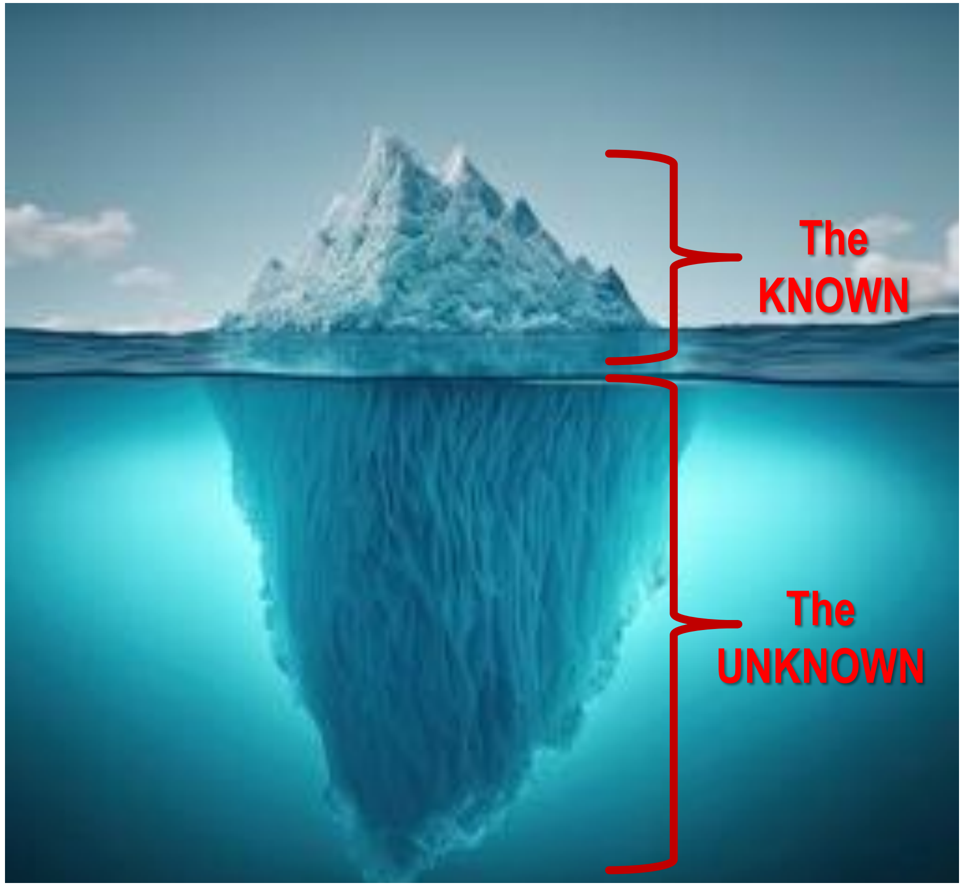
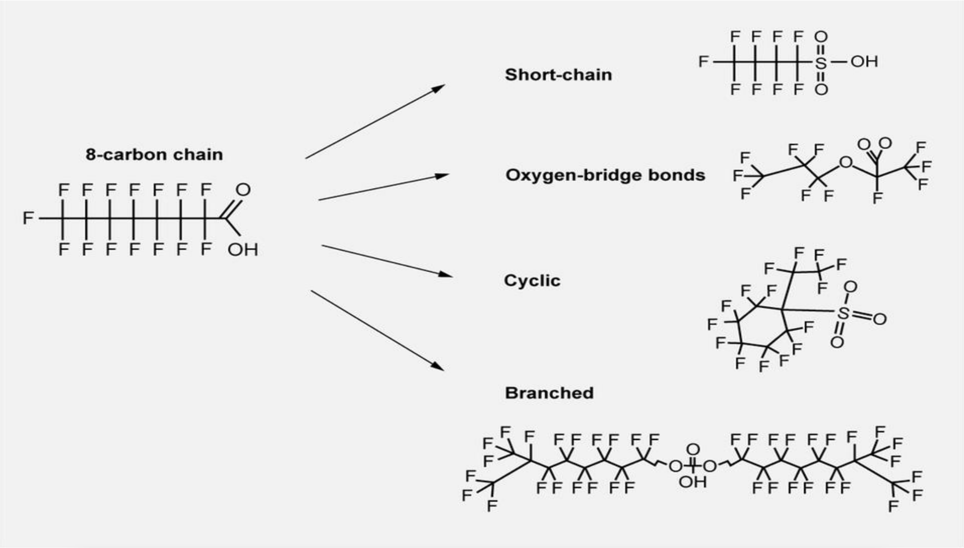
esaa Environmental Services Association of Alberta

PFAS Symposium 2025

Edmonton Nov. 25 + Calgary December 4





PFAS
THE UNTOLD EVOLVING GLOBAL STORY

MY GLOBAL WALKABOUT OBSERVING PFAS TRENDS AND POTENTIAL FUTURE MANAGEMENT

Warning - Some Of The Content Of This Presentation May Be Concerning Personally - Professionally - With Ramifications To Day-To-Day Life → Your Future

BIOGRAPHY
GEORGE (BUD) IVEY, B.SC, CES, CESA, P.CHEM, EP
PRESIDENT, SENIOR REMEDIATION SPECIALIST
IVEY INTERNATIONAL INC.

- President and Senior Remediation Specialist with Ivey International Inc.
- Environmental Professional with >35 years of international Remediation experience.
- Education: Organic Chemistry, Geological Engineering, and a Master's in Project Management
- Worked on >3500 environmental projects globally
- Holds >30 international Patents and Trademarks
- Has been to >70 countries (Every continent except Antarctica)
- Recipient of >12 International Environmental Awards and
- Loves the outdoors, hiking, kayaking, completed several marathons and an Ironman

IVEY

PFAS

PER- AND POLY-FLUOROALKYL SUBSTANCES

MOVIE DARK WATERS (2019)

Dark Waters is a 2019 American legal thriller film directed by Todd Haynes and written by Mario Correa and Matthew Michael Matthew.

The story dramatizes lawyer Robert Bilott's case against the chemical manufacturing corporation DuPont after they contaminated a town with unregulated PFAS chemicals.

[3M + DUPONT >200 Billion USD In Litigation To Date]

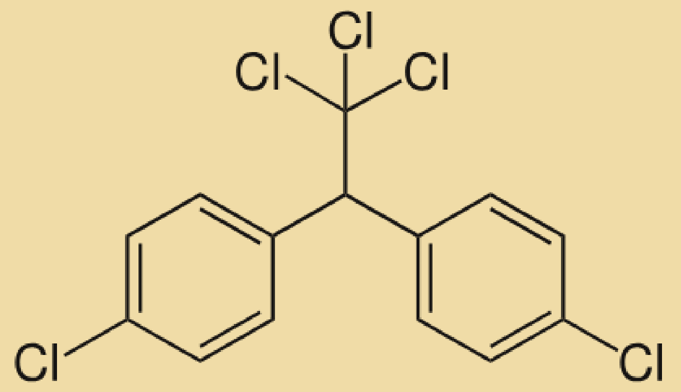
It starred Mark Ruffalo as Bilott, along with Anne Hathaway, Tim Robbins, Bill Camp, Victor Garber, Mare Winningham, William Jackson, and Bill Pullman.

Robert Bilott – Was A Guest Speaker At REMTECH Oct. 2025

WHAT WAS THE FIRST FOREVER CHEMICAL OF GLOBAL CONCERN BEFORE PFAS ???

Dichlorodiphenyltrichloroethane

DDT



DDT can affect the nervous system and liver, with symptoms including tremors, nausea, and irritation from acute exposure, and potentially more severe effects like seizures at high doses. Long-term and high-dose exposure has been linked to chronic effects on the nervous, liver, kidney, and immune systems, as well as reproductive issues like sterility and birth defects in animals.

☹

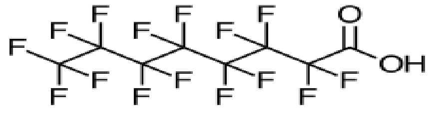
Paul Müller was awarded the 1948 Nobel Prize in Physiology or Medicine for his discovery of the insecticidal properties of DDT

AUDIENCE
WHICH COUNTRIES GLOBALLY ARE AWARE OF PFAS AND HAVE **REGULATIONS**

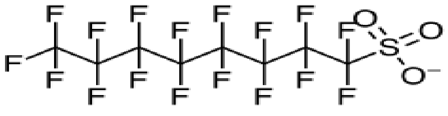
- Canada
- United States
- India ❌
- Zimbabwe ❌
- Australia
- Russia
- Indonesia ❌
- Iceland
- Brazil ❌
- Argentina ❌
- Nigeria ❌
- Chile ❌
- Mexico
- China
- United kingdom
- Kuwait
- Afghanistan ❌
- Antarctica ❌
- Monico
- Singapore

IN THE SIMPLEST MOLECULAR TERMS

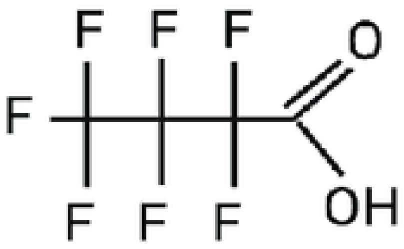
WHAT IS A PFAS - AUDIENCE ?

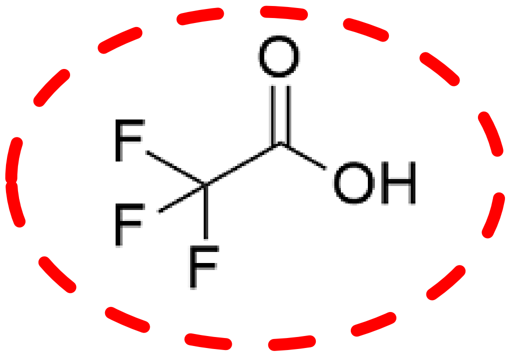


Perfluorooctanoic acid (PFOA)



Perfluorooctane sulfonate (PFOS)





<u>OECD's 2021 Definition Of A Per- and Polyfluoroalkyl Substance (PFAS) Is:</u>

Any fluorinated substance that contains at least one fully fluorinated methyl **(-CF3**) or methylene (-**CF2**) **carbon atom**. This means a carbon atom bonded to three (**3**) or two (**2**) other fluorine (**F**) atoms, respectively, with no other atoms like hydrogen, chlorine, bromine, or iodine attached. This broad definition includes thousands of different chemicals.

- **<u>Core Requirement</u>**: A PFAS must have a perfluorinated methyl **(-CF3**) or methylene (**-CF2**) group;
- **Chemical Structure**: A fluorinated substance with at least one (**1**) carbon atom bonded to three (**3**) or two (**2**) fluorines (**F**), without other halogens or hydrogen;
- **Purpose of the definition**: This definition was developed to provide a coherent and consistent way to identify PFAS across different compounds for risk management and regulatory purposes.

AUDIENCE PARTICIPATION

SO HOW MANY PFAS COMPOUNDS ARE THERE ?

USEPA CompTox database lists approximately **14,735** unique PFAS chemicals

European Chemicals Agency (ECHA) is proposing a restriction on over **12,000** PFAS.

USGS indicates the total number of PFAS compounds is over **12,000**.

~7 million represents the vast chemical space that fits the general OECD definition.

