The Morass of PFAS

Or

Dead cows and a smoking gun.

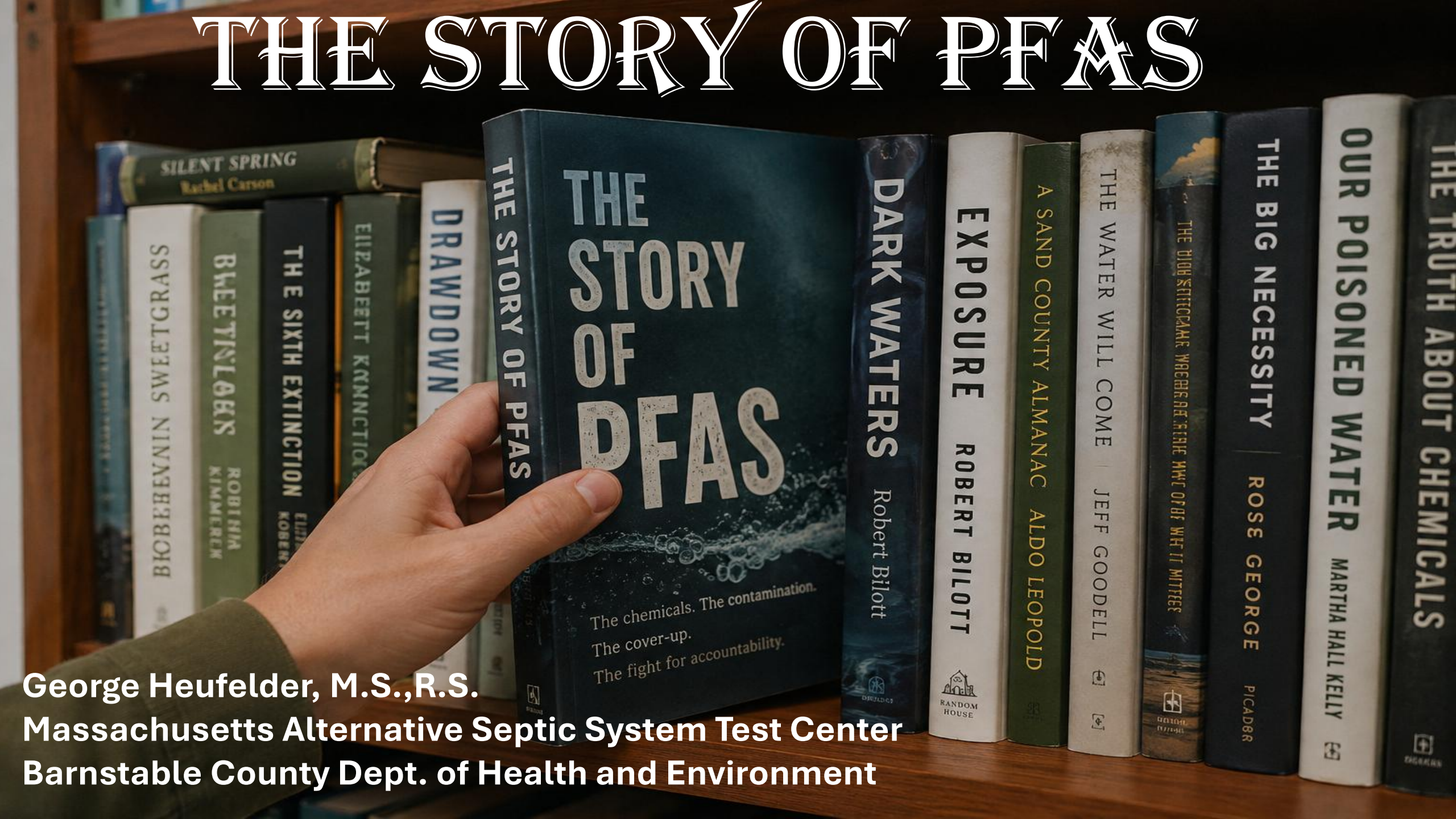


the birth of the PFAS story

..and yes, how this relates to septic systems

George Heufelder M.S., R.S. Massachusetts Alternative Septic System Test Center gheufelder@capecod.gov

THE STORY OF PFAS



George Heufelder, M.S.,R.S.
Massachusetts Alternative Septic System Test Center
Barnstable County Dept. of Health and Environment

Take Home

Sometimes scientific revolutions don't begin in a laboratory. This one began in a pasture. In 1998, a West Virginia farmer noticed something terribly wrong with his cattle. His search for answers would help uncover one of the most consequential environmental contamination stories of our time.

CHAPTER 1

DISCOVERY

Another day which will live in infamy

The discovery of polytetrafluoroethylene (PTFE)

A carbon backbone shielded in fluorine

- Exceptional chemical resistance
- High heat resistance
- Slippery
- Almost insoluble

Teflon®

One of the most chemically inert substances ever made



Chapter 2

The Invisible Helper

The Plot Thickens

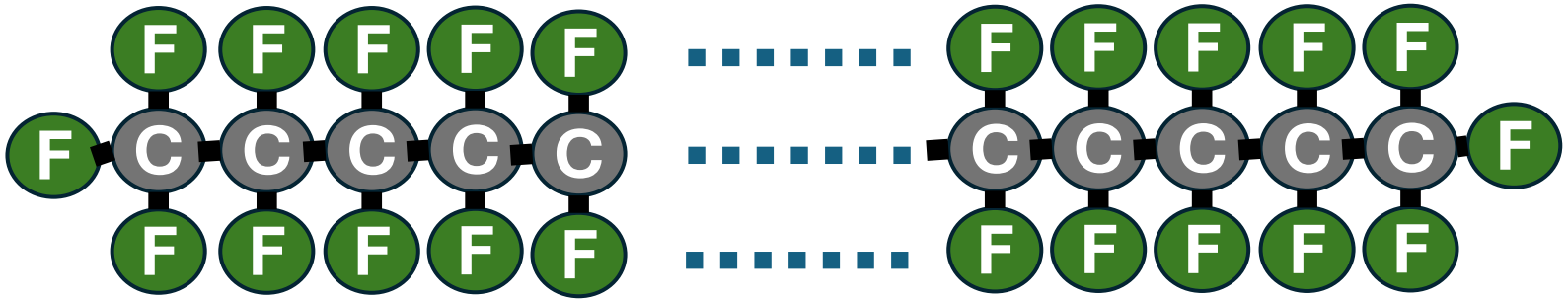


Making PTFE in water presented a problem: keeping the tiny polymer particles from clumping together



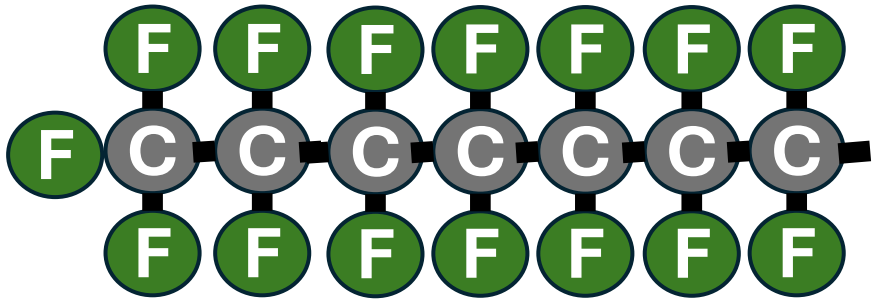
In order to commercially make Teflon® you need to keep the PTFE from clumping in aqueous dispersion polymerization.

