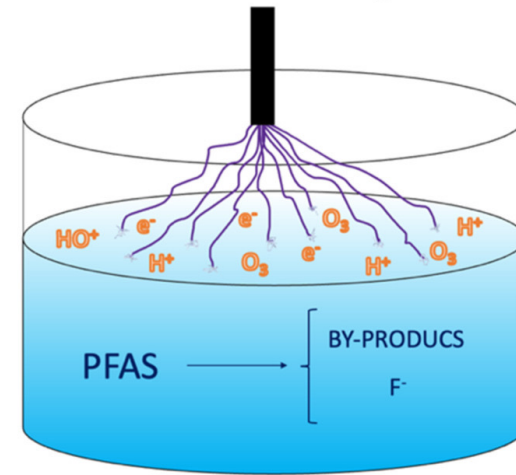
PFAS Destruction



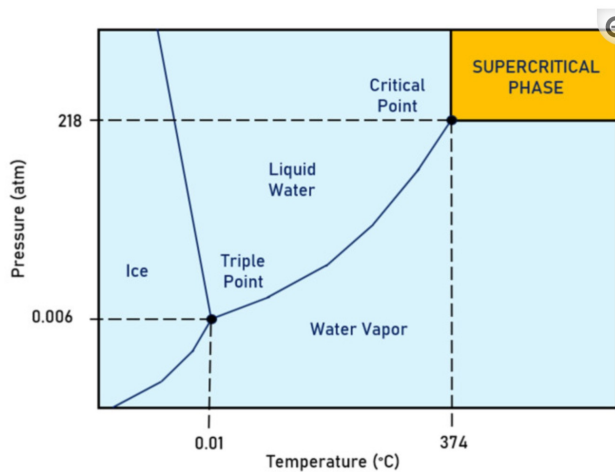