The actual number of commercially produced, or widely detected PFAS is much smaller, with various regulatory lists typically tracking a **few thousand** specific compounds.
Globally you will find estimates between 8000 to 7 Million

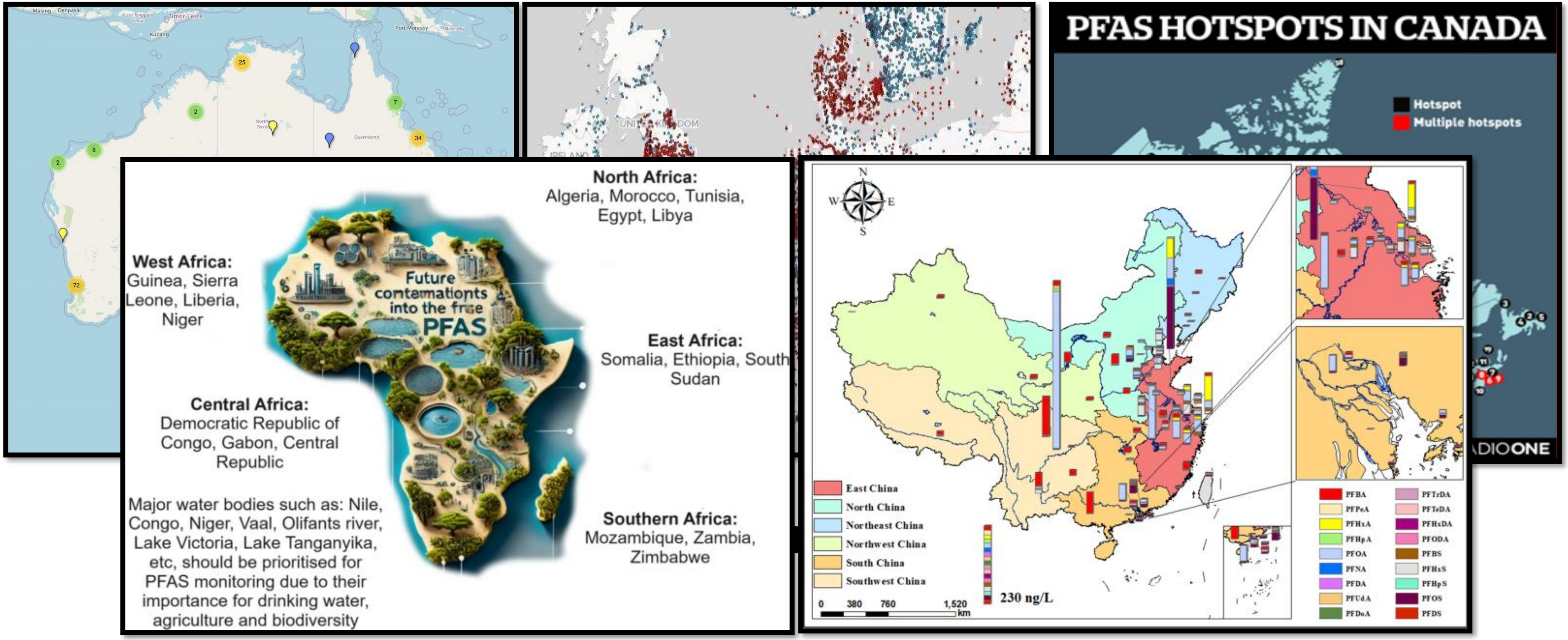
OECD 2021 definition has led to the identification of approximately **24 million** distinct PFAS molecules in the CAS (A large chemical database).

WHY BOTHER!!!
What's Are The Drivers Globally

The World Is Contending With PFAS Remediation and Decontamination For Many Reasons Including:

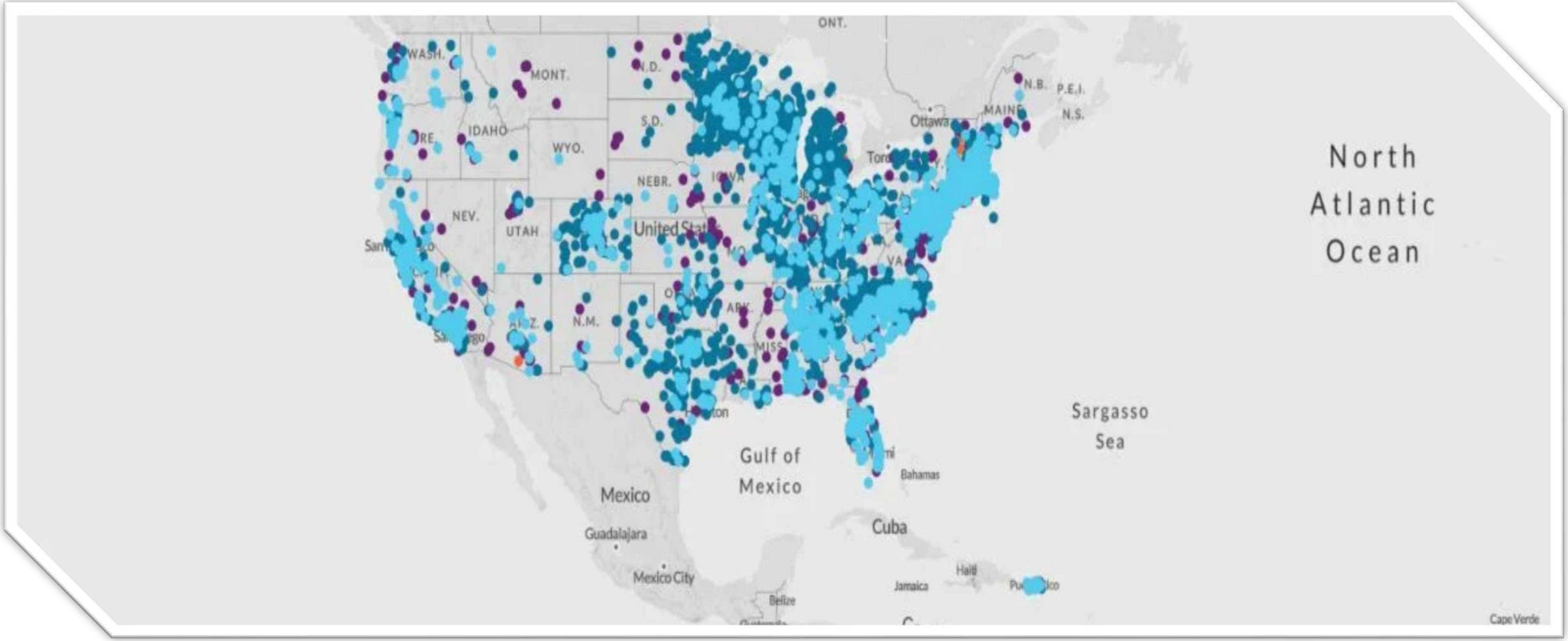
- **Protect Human Health And Environmental Risk** → Regulations.
- **Comply With Local Regulations (Environmental & Health Risk)** - *Prohibitions, Bans, Guidelines To Standards.*
- **Response To Worker Health & Safety Concerns** - *Some Fire Unions Are Driving AFFF Decontamination.*
- **Legal Liability Management** - *Proactive Remediation/Decontamination Help Mitigate Costs + Avoid Negative Publicity.*
- **Tightening Insurance Pressure** - *Banning or restricting coverage due to high financial risk associated with wave of litigation.*
- **Stakeholder + Public Pressures** - *'Social License' public/community awareness of PFAS contamination leading to significant pressure on government/private entities to investigate and remediation sites to protect public health and local resources.*
- **Manufacturer Supply Chain Pressure** - *They are phasing out PFAS options to new safer (Non-PFAS) products.*

Global PFAS Snapshot



Africa

China



PFAS IN USA CONTAMINATION FACTS

~**71 to 95 million people in the Lower 48 states, >20% of the country's population** may **rely on groundwater that contains** detectable concentrations of **PFAS**, in their drinking water supplies.

GLOBAL DANGER PFAS EXPOSURE FOR WILDLIFE ≤ HUMAN EXPOSURES (?)

The Global PFAS Foot Race

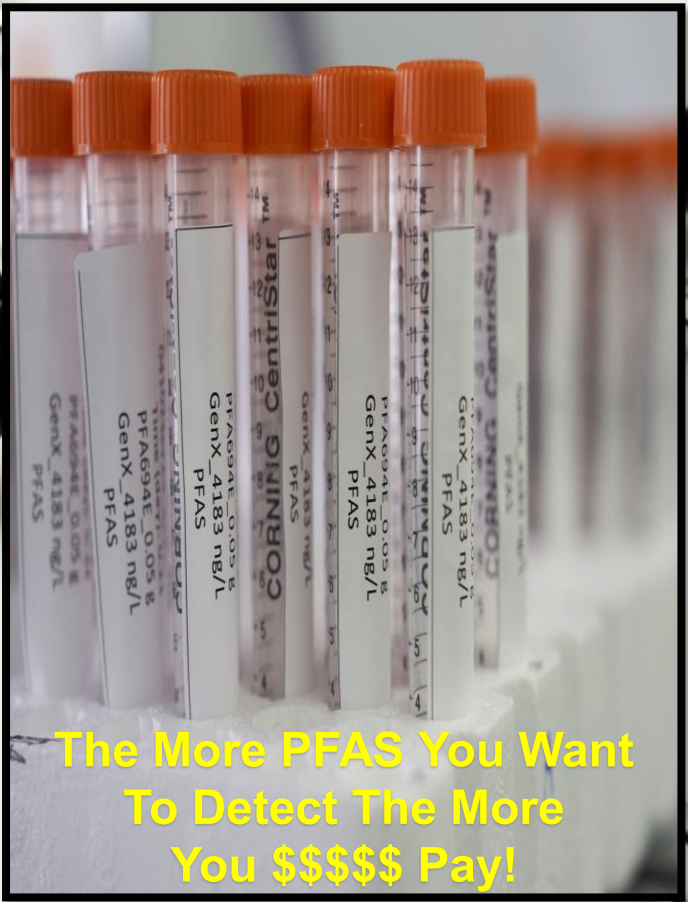
Standings For Managing:

1. **Australia**
2. **Europe (EU)**
3. **United States**
4. **Canada & UK**
5. **The Rest of the World**

HOW MANY PFAS CAN LABORATORIES *DETECT ???*

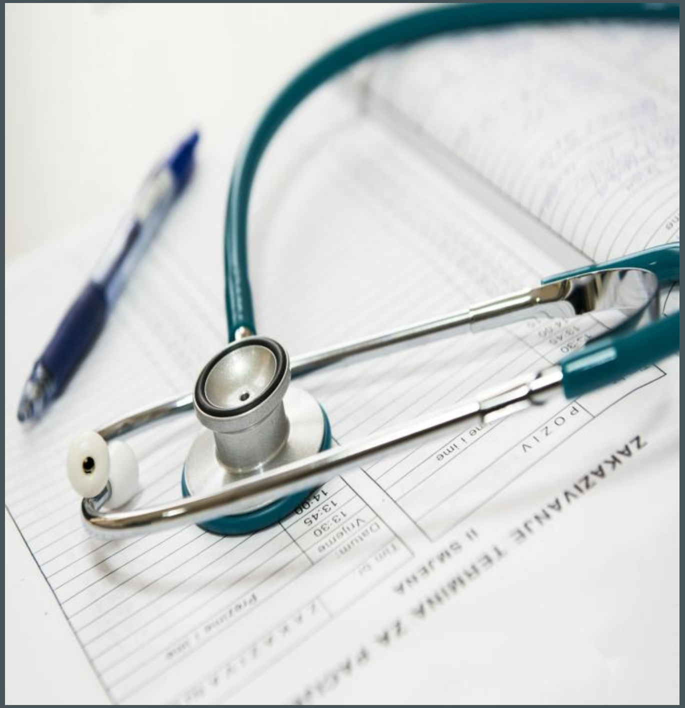
Environmental laboratories can detect anywhere from a few dozen to over a hundred specific PFAS compounds using standard targeted analysis methods, with some advanced techniques capable of screening for over 10,000 compounds:

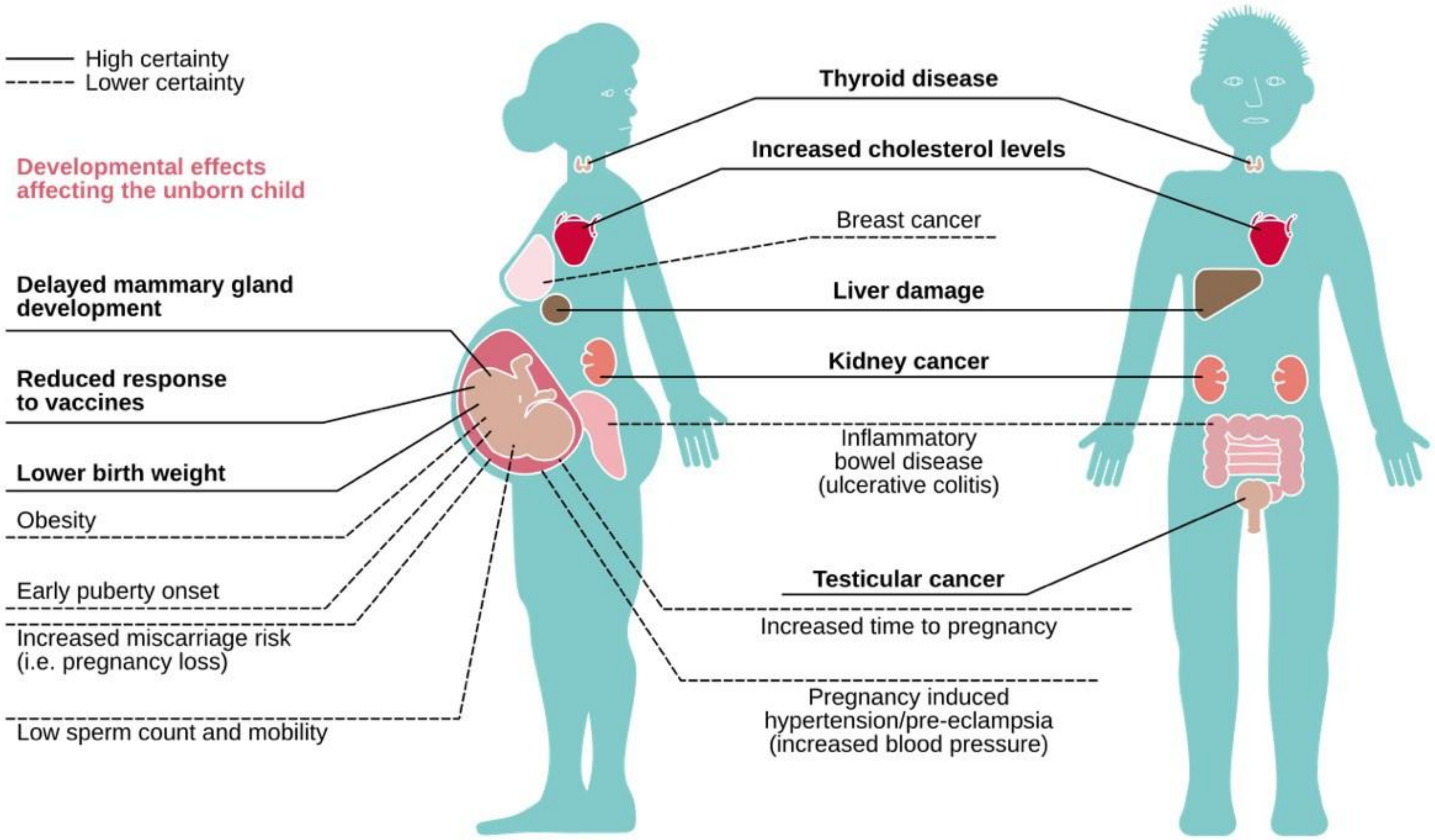
- USEPA Method 537.1: Can detect 18 specific PFAS analytes in drinking water.
- US EPA Method 533: Targets 25 PFAS compounds in drinking water, including many short-chain varieties.
- USEPA Method 1633: Quantifies 40 target PFAS analytes in a wide range of non-drinking water matrices: soil, sediment, and wastewater.
- Commercial Laboratories: Offer expanded target lists. For example, some labs can analyze up to 70 compounds using modified EPA methods, or even up to 100 or 165 specific compounds with their own validated workflows.
- Non-Targeted Analysis: For a broader understanding of contamination, non-targeted analysis methods using high-resolution accurate mass (HRAM) mass spectrometry are used. These advanced techniques can enable the detection and identification of over 10,000 PFAS compounds in a single analysis



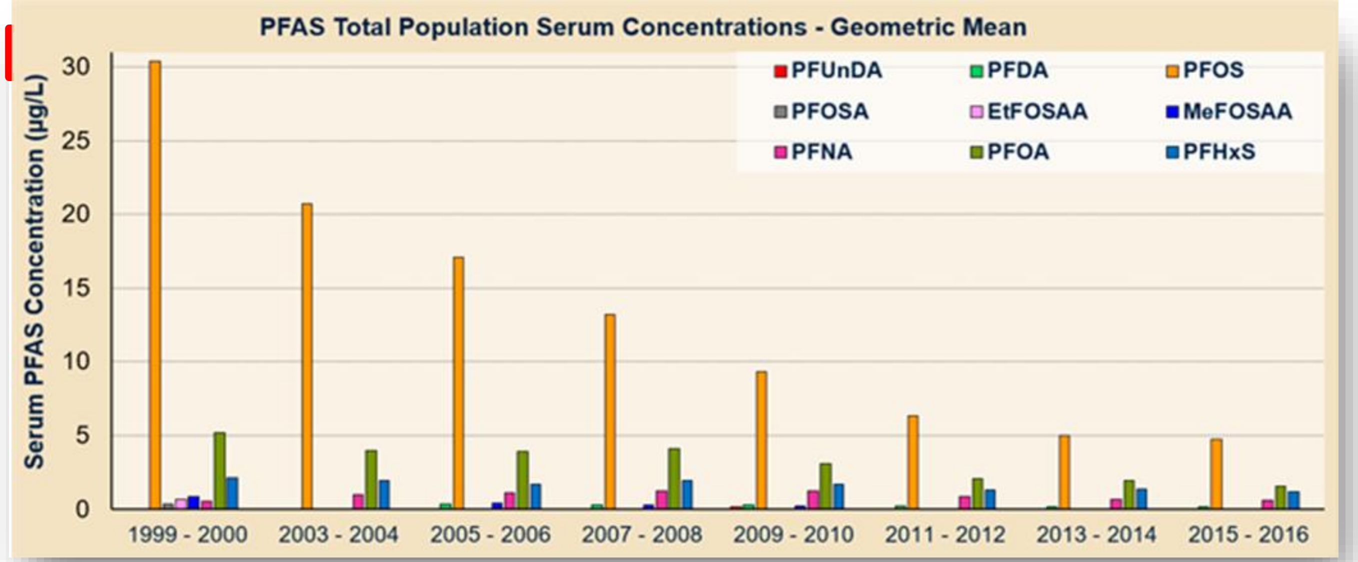
Focus On Precision, Accuracy, Detection Limits, Use of Carbon Spiked Standards and QA/QC Reports - All Labs Are Not Equal!

SIGNIFICANT HUMAN HEALTH PFAS EXPOSURE IMPACTS





PFAS
EXPOSURE
HEALTH EFFECT
<C_4 TO >C_{14}



In general population, where this is no specific source of PFAS contamination, and PFAA concentrations in drinking water and serum are in the typical "*background*" range, the primary sources of PFAS appear to be food and food packaging, and consumer products (particularly nonpolymer aftermarket treatments and coatings).

In communities near sources of PFAS contamination, exposures are higher than in general population resulting from ingestion of contaminated drinking water, consumption of fish from contaminated waters.

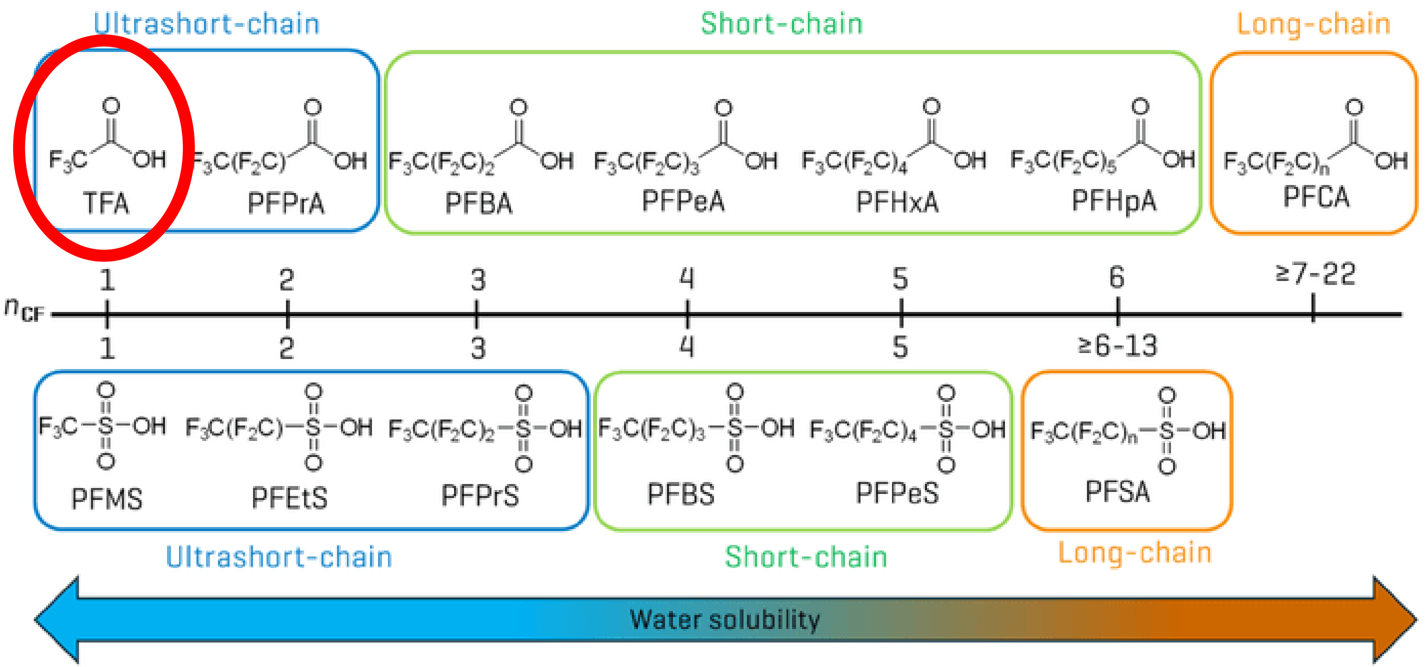
As PFAS concentrations in drinking water increase, the contribution of drinking water to the total body burden increases and typically dominates an individual's exposure.