20,000 – 200,000 Carbon atoms





Insoluble



\+ Attach Functional group

TO MAKE

Sulfonates
Alcohols
Sulfonic Acids
Sulfonamides
Carboxylic acids

May or may not be soluble

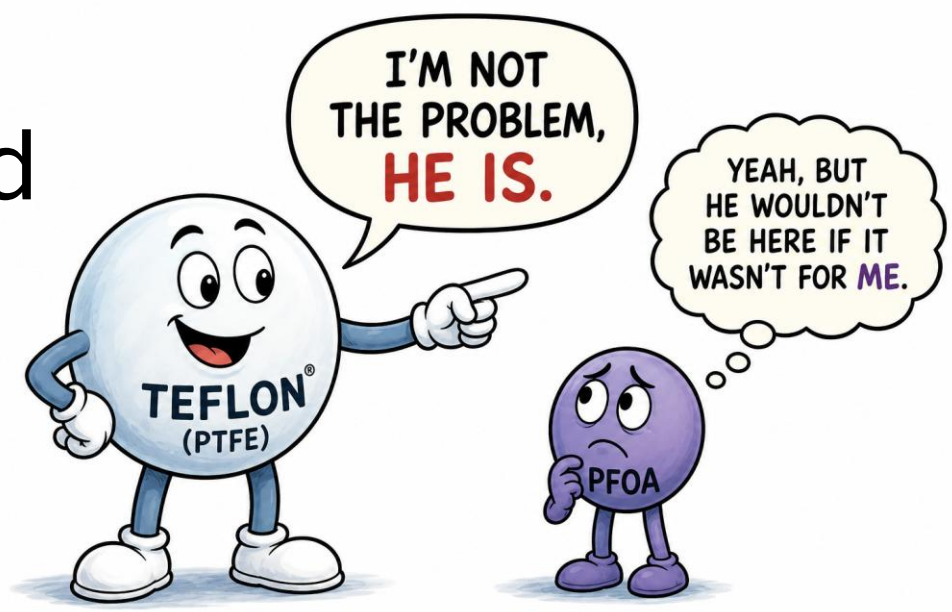
The PFAS Story: Pandora's Chemistry



- Breakthrough discovery
- Countless applications
- Unintended consequences

How did we go from there to here?

The PFAS problem is not that we invented one remarkable chemical (PTFE). It's that we discovered an extraordinarily useful ***family*** of chemicals and then found thousands of ways to use them before we fully understood what their persistence would mean for the environment.



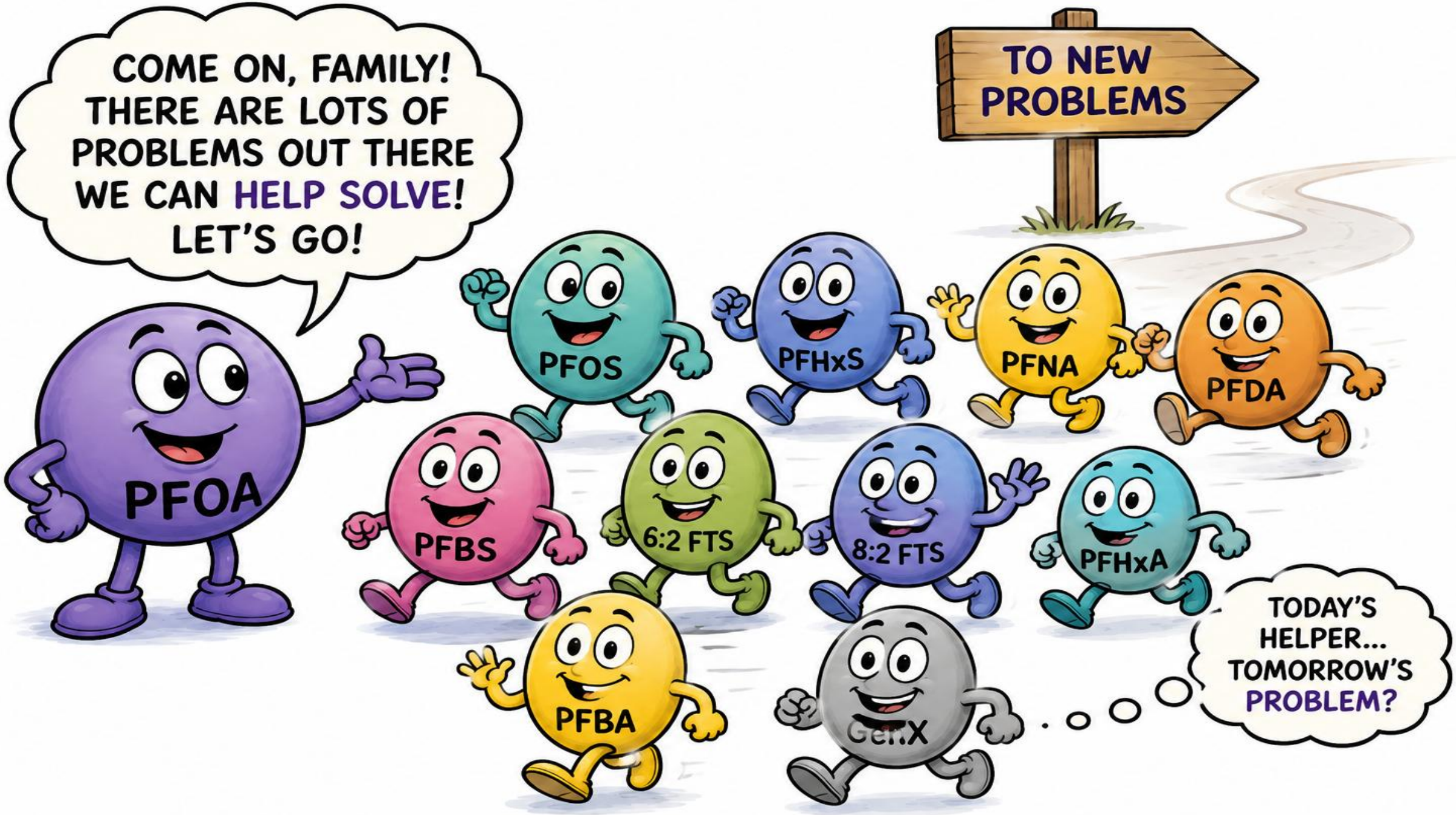
PFOA (perfluorooctanoic acid) did NOT come from Teflon®