Electrochemical



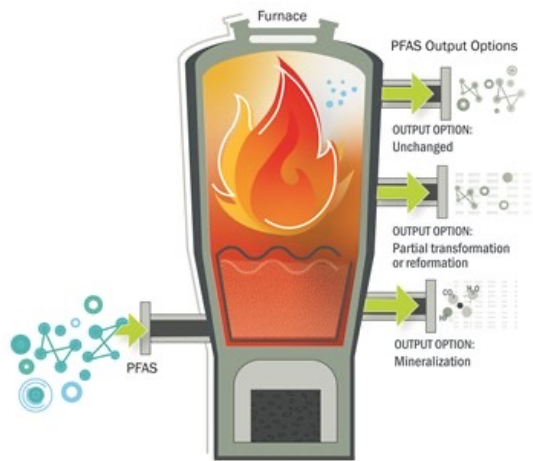
Photochemical



Plasma



Supercritical Water Oxidation

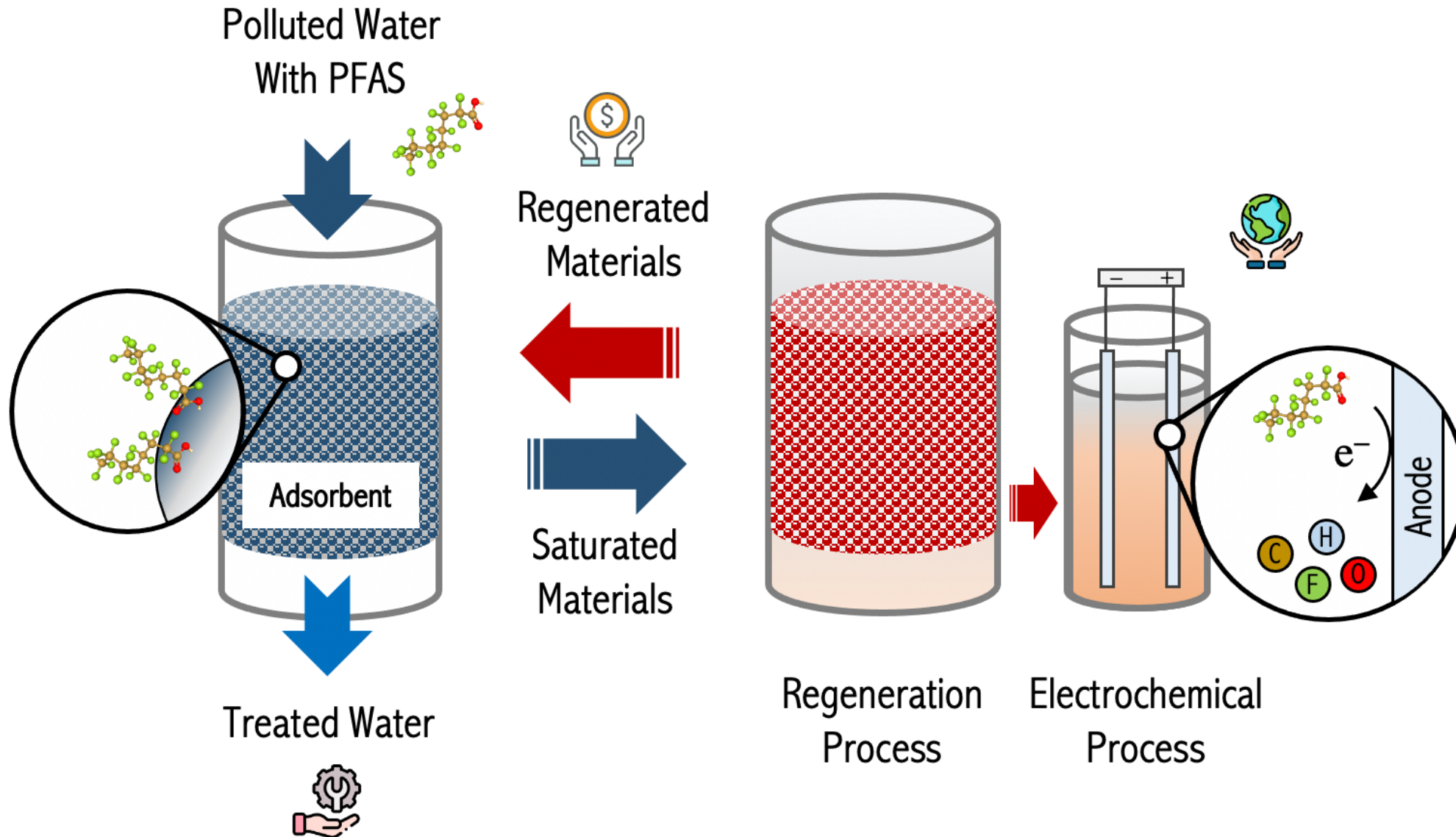


Incineration

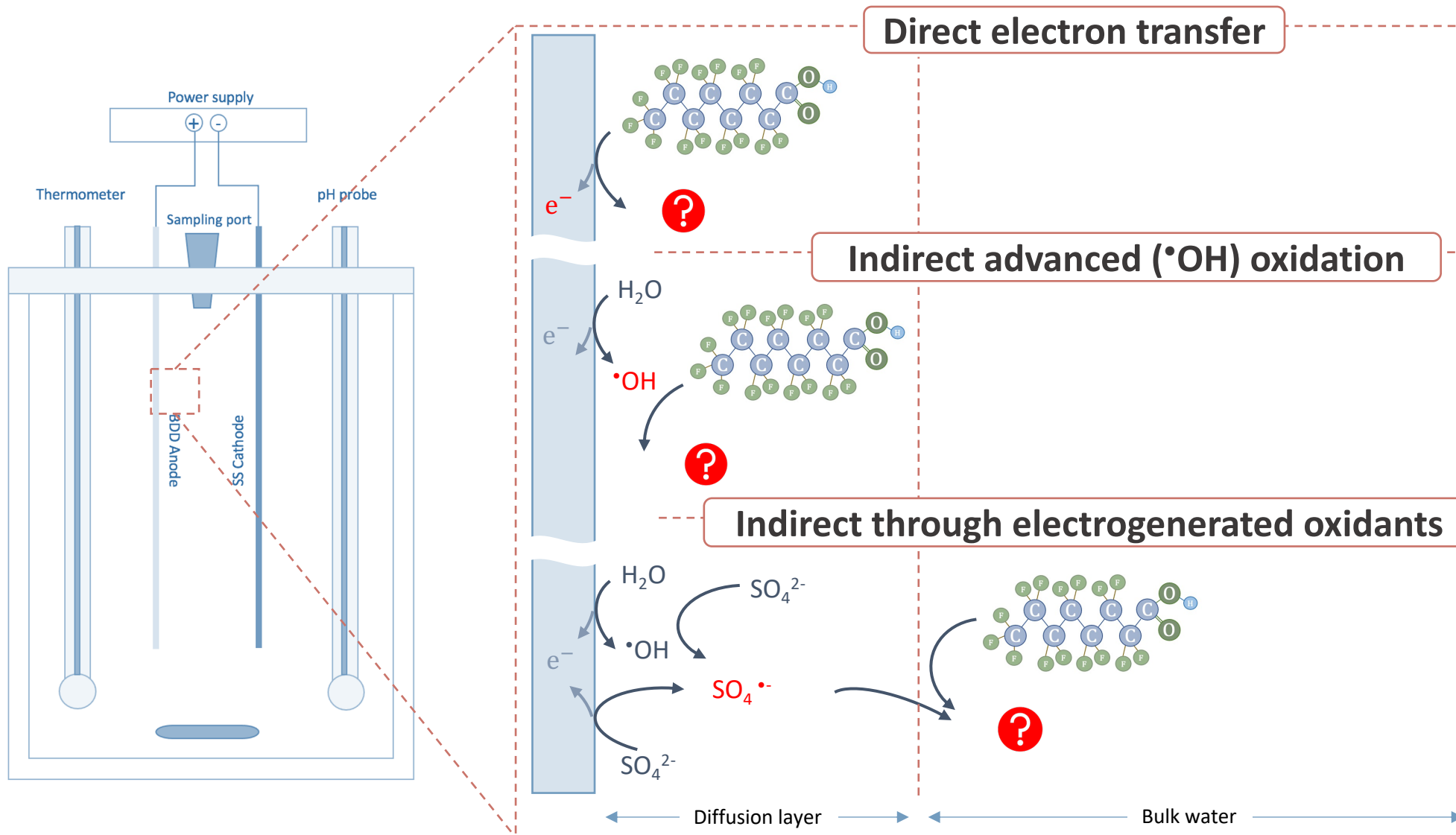


Sonolysis