Finally, occupational exposures to workers (for example, in fluoropolymer manufacturing facilities, fire fighting) can be higher than exposures from environmental media.

Center for Disease Control & Prevention - Using Data From National Health & Nutrition Examinations Survey

Found PFAS in Blood of 98% of Americans!

ULTRA SHORT-CHAIN PFAS



Trifluoroacetic acid (**TFA**) currently getting huge attention In Europe

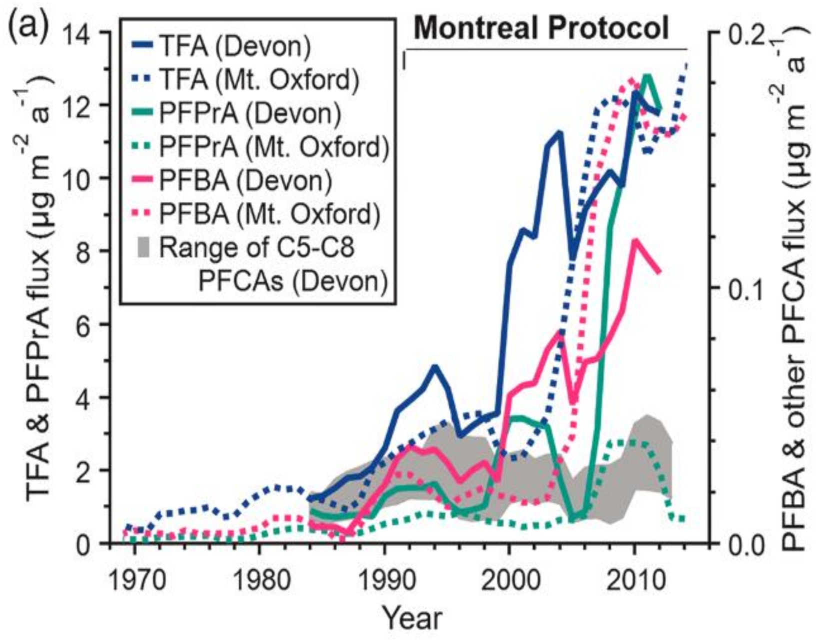
HOUSTON WE HAVE A PROBLEM !!!

- Very persistent and very mobile (vPvM – new regulatory paradigm)
- Difficult to remove via conventional "sorptive" treatment methods
- Analysis: requires specialized chromatography columns and ionization methods

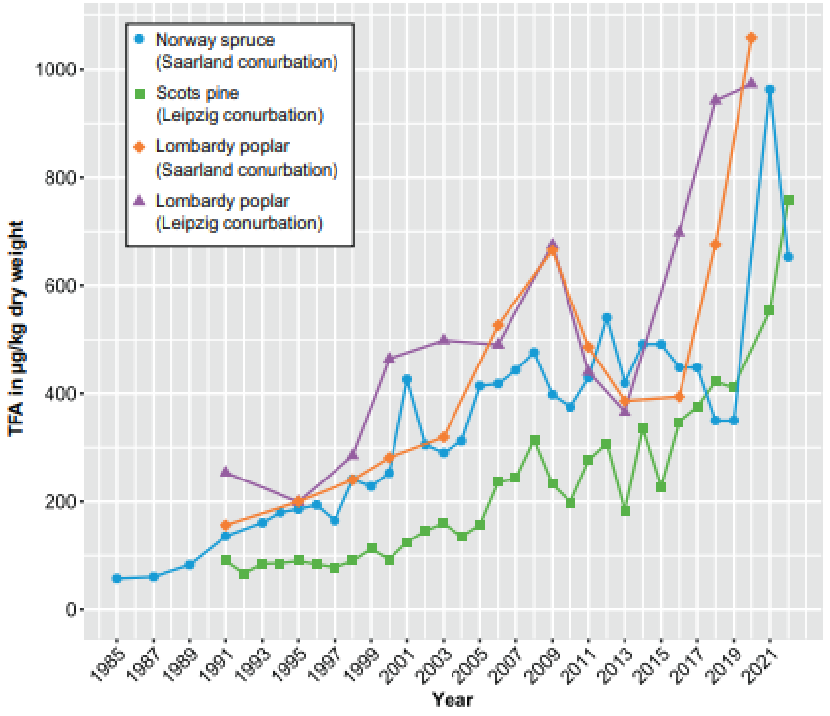
Reference: Dr. Ian Cousins
Department of Environmental Science
Stockholm University, Sweden

TFA IS ACCUMULATING EVERYWHERE - THE "*POSTER CHILD*" FOR THE PROBLEM WITH HIGH PERSISTENCE

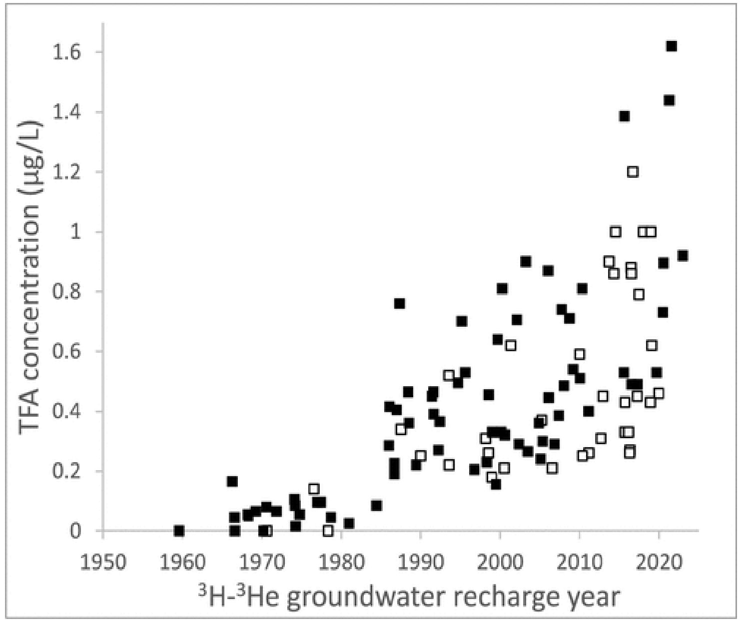
TFA Accumulating In Arctic Ice Cores



In Tree leaves



In Groundwater



Reference: Dr. Ian Cousins
Department of Environmental Science
Stockholm University, Sweden

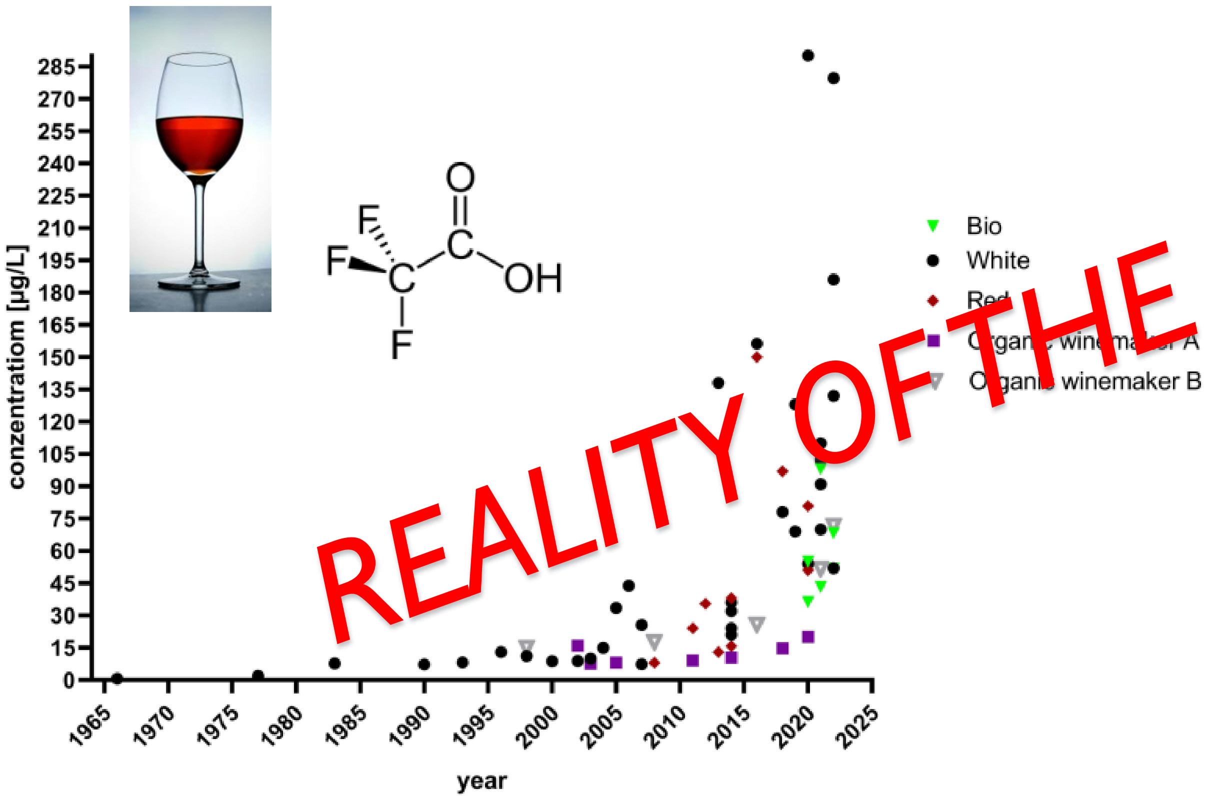
Pickard et al. Geophysical Research Letters (2020),47, e2020GL087535

Freeling and Björnsdotter, Current Opinion in Green and Sustainable Chemistry 2023, 41:100807

Albers and Sültenfuss, Environmental Science & Technology Letters 2024 11 (10), 1090-1095

TFA IS INCREASING IN ALL OF WHAT WE DRINK

TFA in Wine (µg/L) 1966 - 2022



REALITY OF THE SITUATION

Drinking Water (median)[1,2]

- Germany: .5 µg/L
- 19 countries: 0.23 µg/L

Tea (median): 2.4 µg/L[2]

Beer (median) 6.1 µg/L[2]

Orange Juice (mean 34 µg/L)[3]

Apple Juice (mean 6.2 µg/L)[3]