It helped MAKE Teflon®

- it was a surfactant that kept it from clumping

Chapter 3

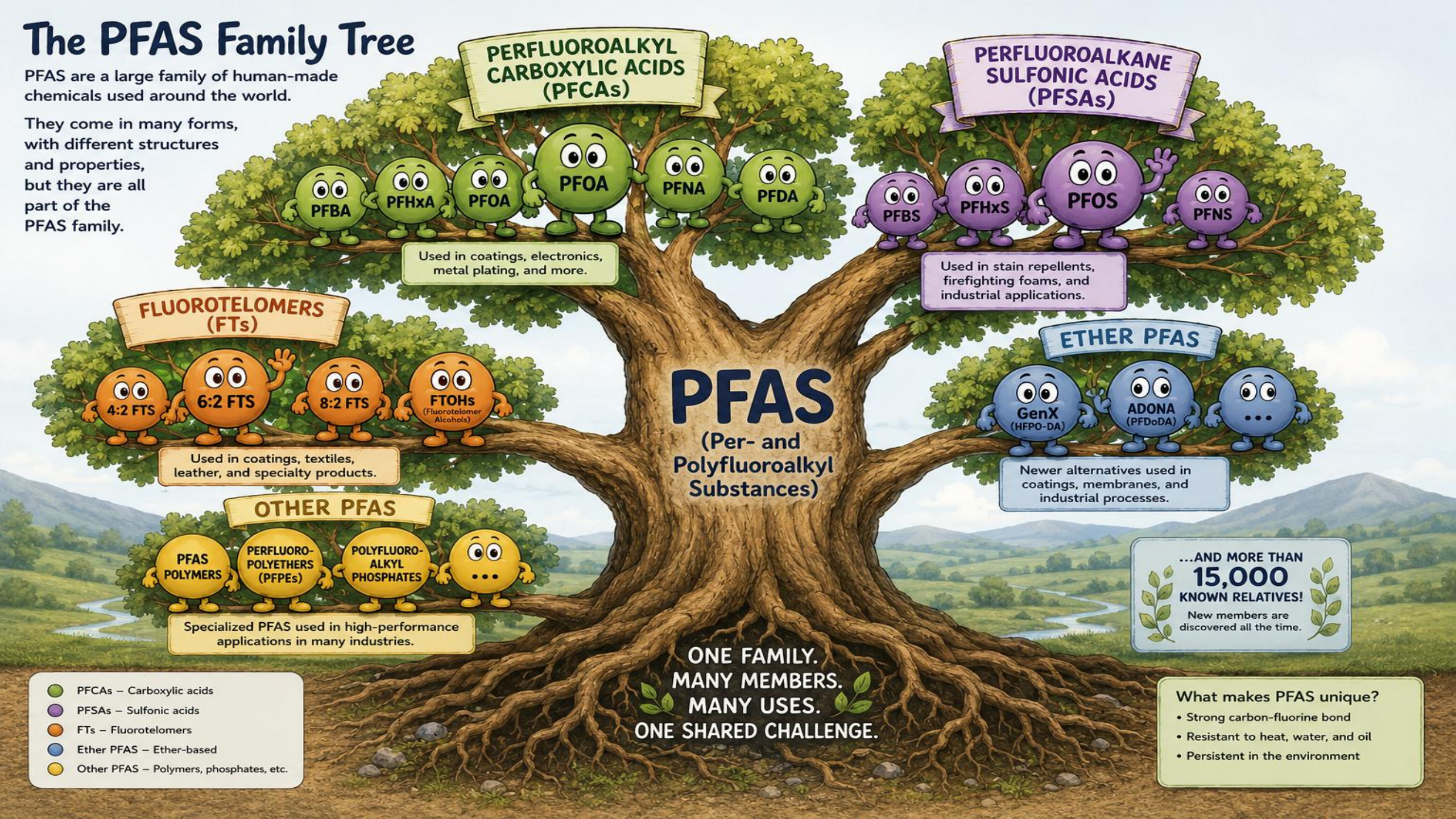
The Family Continues to Grow


COME ON, FAMILY! THERE ARE LOTS OF PROBLEMS OUT THERE WE CAN HELP SOLVE! LET'S GO!
TO NEW PROBLEMS
PFOA
PFOS
PFHxS
PFNA
PFDA
PFBS
6:2 FTS
8:2 FTS
PFHxA
PFBA
Gen.X
TODAY'S HELPER... TOMORROW'S PROBLEM?

The PFAS Family Tree

PFAS are a large family of human-made chemicals used around the world.

They come in many forms, with different structures and properties, but they are all part of the PFAS family.



Perfluorocarboxylic acids

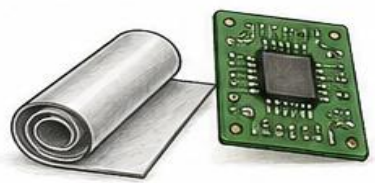
PFOA

Non-stick cookware, stain resistant fabrics, firefighting foams.



PFNA

Coatings, plastics, electronics, industrial processing aid.



PFDA

High performance coatings, lubricants, sealants.



PFUnA

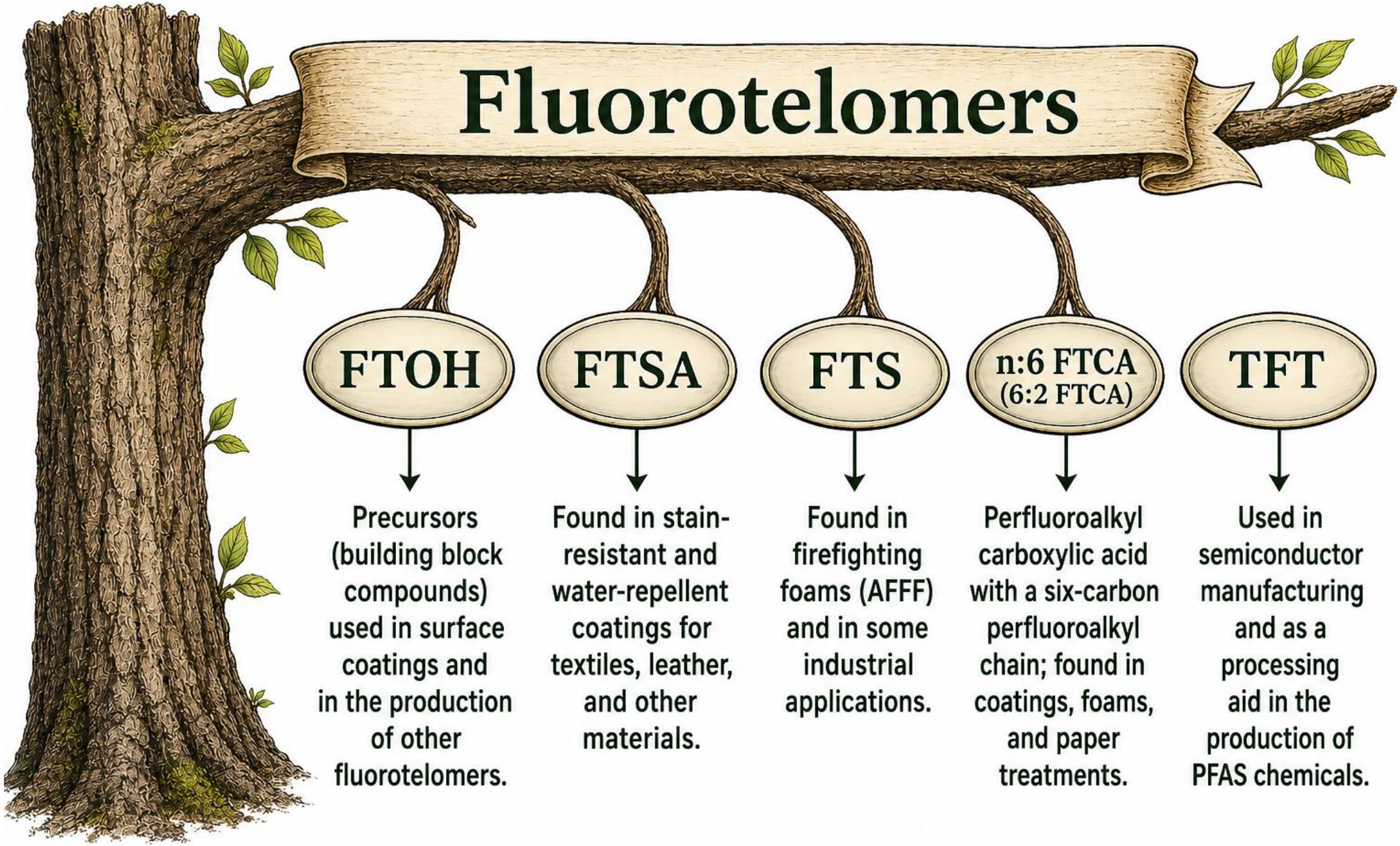
Specialty coatings, inks, adhesives, electronic applications.