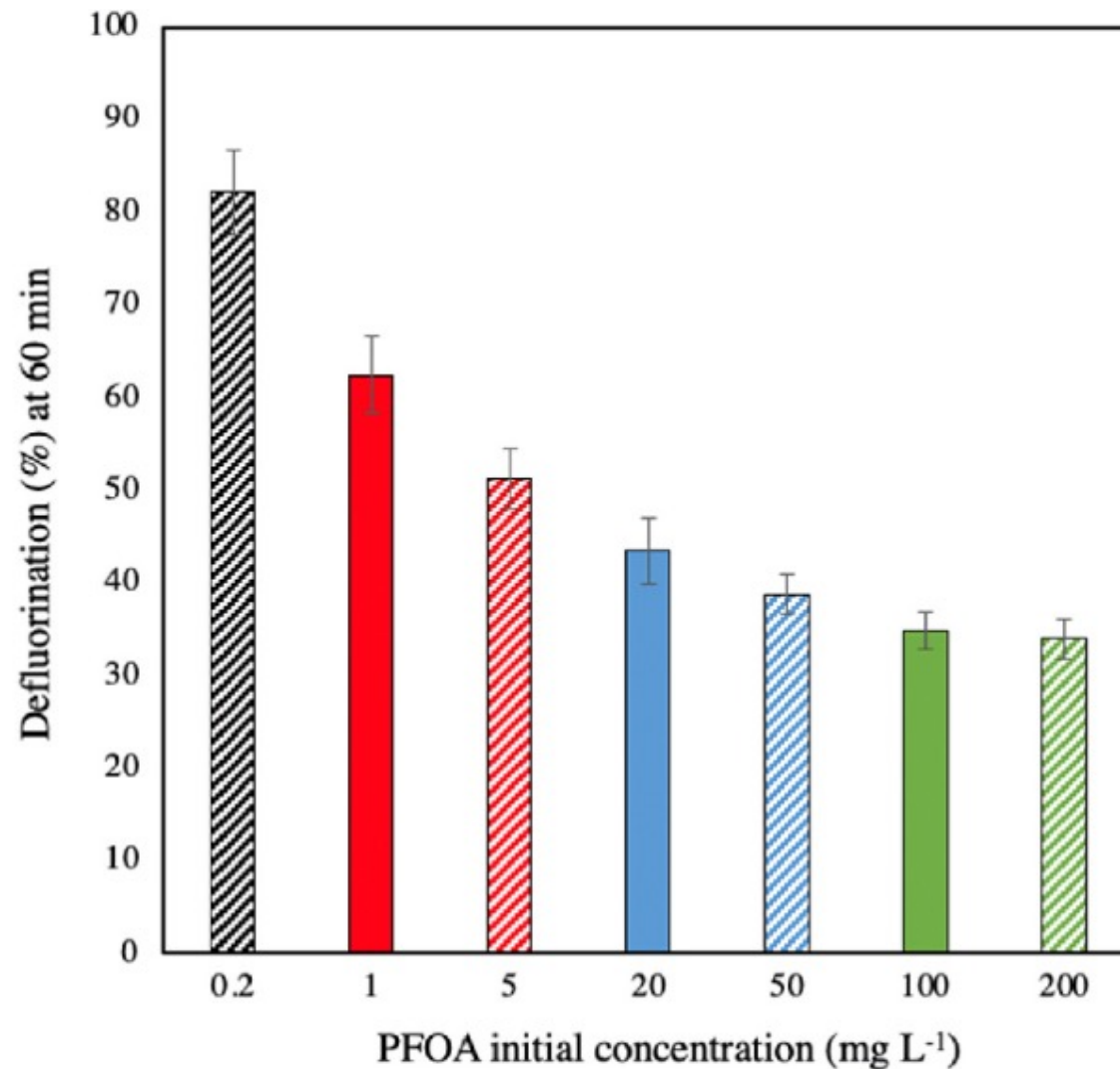
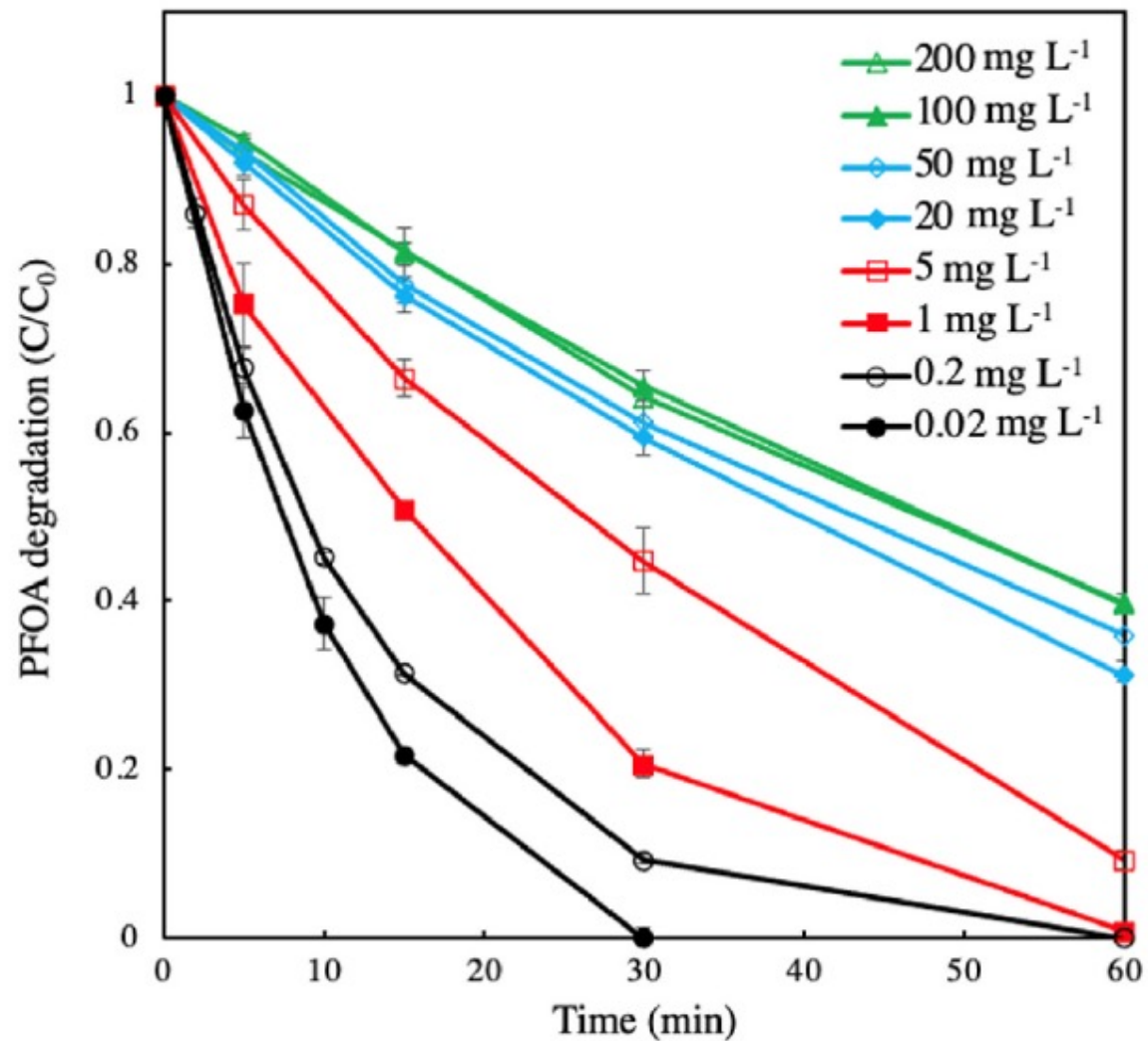
Complete PFAS Destruction