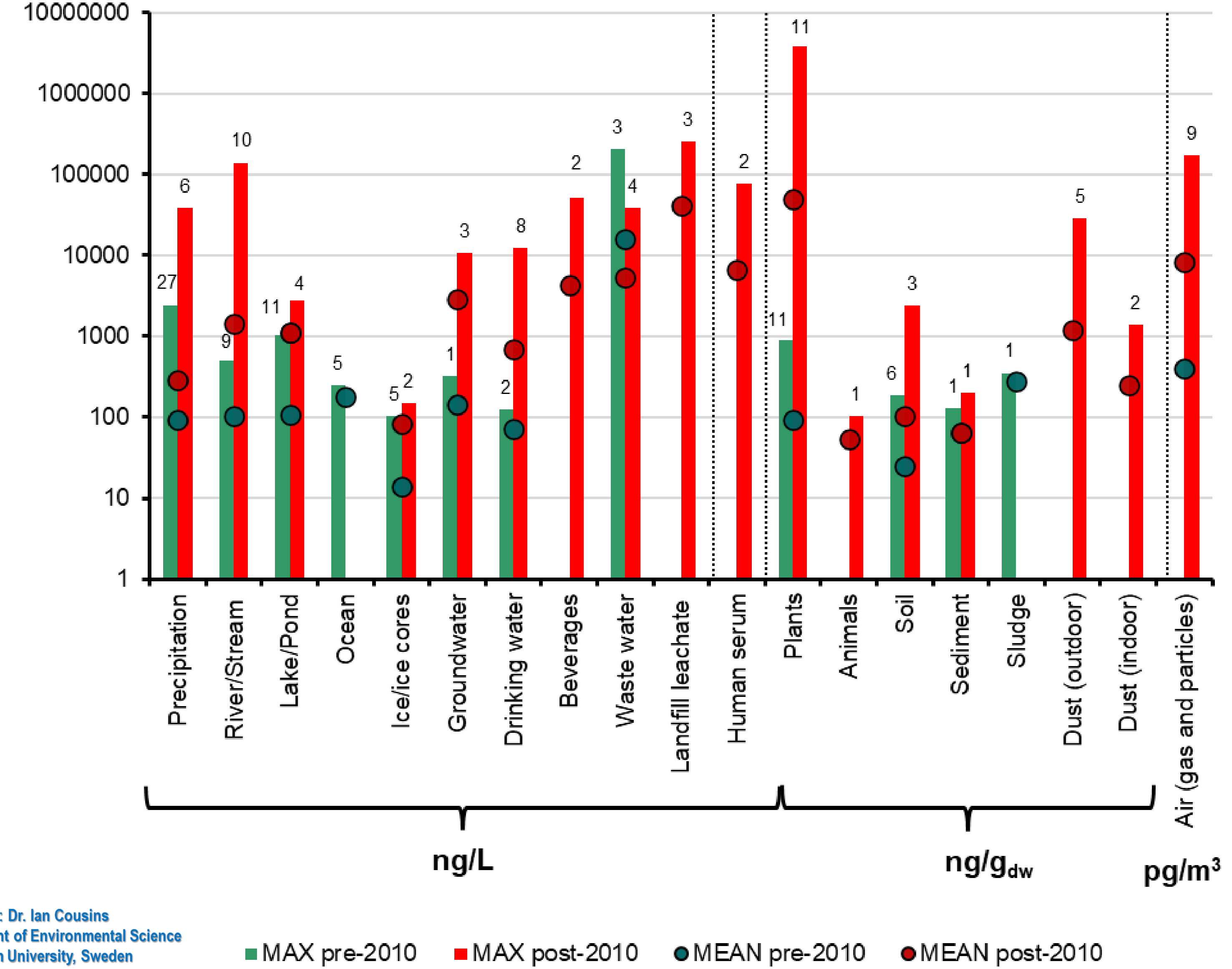
Unpublished data: Michael Müller. Uni. Freiburg michael.mueller@pharmazie.uni-freiburg.de (used with permission)

Wine image: Sai Balaji Varma Gadhiraju

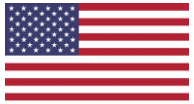
Reference: Dr. Ian Cousins
Department of Environmental Science
Stockholm University, Sweden

1. Neuwald et al. *Environmental Science & Technology* **2022** *56* (10), 6380-6390
2. Scheurer & Nödler. *Food Chemistry*, *351*, 129304.
3. Van Hees et al. https://cdnmedia.eurofins.com/european-east/media/uxcnaa2c/eurofins_tfa_tfms_juice_24_final.pdf

TFA IS ACCUMULATING EVERYWHERE IT CAN BE MEASURED



Chinese blood 97% detection
Median 8.5 µg/L
Similar to levels of the sum of all long-chain, bioaccumulative PFAS



USA blood serum 74% detection
Median 6.0 µg/L
Twice the levels of the sum of all long-chain, bioaccumulative PFAS

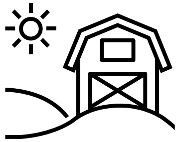
What levels of **TFA** will be in the blood of future generations?

What will the impact of this be to human health and the environment?

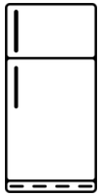
Reference: Dr. Ian Cousins
Department of Environmental Science
Stockholm University, Sweden

Duan et al. (2020) Environ Int 134:105295.
Zheng et al. (2023) ES&T 2023, 57, 15782-15793
Arp et al. ES&T 2024, 58, 45, 19925-19935

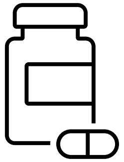
Increasing Sources of **TFA**



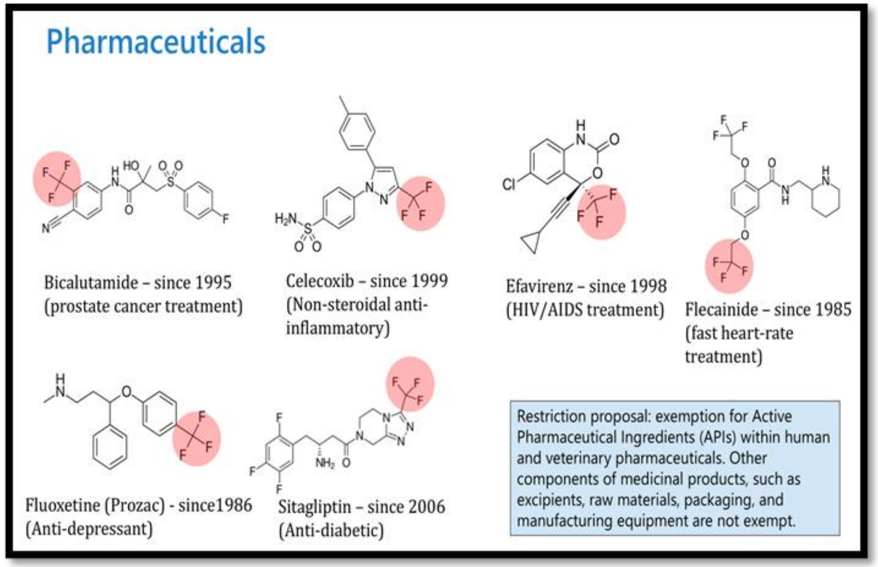
Agricultural chemicals

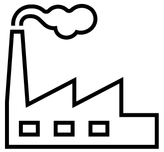


Refrigerants and blowing agents

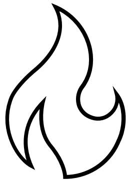


Pharmaceuticals

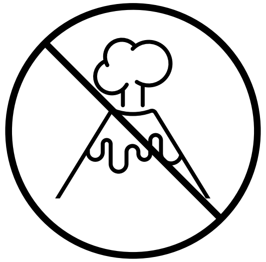




PFAS production and products



PFAS remediation

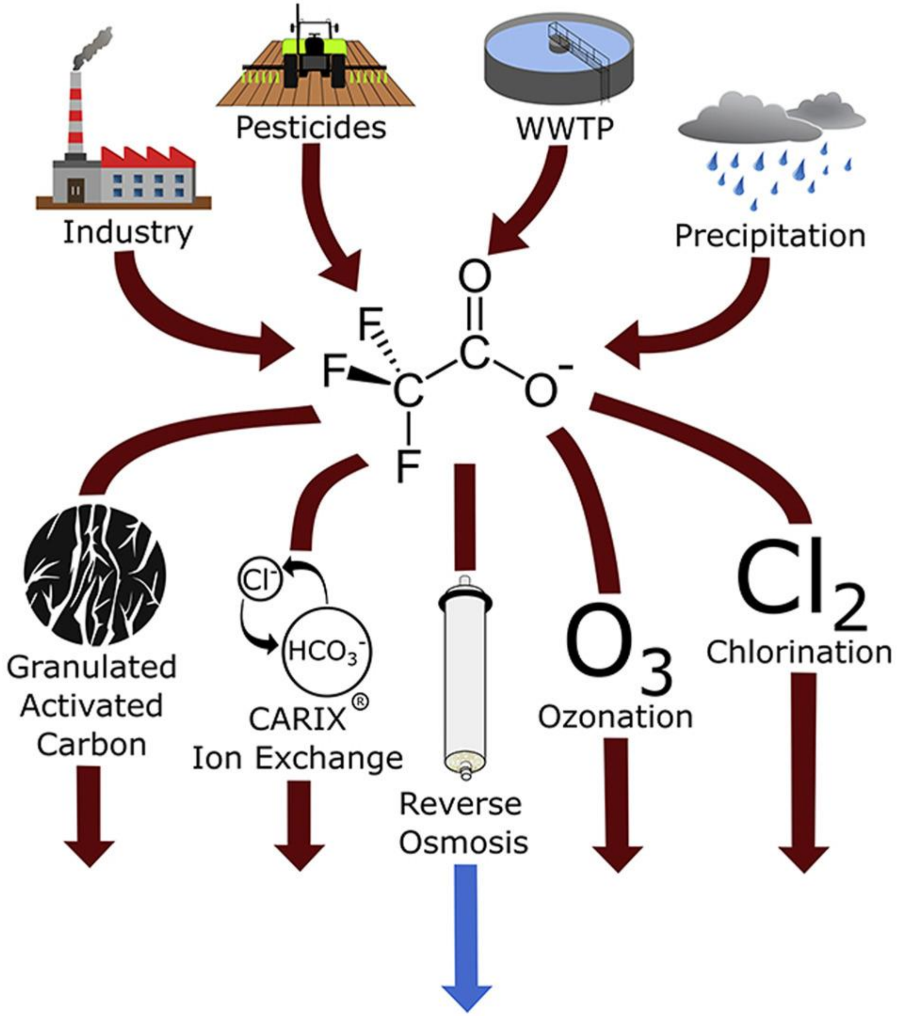


No natural sources

Reference: Dr. Ian Cousins
Department of Environmental Science
Stockholm University, Sweden

WATER TREATMENT INEFFECTIVE AT REMOVING TFA, ….OR CAN FORM TFA

- **Sorption techniques** (activated carbon, ion exchange resins) -> **Do not filter TFA.**
- **Enhanced degradation techniques** (ozonation, chlorination, photolysis, electrolysis, incineration, pyrolysos etc.) **Can lead to TFA formation from precursors** (along with other PFAS, F-gases).
- **Reverse Osmosis** only technique that works for TFA, but requires an expensive destruction step for brines.
- Future innovations brings an as yet unknow solution for cost effective TFA removal from water…