PFDoA

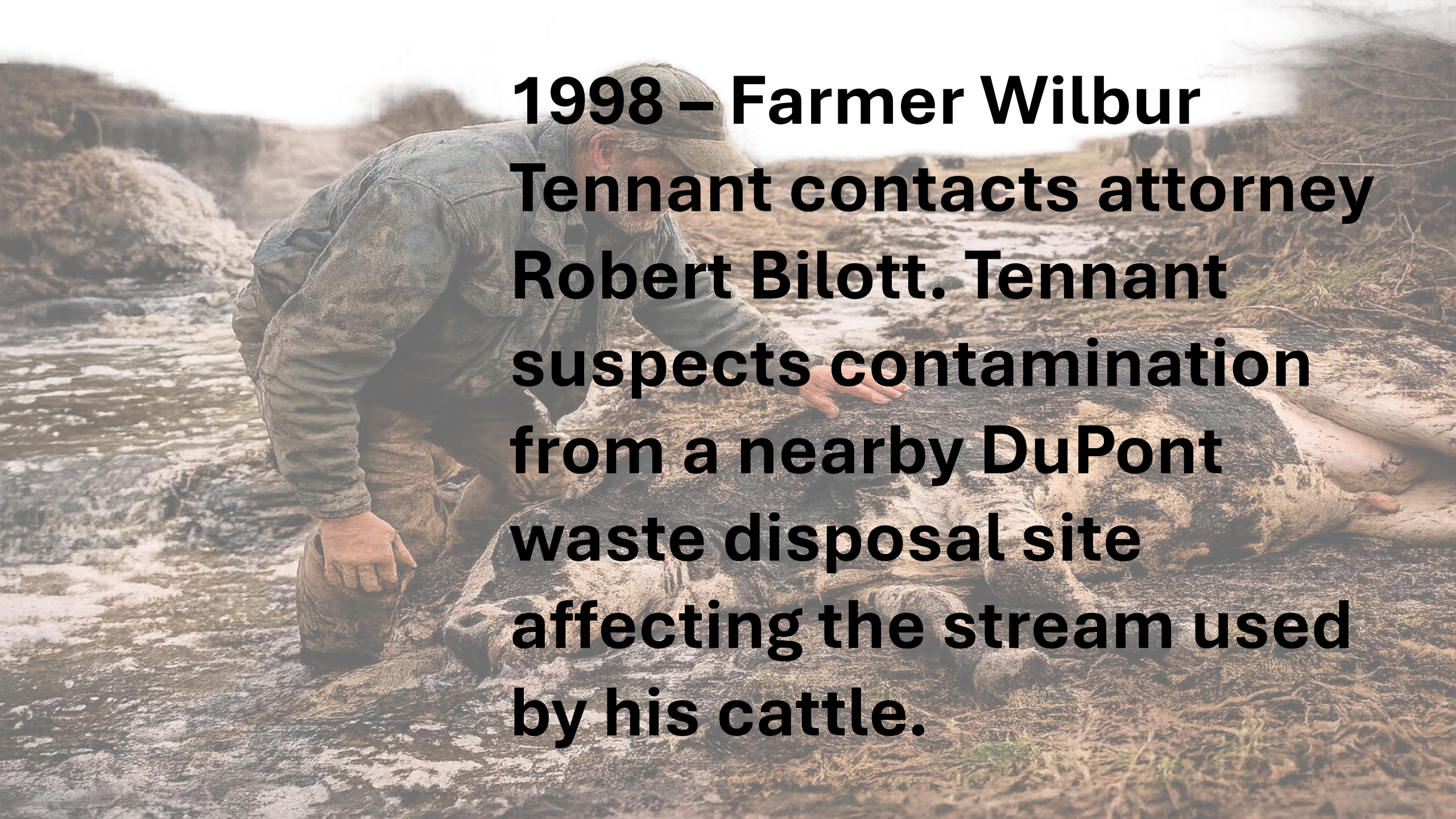
Lubricants, coatings, surface treatment formulations.




Fluorotelomers
FTOH
FTSA
FTS
n:6 FTCA
(6:2 FTCA)
TFT
Precursors (building block compounds) used in surface coatings and in the production of other fluorotelomers.
Found in stain-resistant and water-repellent coatings for textiles, leather, and other materials.
Found in firefighting foams (AFFF) and in some industrial applications.
Perfluoroalkyl carboxylic acid with a six-carbon perfluoroalkyl chain; found in coatings, foams, and paper treatments.
Used in semiconductor manufacturing and as a processing aid in the production of PFAS chemicals.

Chapter 4

Dead Cows, a Smoking Gun, and a Momentous Discovery



1998 – Farmer Wilbur Tennant contacts attorney Robert Bilott. Tennant suspects contamination from a nearby DuPont waste disposal site affecting the stream used by his cattle.

During the discovery phase of the lawsuit against Dupont, it was found that the company was dumping waste into a stream that crossed his property and knew about PHAS:

The company had

- Animal toxicology studies.
- Worker health monitoring data.
- Internal memoranda discussing contamination.
- Waste disposal practices and emissions.

FOR DECADES !

Chapter 5

Dead Cows Open Door


A QUESTION THAT NEEDED ANSWERS
LARGE EPIDEMIOLOGICAL STUDY
DISCOVERY
DOCUMENTS
SCIENCE
TRUTH
JUSTICE

Formation of “C8 Science PANEL”



https://www.c8sciencepanel.org/

C8 Science Panel

Panel Members

Home
The Science Panel
Panel Members
C8 Probable Link Reports
C8 Science Panel Studies
C8 Study Publications
C8 Health Project
Newsletter Archive

Members of the C8 Science Panel are:

Dr. Tony Fletcher, London School of Hygiene and Tropical Medicine
Dr. David Savitz, Brown University
Dr. Kyle Steenland, Emory University

Dr. Tony Fletcher
London School of Hygiene and Tropical Medicine

Chapter 6

2004 - Enter Science

- **2004**: The Class-action settlement establishes the C8 Science Panel
- **2005 – 2006** Major health data collected and analyses begin
- **2011 – 2012** Panel releases probable-link findings


C8 Science panel
The cows didn't provide the answers. They opened the door. Discovery uncovered decades of internal documents, leading to one of the largest environmental health studies ever conducted and launching a new era of PFAS research

The six conditions for which the panel found a "probable link"

- **Kidney cancer** (April 2012 report)
- **Testicular cancer** (April 2012 report)
- **Ulcerative colitis** (July 2012 report)
- **Thyroid disease** (July 2012 report)
- **Pregnancy-induced hypertension (including preeclampsia)** (December 2011 report)
- **Diagnosed high cholesterol** (October 2012 report)

CHAPTER 7

THE SEPTIC CONNECTION

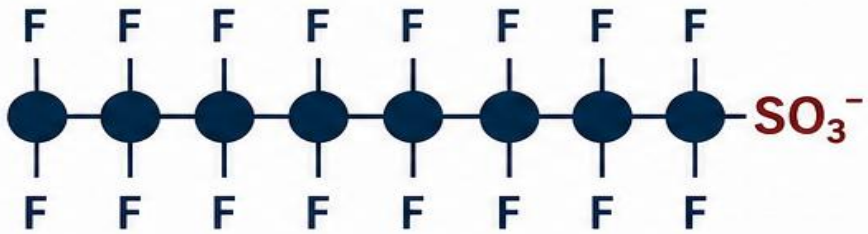
What does all this have to do with septic systems ?