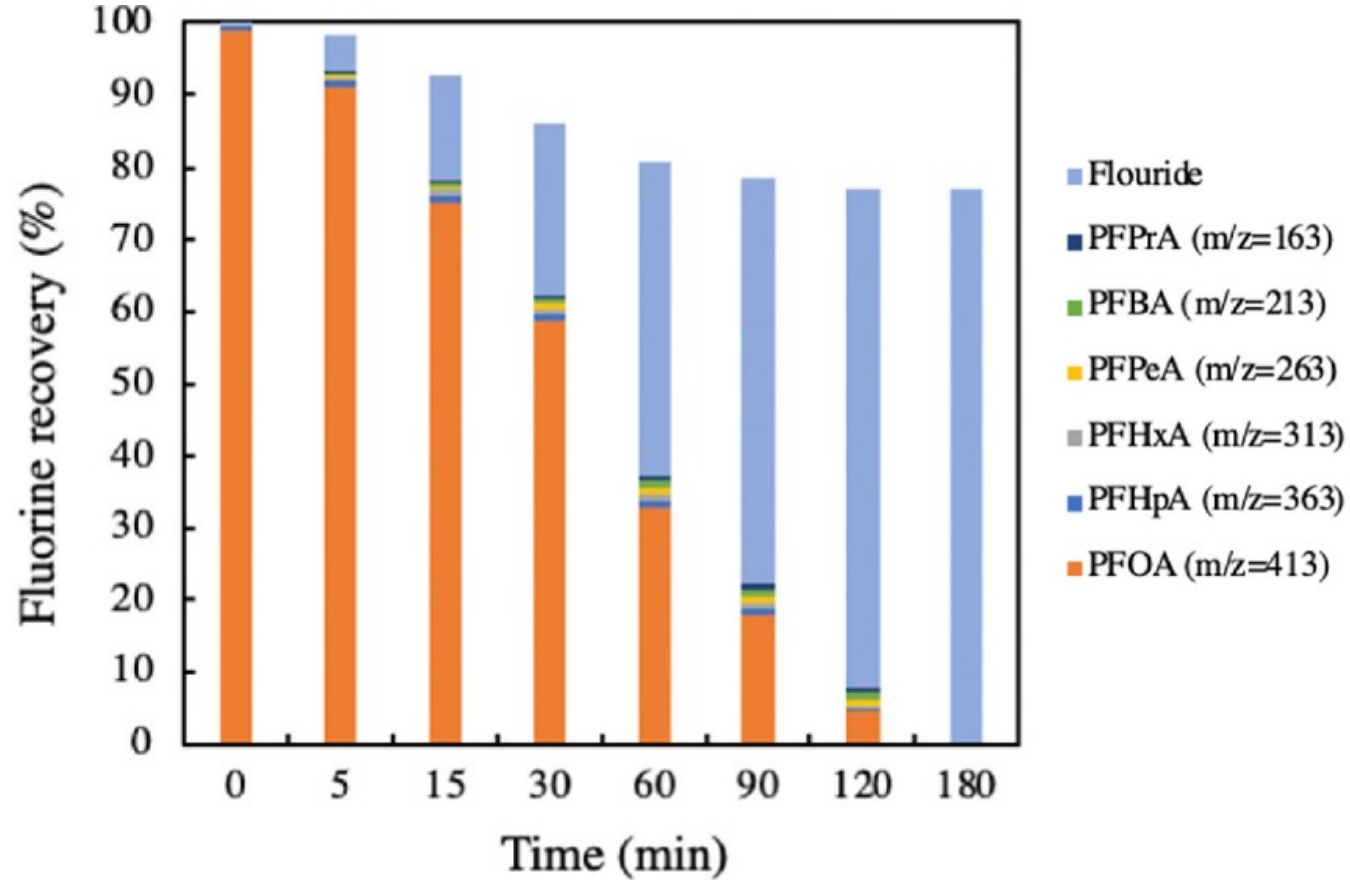
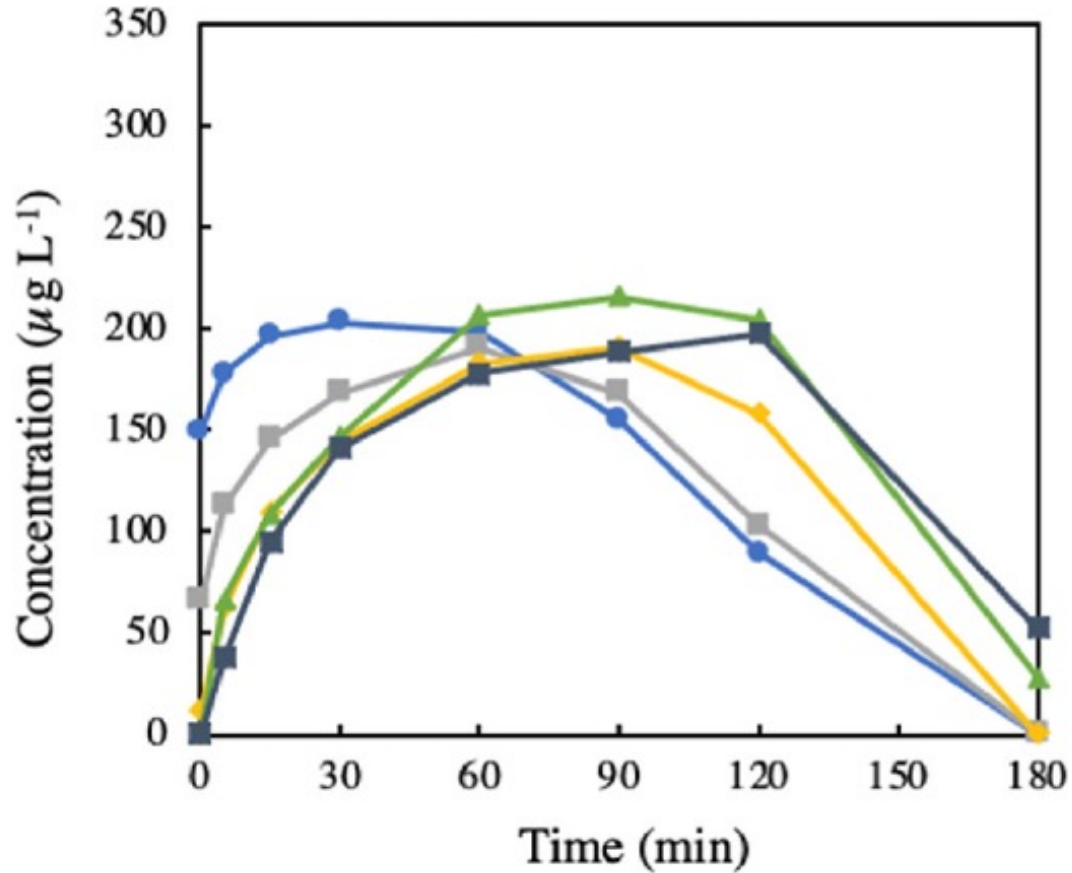
Electrooxidation of PFAS proceeds in direct and indirect oxidation



Electrochemical destruction of PFAS



Electrochemical destruction of PFAS



Thank you!

Madjid Mohseni

Madjid.Mohseni@ubc.ca