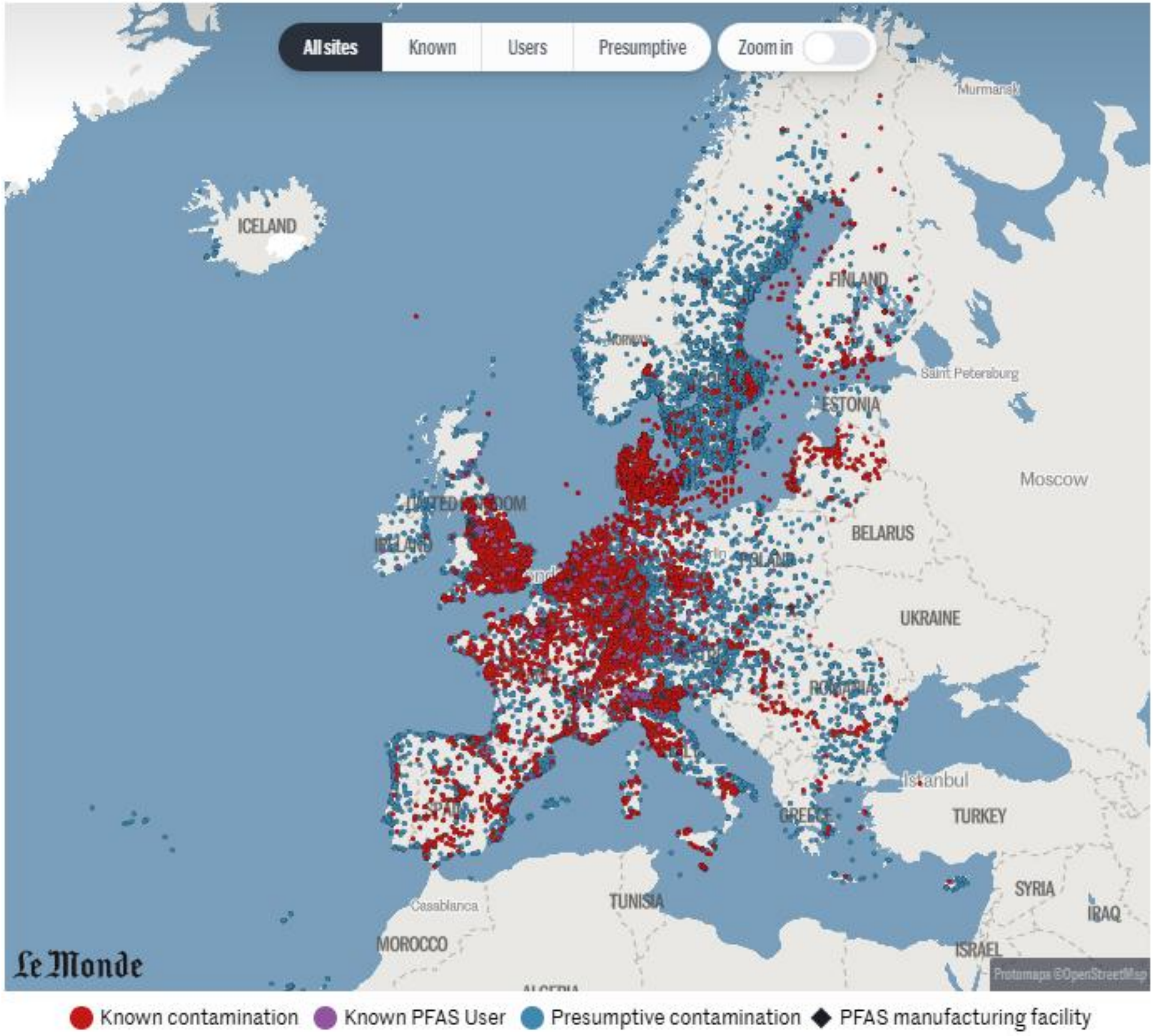


Scheurer et al. (2017). *Water research*, *126*, 460-471.

Reference: Dr. Ian Cousins
Department of Environmental Science
Stockholm University, Sweden

THE ABSURD COSTS OF TFA REMEDIATION EUROPE…

- Recent collaboration with ***Forever Pollution Project*** and Prof. Ali Ling
- Cost to remediate emerging ultra-short chain PFAS like TFA in Europe **100 billion EUR/year ~115 billion USD/year**) for water and soil
- Combination of reverse osmosis and super critical water oxidation for brines
- Would make drinking water more expensive **$$$**
- Still be exposed to **TFA**…fruit beverages will still be contaminated…



Source: Forever Pollution Project

https://foreverpollution.eu/lobbying/

DECONTAMINTION OF PFAS IMPACTED SURFACES

ASTM D5088 Decontamination Standards

PFAS-SOL Used By GST (Dallas, TX) To Achieve 99.99998% PFAS Surface Decontamination of AFFF Fire Suppression System

Miscellaneous Observations

The Federal (USA) MCLs have settled at **4 parts per trillion (ppt)** for both PFOA and PFOS compounds in water.

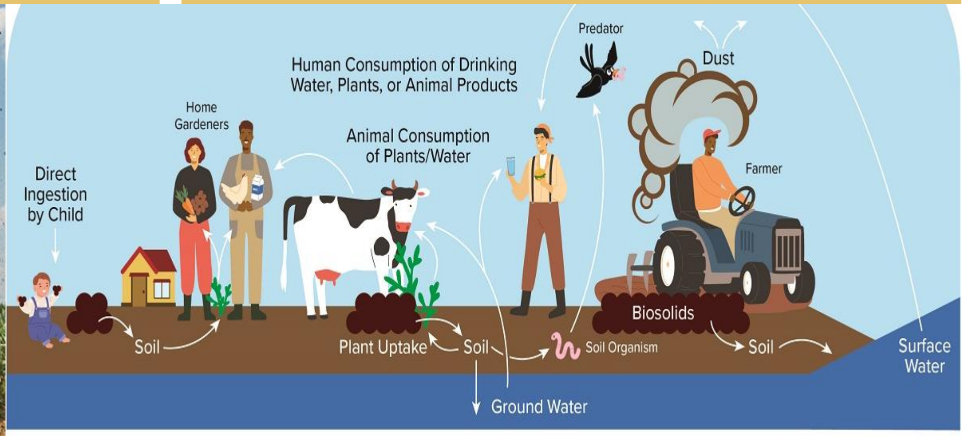
Globally Governments have different views on managing and regulating PFAS

Australia Vs. Europe (EU)
(PFAS, PFOS, PFHxS) Vs. ~All PFAS

Biosolids Contain PFAS

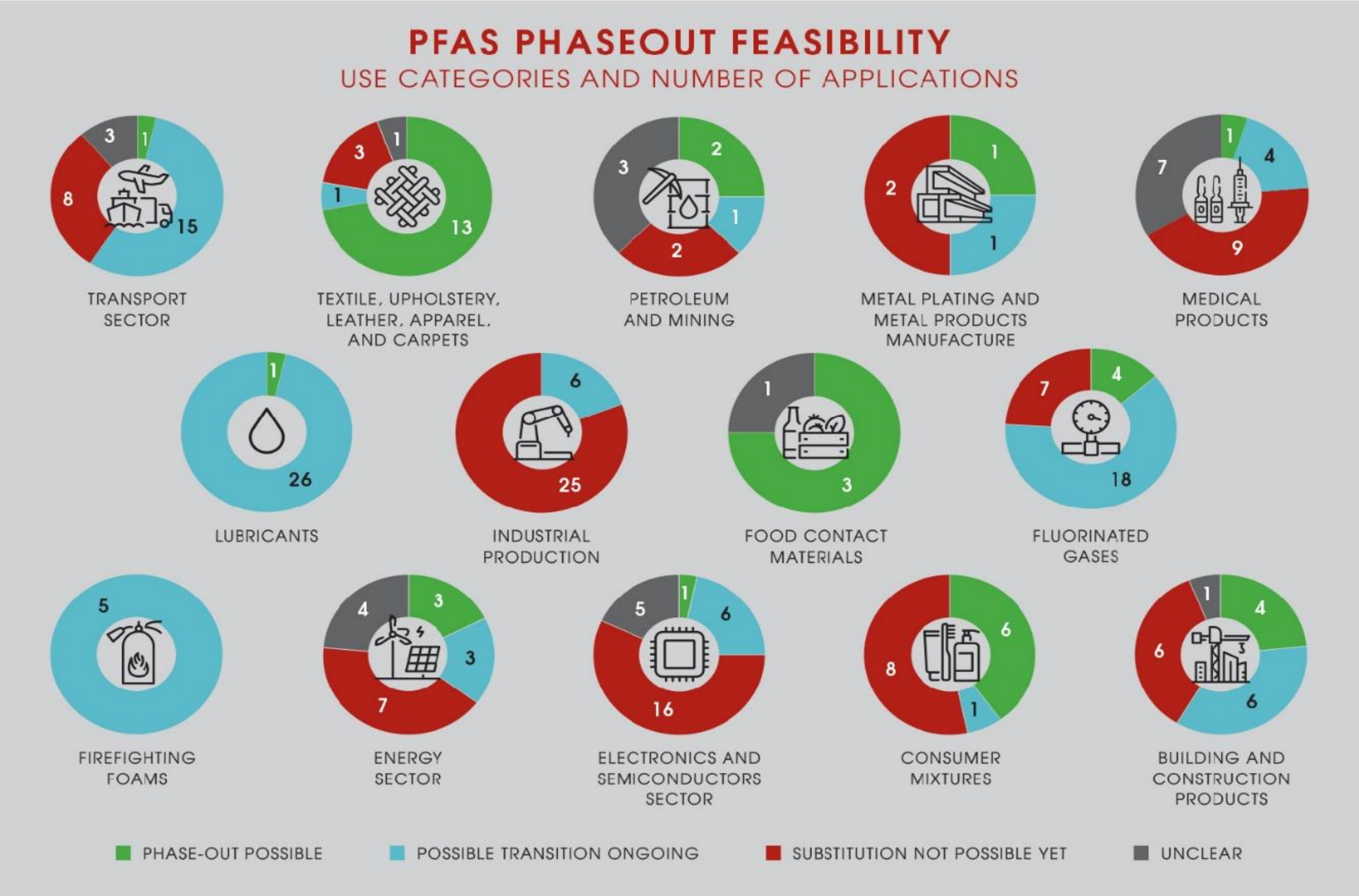
Given the extensive agricultural uses they are getting into our food chain and localenvironments!

The scope of issues for human and environmental impacts are considerable!



EXAMPLES OF POTENTIAL EXPOSURE PATHWAYS FOR ASSESSING RISKS FROM LAND-APPLIED BIOSOLIDS

PFAS PHASEOUT FEASIBILITY



- For about **40%** of applications, substitution is already possible or underway
- The database is being expanded. Work is ongoing with ChemSec (Marketplace) and broader (AI-based) search methods.