PFAS USE IN TRANSITION

A shift in chemistry. Not the end of the problem.

C8 ERA

1990s–Early 2000s

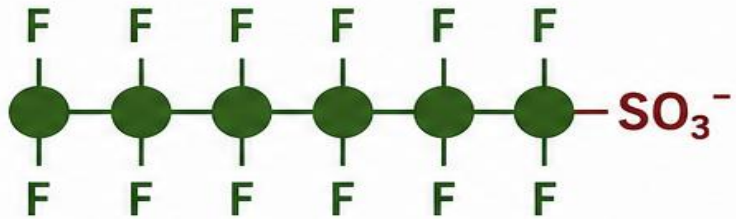


Highly persistent
Bioaccumulative
Travel far

INDUSTRY TRANSITION

C6 ERA

Mid-2000s–Present



Less bioaccumulative
More mobile
Still persistent



Different chemistry. Different behavior. Same need for protection.

C8 ERA

One focal compound
One lawsuit
One exposed population
One independent Science Panel
One landmark epidemiological study

C6 ERA

Thousands of replacement compounds
Thousands of individual studies
No single exposed population
No “C6” Independent Science Panel
No one landmark epidemiological study

C8 ERA

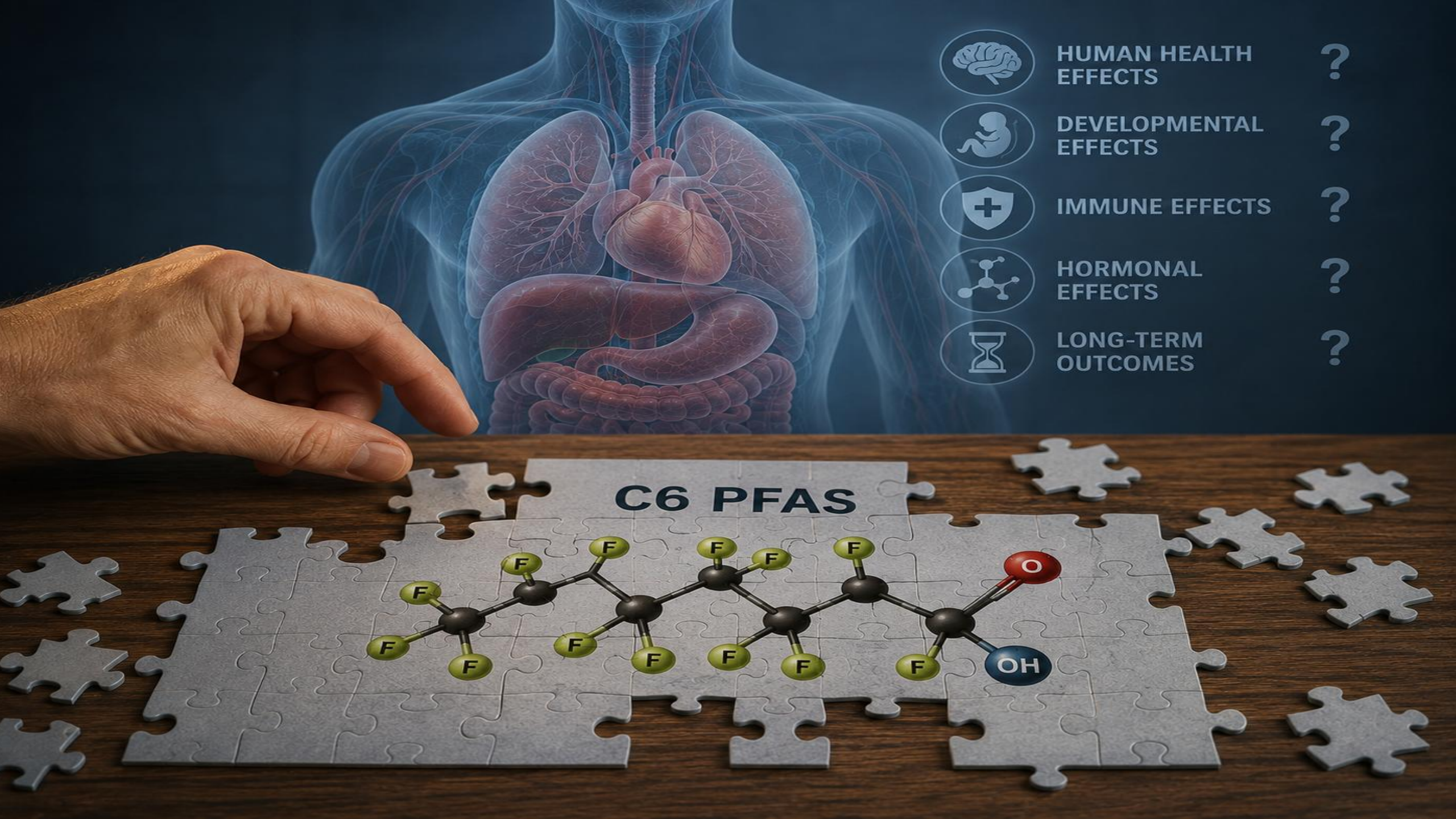
Many C8 compounds showed affinity for adhering to sludge, and some went through transformation to “measureable” compounds

C6 ERA

Many shorter-chain PFAS remain dissolved, passing through conventional treatment systems and entering receiving groundwater and surface waters

IMPORTANT !!