ZEROPM
ALTERNATIVE
ASSESSMENT
DATABASE

https://zeropm.eu/alternative-assessment-database/

Reference: Dr. Ian Cousins
Department of Environmental Science
Stockholm University, Sweden

How To Reduce Your PFAS EXPOSURE

- **Regular Home Cleaning:** HEPA vacuum & dusting to limit exposure consumer products dust, like some carpets and sprays.
  (Air out rooms by opening windows if the outdoor air quality is good).
- **Install Water Filters** *(activated carbon or reverse osmosis)* at the tap or where water enters your house.
- **Cookware**: Replace nonstick "Teflon" cookware with alternatives like stainless steel, cast iron, glass, or ceramic.
- **Food Packaging**: Reduce fast-food wrappers, takeout containers, microwave popcorn bags, as often coated with PFAS.
- **Textiles**: Discard old, stain-resistant carpets, upholstery, and waterproofing treatments. Look for PFAS-free options.
- **Labels**: Check product labels for PFAS-free claims. If you have questions, contact the manufacturer directly.
  (The Duty to disclose is and will increase!)
- **Stain-Proof Claims:** Avoid textiles that advertise their stain or waterproof qualities unless they are certified PFAS-free.
- **PFAS-Free Alternatives**: Look for PFAS-free food containers (Glass and Silicone) products as safer alternatives.
- **Fish Consumption:** Avoid fish caught from waterways known to have high levels of PFAS contamination.

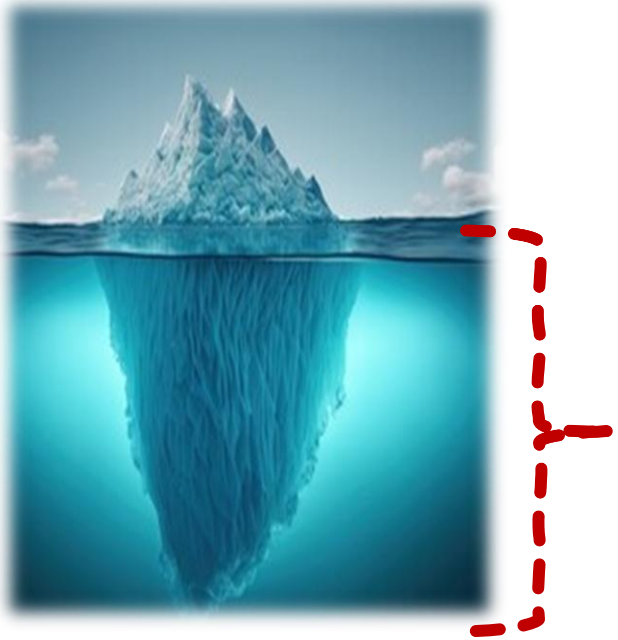
Check with environmental agencies, environmental associations, health authority, and related organizations for PFAS advice as still developing!

FOREVER PFAS WEATHER FORECAST

DO YOUR DUE DILIGENCE AT ALL TIMES!
FROM CLIENT ENGAGEMENT
THROUGH INVESTIGATION
THEN ON THROUGH
REMEDIATION & DECONTAMINATION

BE MINDFUL OF THE **LIABILITY** YOU FACE WORKING ON PFAS SITES!

DUE-DILIGENCE DEFENSE



AS REGULATIONS ENFORCEMENT INCREASES
INVESTIGATION-REMEDIATION-DECONTAMINATION
WILL NEED TO INNOVATE

PFAS IS A GLOBAL CONCERN - THAT WILL LAST YOUR ENTIRE CAREERS

But I'm Not Without Hope!

HELP!
Where Do We Go From Here ???

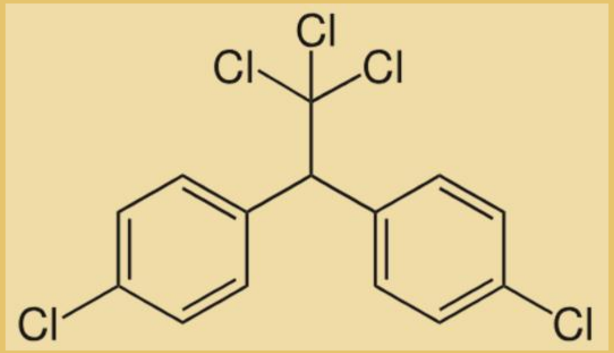
Stay Calm & Move Along

I Suggest We Can Learn From Our Past And Make The Necessary Adjustments As We Mature Through The Process

Make Changes That Eliminate PFAS Production & Sources To Minimize Human & Environmental Exposures – Then Over Time…We will See Measurable Human Health & Environmental Impacts Subside To A Point We Achieve Acceptable Risks Levels

Today No Unified Global Position On PFAS Exists

DDT



DDT Decades Of Impacts To Human & Environment

USEPA-Banned in 1972

No, the impacts of DDT have not fully resolved since its 1972 ban. Ban led to significant environmental improvements and recovery of many wildlife populations! DDT and its breakdown products (DDE and DDD) are persistent organic pollutants that still remain in the environment and human populations today…

Nuclear Testing Radioactive Fallout

JFK -Treaty To Ban Testing 1963

No, nuclear testing impacts have not been fully resolved since 1963 treaty. The treaty and subsequent agreements drastically reduced testing overall amount of radioactivity released to environment! Some long-term environmental & health consequences persist. A comprehensive treaty is still not in effect…


ENVIRONMENTAL BUSINESS JOURNAL®

BUSINESS ACHIEVEMENT AWARD

This certificate hereby witness that

Ivey International Inc.

has been selected for the honor of

Technology Merit: PFAS Mass Removal

awarded by Environmental Business Journal® for outstanding business achievement in the environmental industry in 2023
San Diego, California, USA
March 25, 2024

Grant Ferrier
CEO & Editor

Environmental Business Journal March 25, 2024
National Award
Patent Pending - August 2023

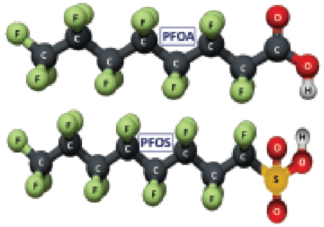
Total PFAS Mass Recovery 242% to 622%

Tests show surfactant-based technology effective in removing PFAS from soil and groundwater

By George (Bud) Ivey, David Holmes, and Cecilia MacLeod

In recent years, several major corporations, including 3M, DuPont, and Chemours (a DuPont spinoff), have reached major settlements with municipal governments and other plaintiffs, agreeing to spend billions of dollars to remove PFAS from their production processes, products and the environment.

A substantial amount of these settlement funds will go towards helping water treatment facilities to remove PFAS from drinking-water supplies. But significant dollars will also have to be spent to remediate PFAS-contaminated soil, bedrock, and groundwater.



The PFAS family consists of nearly 15,000 chemicals.

The potential markets for PFAS remediation are numerous, ranging from chemical and other product manufacturing to electric power, wastewater treatment, real estate development, retail petroleum, landfill operations, mining, ports and harbors, federal facilities, and more (*Environmental Business Journal, Vol. XXXII, No. 5/6, 2019*). All face significant future liabilities as the regulatory net and public awareness around PFAS grows and tightens. However, remediation contractors can face these future liabilities as well if their PFAS cleanup solutions prove inadequate to the task.

The traditional pump-and-treat solution has been applied to the remediation of PFAS-impacted groundwater, but it is expensive and can take decades to achieve any significant levels of removal.

Additionally, contamination in the more mobile, high-permeability groundwater zone can migrate into immobile, low-permeability subsurface zones, and pump-and-treat is not effective in removing contamination from those low-permeability zones. This can lead to future releases and back-diffusion into the high-permeability zone, and thereby failure to meet regulatory standards.

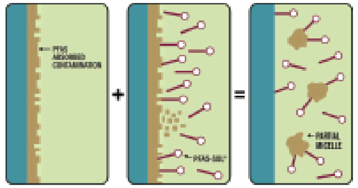
Some chemical and biological removal methods are being tested, but satisfactory results have not emerged. Methanol solvent extraction is used in laboratory soil extraction, and some small-scale testing. However, regulators are not likely to look approvingly at injecting many of these impactful chemicals into the ground.

One potential solution, however, has been shown to be effective in recently completed tests. Ivey International Inc. (IVEY) has developed a new formulation from its Ivey-sol® enhanced remediation (SER) technology to address PFAS contamination in groundwater, soil, and bedrock regimes.

Tests of the PFAS-SOL® formulation conducted in the United Kingdom (UK) in collaboration with the University of Greenwich, with analysis by ALS, have shown significant PFAS mass removal rates. This formulation is non-toxic, biodegradable, and pH neutral. It is based on non-ionic formulations, with a novel additive, that can selectively desorb contaminants and render sorbed, globular and non-aqueous phase liquids (NAPL) soluble in the aqueous phase. This means it forms a non-emulsified mixture with water and can thus be more easily controlled and removed from impacted soil, fractured bedrock, groundwater, and surface water while maintaining plume control.

The PFAS-SOL surfactant structure consists of a hydrophilic head and a hydrophobic tail. The hydrophobic tail is by design, selectively attracted to the organic functional groupings on target contaminant molecules, while the hydrophilic head is attracted to groundwater.

Based on this modulated structure, these surfactants offer multiple properties that improve the effectiveness of most remediation strategies, predominantly by overcoming the limitations associated with contaminant sorption and low solubility. In addition, they lower the relative surface tension of water and overcome interfacial tension, thereby improving its wetting and associated hydraulic properties across

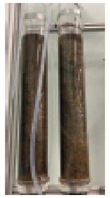


PFAS-SOL can selectively remove PFAS from sorbed soil and bedrock surfaces.

broader soil textures.

PFAS-SOL can selectively remove PFAS from sorbed soil and bedrock surfaces, from globule and/or NAPL phase-partitioned layers, to make them more available for enhance physical, biological, and/or chemical remediation.

For the column tests, one metre by 14 centimetre diameter columns were filled with a mineral sand (a building sand), with 10% activated carbon to act like natural organic carbon absorptive content within the soil. The columns were then slowly saturated with water from the base and drained to a set the volume. They were next spiked with 250 mg each of PFOA and PFOS to mimic a PFAS source zone and then drained and filled, with the effluent sampled to show contaminant recovery in water.



The two test column tubes were spiked with 250 mg each of PFOA and PFOS to mimic a PFAS source zone.

The columns were filled again, one with methanol at a 50% concentration in water, the other with the PFAS-SOL surfactant formation at a 4% concentration. They were then drained, with the increased concentration in the effluent in the PFAS-SOL column showing a large increase in PFAS concentration. The columns were then slowly taken apart to deliver a moisture profile and obtain soil samples to measure retained PFAS.

The results showed significant mass PFAS removal from the PFAS-SOL flushes. Flushes with water alone yielded PFAS recovery of approximately 5 micrograms per liter (µg/L), whereas surfactant flushes exhibited improved recovery of up to 30.45 micrograms per liter (µg/L). This meant an average improvement in PFAS removal of 240%, with concentration spikes of up to 622%. PFOA recovery averaged 160%, with best results of 185%. PFOS recovery averaged 297%, with best results of 732%. Total PFAS recovery averaged of 242%, with best results of 622%.

Subsequent tests have shown similarly impressive results, suggesting a bright future for this surfactant-based PFAS remediation compared with other methods that are time-consuming and costly, and don't provide assurances against future back-diffusion risks liability associated with new sportive technologies.

Ivey International Inc. won the 2023 M&A Today Global Awards 'Best Environmental Technology Company' in recognition for their innovative technology developments. ■

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99.99998% PFAS Mass Removal

Decontaminating fire-fighting equipment to prevent PFAS from entering water supplies

By J. Scott Poynor

Although there is still much to learn, we know that the class of chemicals known as per- and polyfluoroalkyl substances, referred to generally as PFAS, is ubiquitous in the environment and poses risks to human health and the environment. Of utmost concern lately, PFAS in water supplies has become recognized as a special risk, and municipal water systems, or government agencies acting on their behalf, have taken the lead in suing manufacturers to phase out PFAS production and provide the funds for remediation.