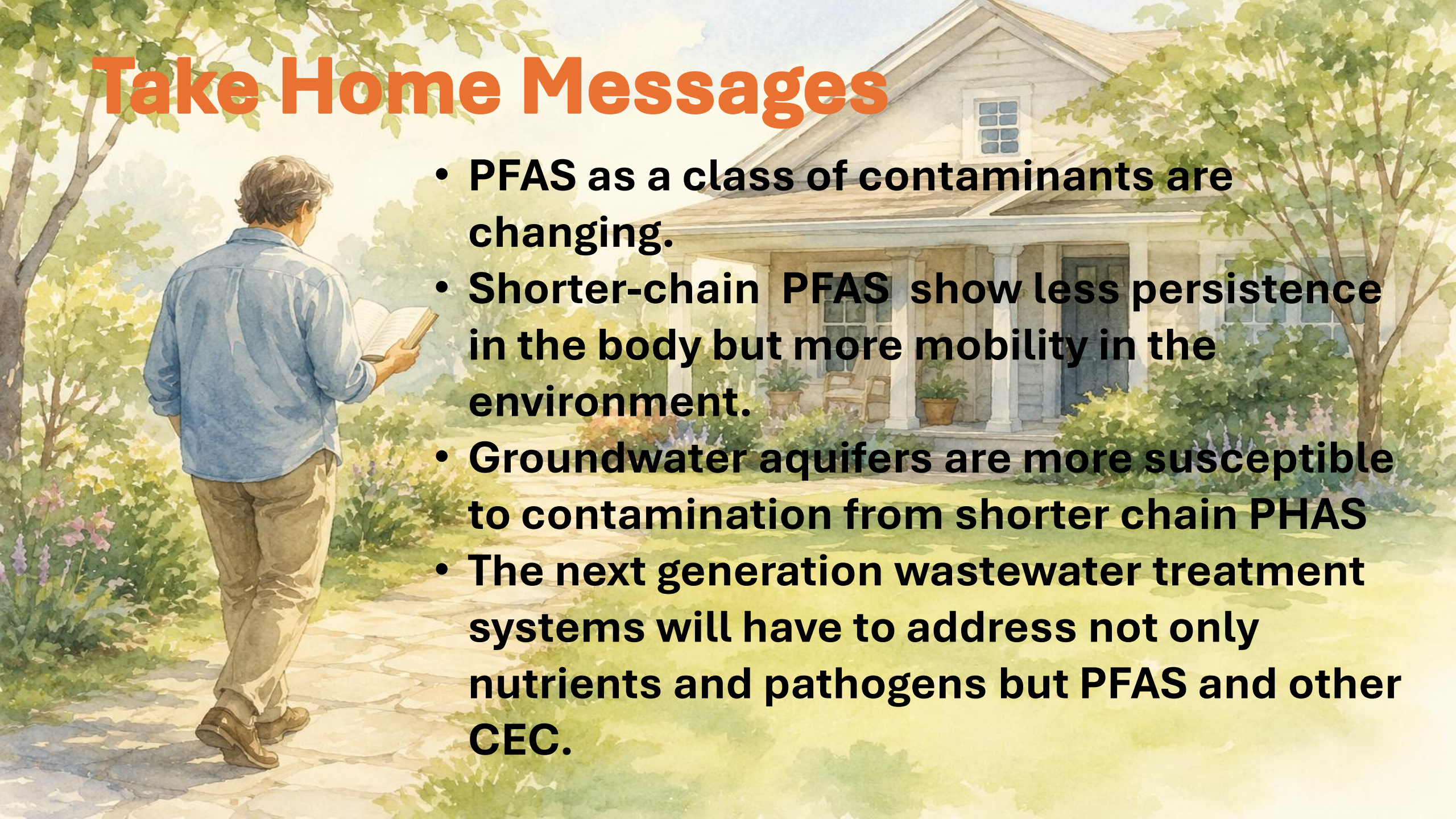
In the transition, industry didn't stop making fluoropolymers like Teflon®. What changed in many manufacturing processes was the chemistry used to make them. The old workhorse PFOA was largely retired and replaced with newer fluorinated processing aids, many based on C6 or ether chemistry.


HUMAN HEALTH EFFECTS ?
DEVELOPMENTAL EFFECTS ?
IMMUNE EFFECTS ?
HORMONAL EFFECTS ?
LONG-TERM OUTCOMES ?
C6 PFAS
F
O
OH

- We have a very long way to go in our understanding of the PFAS chemistry
- There may be some de-fluorination through anaerobic pathways present in onsite septic systems but there is likely very little removal in septic systems or traditional wastewater treatment systems
- **We have dug a very deep hole and left the ladder in the garage**

Bottom Line

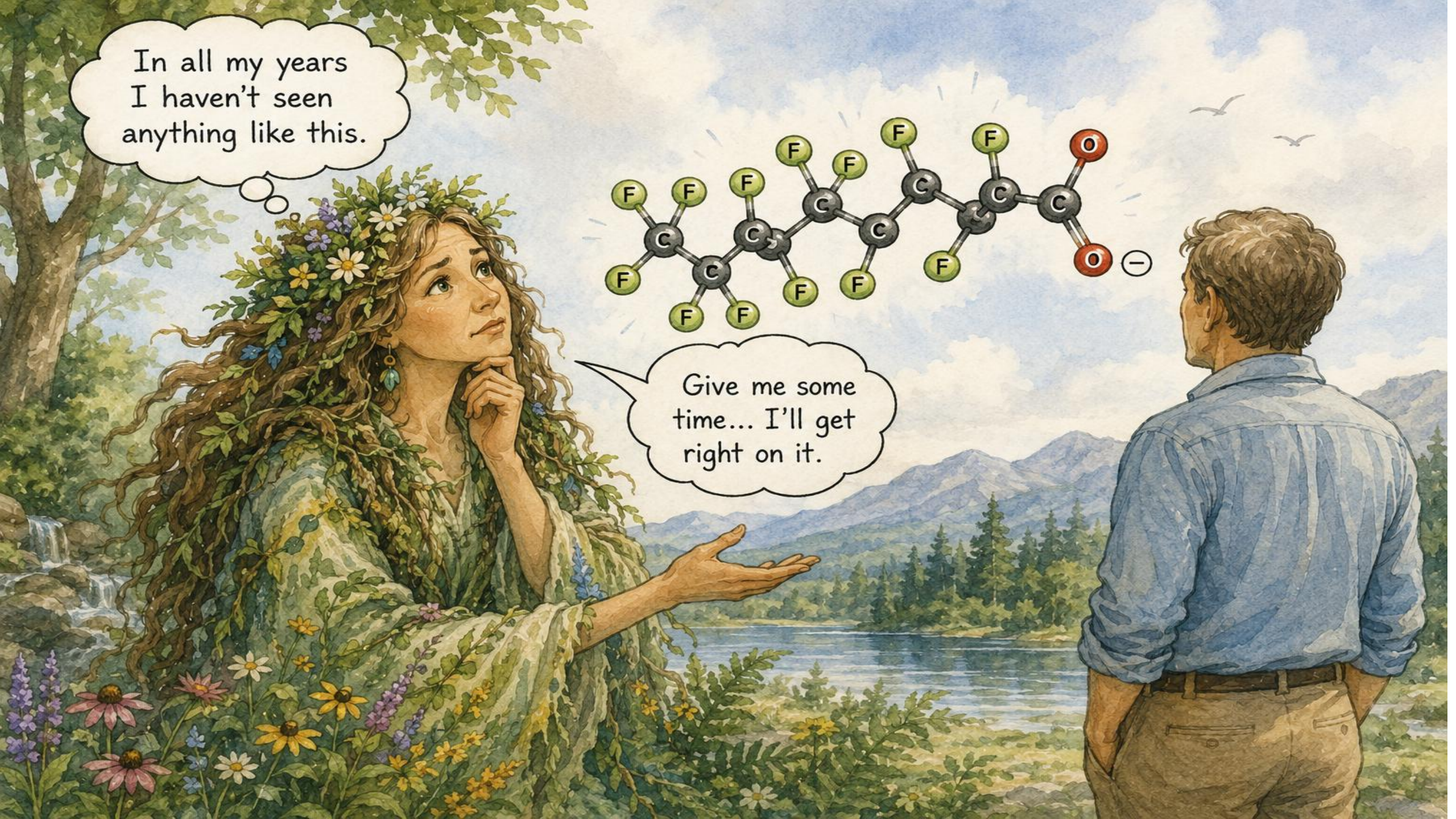
Take Home Messages



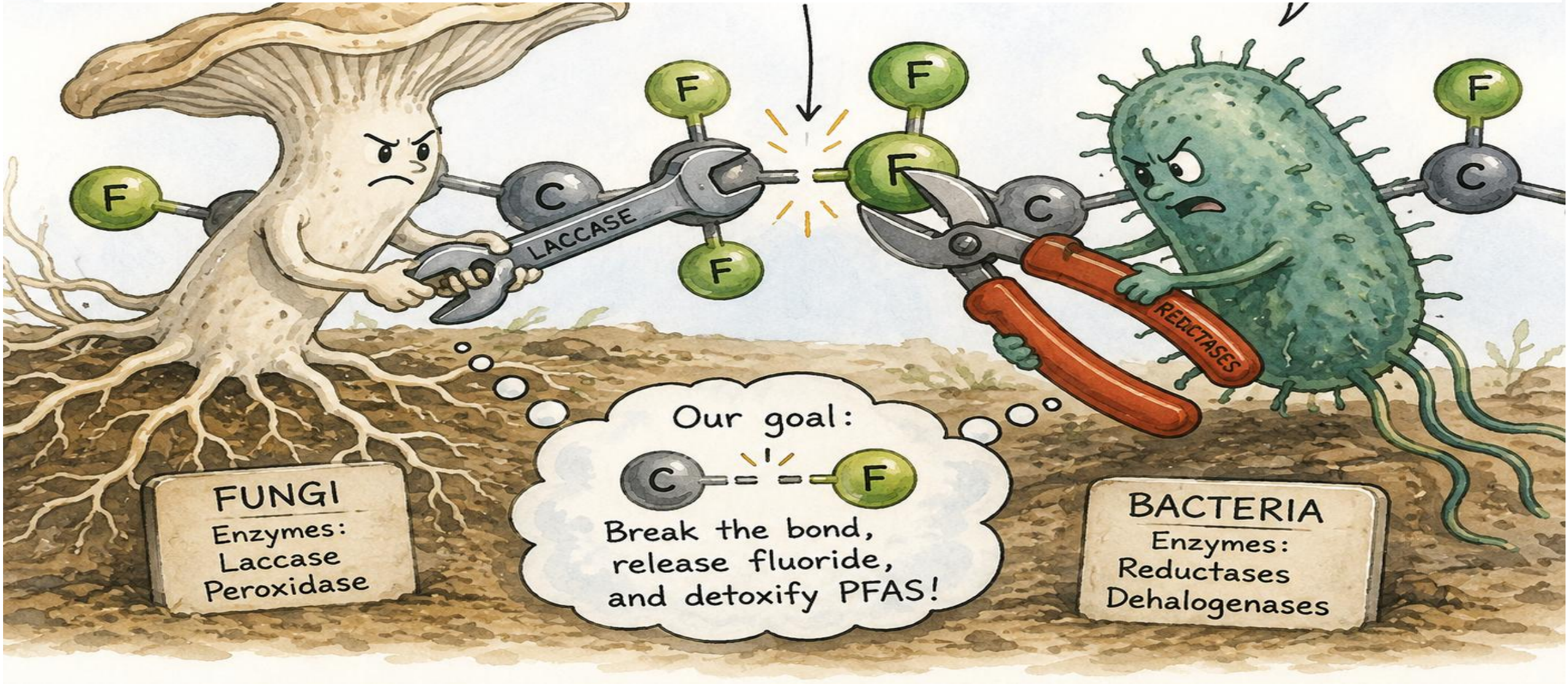
- PFAS as a class of contaminants are changing.
- Shorter-chain PFAS show less persistence in the body but more mobility in the environment.
- Groundwater aquifers are more susceptible to contamination from shorter chain PHAS
- The next generation wastewater treatment systems will have to address not only nutrients and pathogens but PFAS and other CEC.

EPILOGUE

Is there hope ?


In all my years I haven't seen anything like this.
Give me some time... I'll get right on it.

Perhaps it will be a consortium of microorganisms that will “figure out” how to use and break down PFAS compounds – it’s all about the energy.



Areas of Active Research

Better living through chemistry?

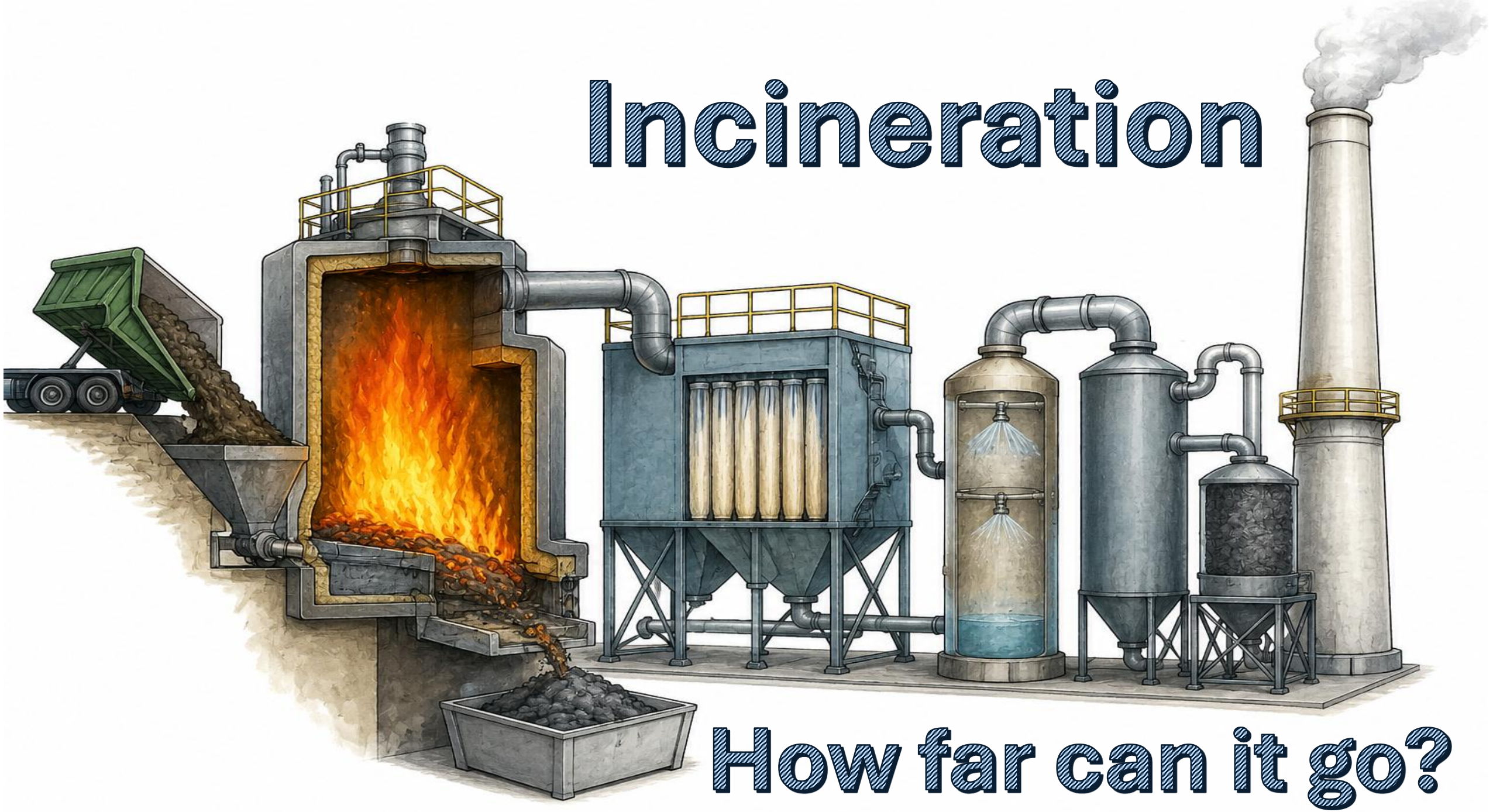
- Concentrating for more efficient treatment
- Incineration
- SCWO
- Plasma
- Electrochemistry

If you can't beat 'em, join 'em!

- Activated carbon
  - ion exchange
  - membranes

Can we modify sludge to attract more PFAS?
Can we design media that preferentially bind the hydrophilic head or the fluorinated tail?
Can biological flocs be engineered to capture PFAS more effectively?