Meanwhile, the development of technologies for removing PFAS from the environment is playing catch-up. These environmental endpoints include not only water and soil but surfaces of all kinds of products and equipment that present human exposure risks. Although multiple technology development efforts are underway, there remains a lack of efficient, scalable, cost-effective, and environmentally benign technologies to deal with this broad range of contamination issues.

One promising technology was recently successfully deployed at a petroleum storage facility, which faced PFAS problems associated with its fire-suppression equipment. The facility operator, recognizing the rapidly advancing tide of PFAS-related action, sought to address contamination in certain equipment, in the interest of liability and risk management and out of concern for potential employee exposures.

The equipment in question consisted of a fire-fighting system, including piping that stored aqueous film-forming foam (AFFF), a fire-fighting liquid that contains PFAS compounds.

Replacing the PFAS-contaminated equipment was not viable, due to cost considerations and, even more, to the time required for procurement and installation of new equipment. Fire-fighting systems at petroleum storage facilities are required to be operational essentially full-time, so removing the residual PFAS from the existing equipment was deemed the preferred option.

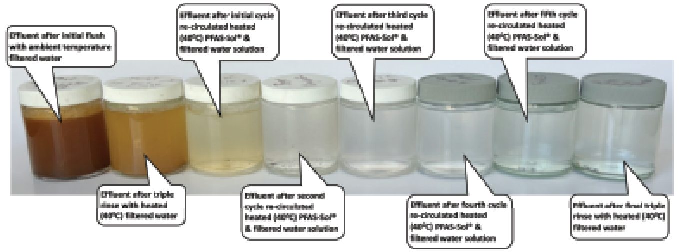
The facility operator agreed to GST's recommendation that PFAS-SOL be deployed to reduce the concentrations of PFAS residues on the fire-fighting system piping and equipment surfaces.

Following removal of the AFFF from the system, residual concentrations of PFAS were detected on the equipment surfaces. The facility operator performed a thorough, high-pressure flushing of the system using filtered municipal potable water, but that action left a PFAS concentration of 342,643 ng/100 cm^2 on the equipment's interior surface, a level deemed significant and falling short of the facility operator's decontamination goals.

The facility operator then engaged Geologic Science and Technology Group (GST), an environmental consulting firm with which the operator had frequently worked in the past, to undertake the equipment decontamination project. The objective of the project was to reduce residual concentrations of detected PFAS constituents to the maximum extent possible using currently available technology.

In initial discussions with the facility operator, GST reviewed the known available options for removing PFAS from surfaces. Flushing with an alcohol-based solvent (ethanol or methanol) has historically worked better than flushing with water, but it is known to leave PFAS concentrations in residue of about 10%, which was substantial and considered to be too high.

GST then presented a surfactant-based solution that had shown the potential to achieve substantially improved removal rates compared with alcohol-based solvents. PFAS-SOL® is a patent-pending,



The remediation project then proceeded with a series of five flush cycles using combinations of PFAS-SOL and filtered municipal potable water.

non-ionic surfactant developed by British Columbia based Ivey International Inc. (IVEY) that is pH neutral, non-caustic, non-corrosive, non-toxic, and biodegradable.

In extensive bench-scale testing, PFAS-SOL® has demonstrated the capacity to desorb PFOA and PFOS, which are associated with AFFF, from a broad range of impacted surfaces, including metal, plastic, glass, ceramics, and composites. The technology has also been tested for more than 157 chemical impurities, with some at parts-per-quadrillion (ppq) levels, including the compounds contained in the removed AFFF.

The facility operator agreed to GST's recommendation that PFAS-SOL® be deployed to reduce the concentrations of PFAS residues on the fire-fighting system piping and equipment surfaces. The equipment decontamination project was undertaken in early March 2024, with a series of sequential phases.

Tanks for blending the surfactant with municipal potable water were staged by the pipe fittings on the portion of the fire-fighting system to be decontaminated, both upstream and downstream to create a closed-loop system.

The emptied piping system was initially flushed with filtered potable water at an ambient temperature (approximately 19°C) and then flushed three times with filtered potable water heated to 40°C. Following this flushing and wipe sampling at the discharge point, laboratory analysis detected a total of 12 PFAS analytes on the piping interior surface. These analytes consisted of nine acid compounds and three sulfonate compounds.

SUMMARY OF PFAS COMPOUNDS DETECTED ON INTERIOR SURFACE OF FIREFIGHTING PIPING SYSTEM AFTER AFFF REMOVAL

DETECTED PFAS			AFTER SYSTEM AFF PURGE & WATER RINSE	AFTER HEATED PFAS-SOL® WASH and HEATED WATER RINSE	
Type	Compound	CAS	Pre-Decon	Post-Decon	% Reduction
Acids	Perfluorobutanoic acid (PFBA)	375-22-4	365.0 ng	<0.203 ng U	> 99.99994%
	Perfluoropentanoic acid (PFPeA)	2706-90-3	336.0 ng	<0.0434 ng U	> 99.99369%
	Perfluorohexanoic acid (PFHxA)	307-24-4	2,800.0 ng	<0.0243 ng U	> 99.99904%
	Perfluoroheptanoic acid (PFHpA)	375-85-9	311.0 ng	<0.0467 ng U	> 99.99281%
	Perfluorooctanoic acid (PFOA)	335-67-1	1,260.0 ng	<0.0312 ng U	> 99.99876%
	Perfluorononanoic acid (PFNA)	375-95-1	108.0 ng J	<0.0155 ng U	> 99.99284%
	Perfluorodecanoic acid (PFDA)	335-76-2	472.0 ng	<0.0333 ng U	> 99.99650%
	Perfluoroundecanoic acid (PFUnDA)	2058-94-8	38.0 ng J	<0.0294 ng U	> 99.96291%
	Perfluorododecanoic acid (PFDoA)	307-55-1	151.0 ng	<0.0349 ng U	> 99.98844%
Sulfonates	Perfluorooctanesulfonic acid (PFOS)	1763-23-1	<10 ng U	0.0269 ng J	> 99.86284%
	6:2 Fluorotelomer sulfonic acid (6:2 FTS)	27619-97-2	284,000.0 ng	0.0629 ng	99.99998%
	8:2 Fluorotelomer sulfonic acid (8:2 FTS)	39108-34-4	82,800.0 ng	<0.0790 ng U	> 99.99995%
		Sum of detected PFAS	372,643 ng	0.0838 ng	99.99998%

NOTE: [illegible]

The remediation project then proceeded with a series of five flush cycles using combinations of PFAS-SOL® and filtered municipal potable water. In each cycle, the surfactant-water solution was heated to 40°C and recirculated for one to 1.5 hours by redundant pumps at high velocity under increased pressure. Following each cycle, the piping system was purged with filtered potable water heated to 40°C to remove all traces of the solution before applying it again in the next cycle. One final triple rinse followed cycle five.

A wipe sample was collected at the discharge point over a 100 cm^2 area of piping and compared with a baseline wipe sample that had been collected prior to the initial flush. The decontamination process reduced residual PFAS contamination on the equipment surfaces by an additional 99.99998%, to 0.0838 ng/100 cm^2, beyond what the AFFF removal and potable water flushing were able to achieve.

Another significant outcome was the fact that decontamination with the PFAS-SOL® surfactant-water solution significantly reduced residues of the longer- and shorter-chain PFAS compounds, such as C4 through C12, and not just the C8 chains that have garnered much of the attention for decontamination.

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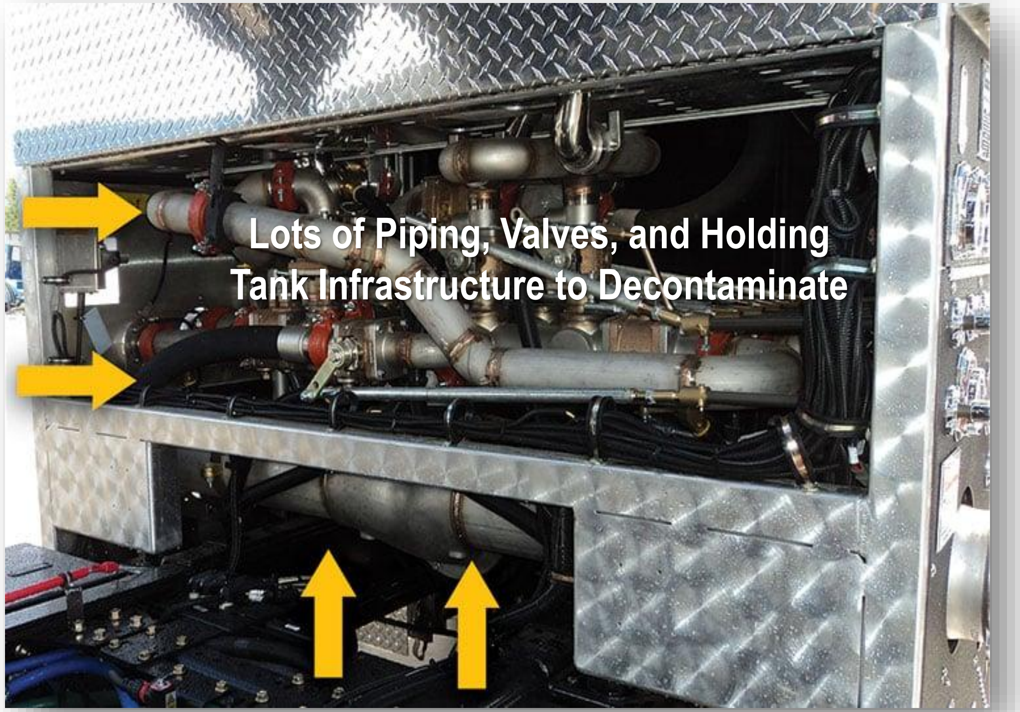
Environmental Science & Engineering October 2024

PFAS Decontamination of Fire Pumper Trucks

- **PFAS Containing AFFF Fire Suppression Product Changes Outs Are Undertaken Globally For Many Reasons Including:**
  - Comply With Local **Regulations** (Environmental & Health Risk)
  - Response To **Worker Health & Safety** (Fire Unions) Concerns
  - Legal **Liability** Management
  - Tightening **Insurance** Pressure
  - **Stakeholder + Public** Pressures (*Social License*)
  - **Manufacturer Supply Chain** pressure to Use New Products



- **PFAS-SOL Application To Decontaminate AFFF Fire Trucks For Safer Change Outs To Non-Florinated Fire Suppression Products**
- **To Avert Risk Of Potential Residual PFAS Cross Contamination**

"The Use of PFAS-SOL® For Decontamination of Fire Trucks At A Refinery Site In USA Exceeded The Client's Expectations! They Are Actively Planning PFAS Decontamination Of Additional Assets In 2026, Using PFAS-SOL®."

Scott Poynor, President, GST *(Project Technical Advisor)*

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IVEY

IVEY-SOL Surfactant Technology

PFAS SOL

DECON-IT® Omni Surface Decontaminator

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