Incineration



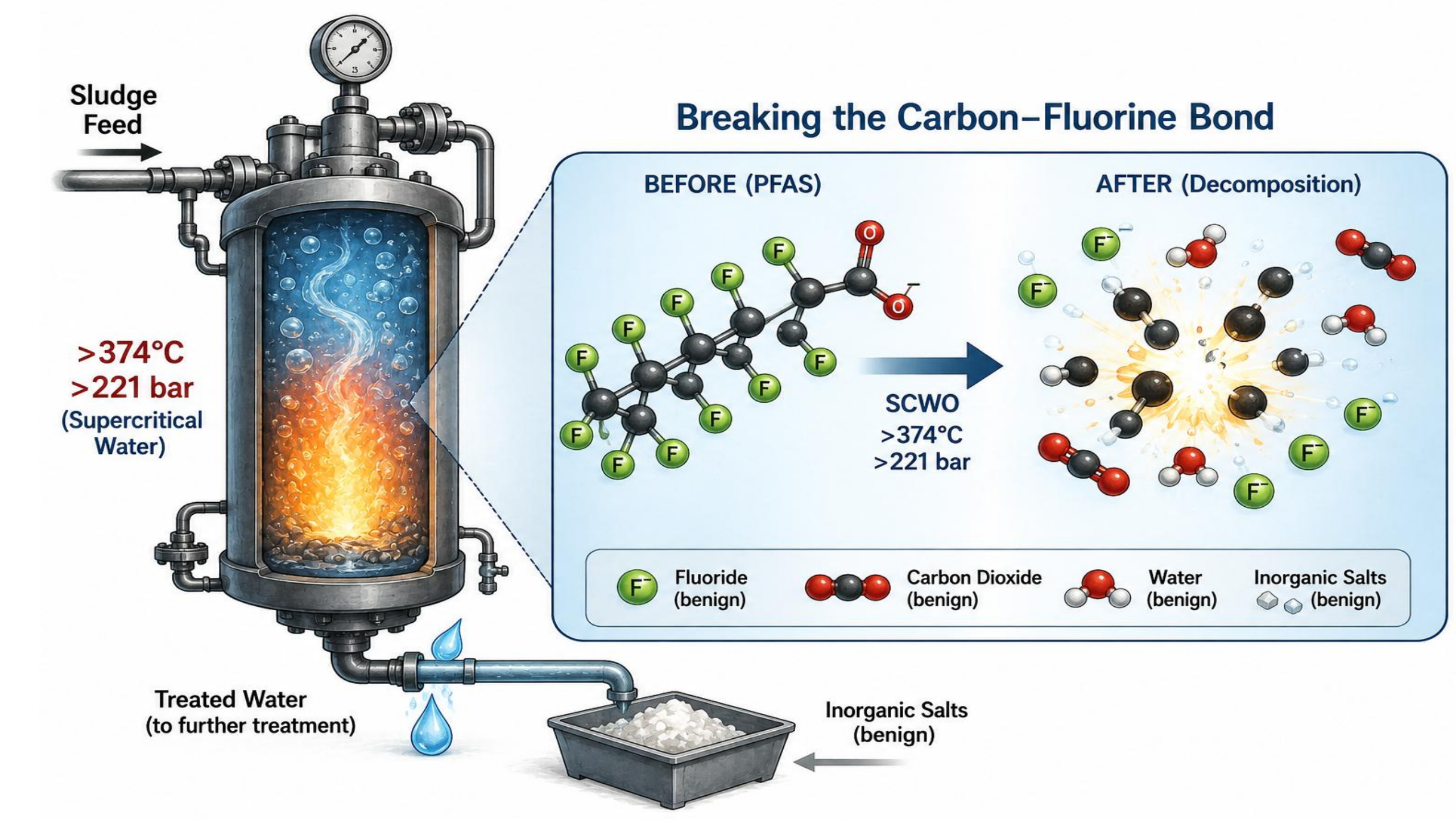
How far can it go?

Supercritical Water Oxidation

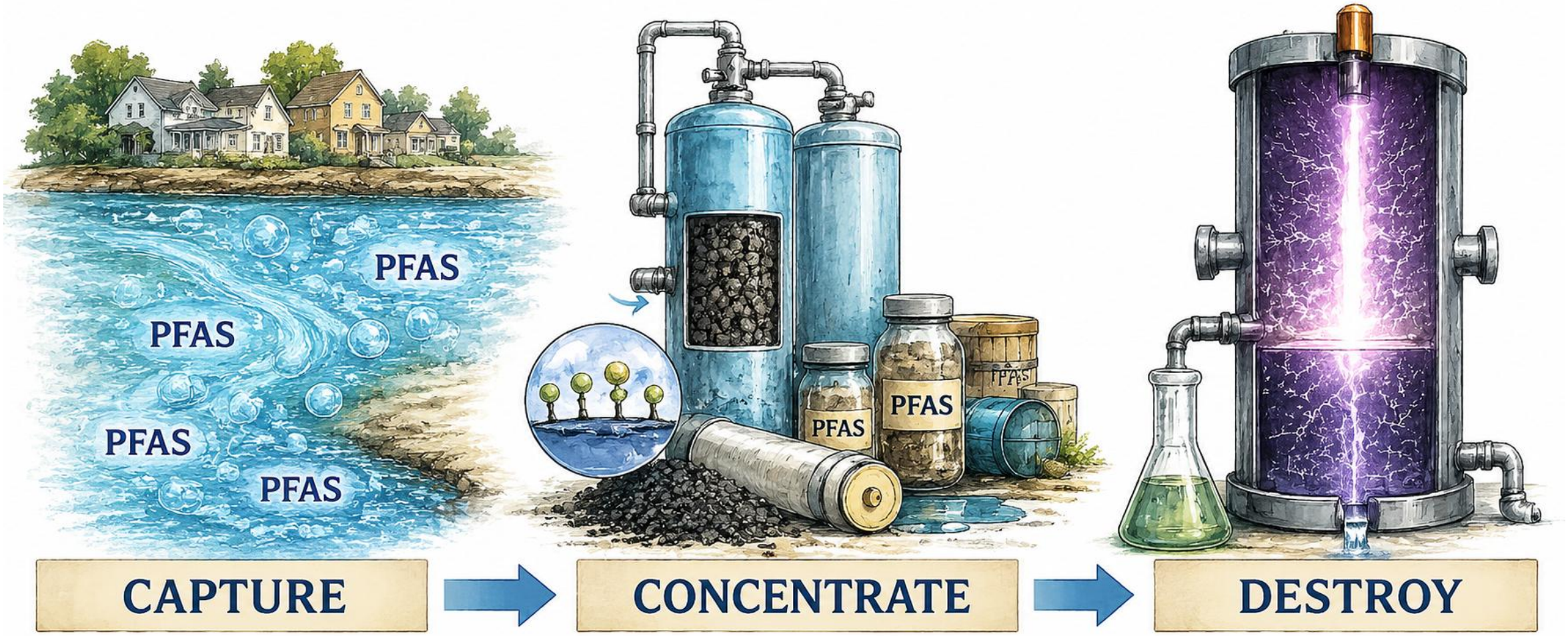
SCWO

Going all the way

Breaking up the carbon-fluorine bond


Sludge Feed
>374°C
>221 bar
(Supercritical Water)
Treated Water
(to further treatment)
Inorganic Salts
(benign)
Breaking the Carbon–Fluorine Bond
BEFORE (PFAS)
AFTER (Decomposition)
SCWO
>374°C
>221 bar
Fluoride
(benign)
Carbon Dioxide
(benign)
Water
(benign)
Inorganic Salts
(benign)

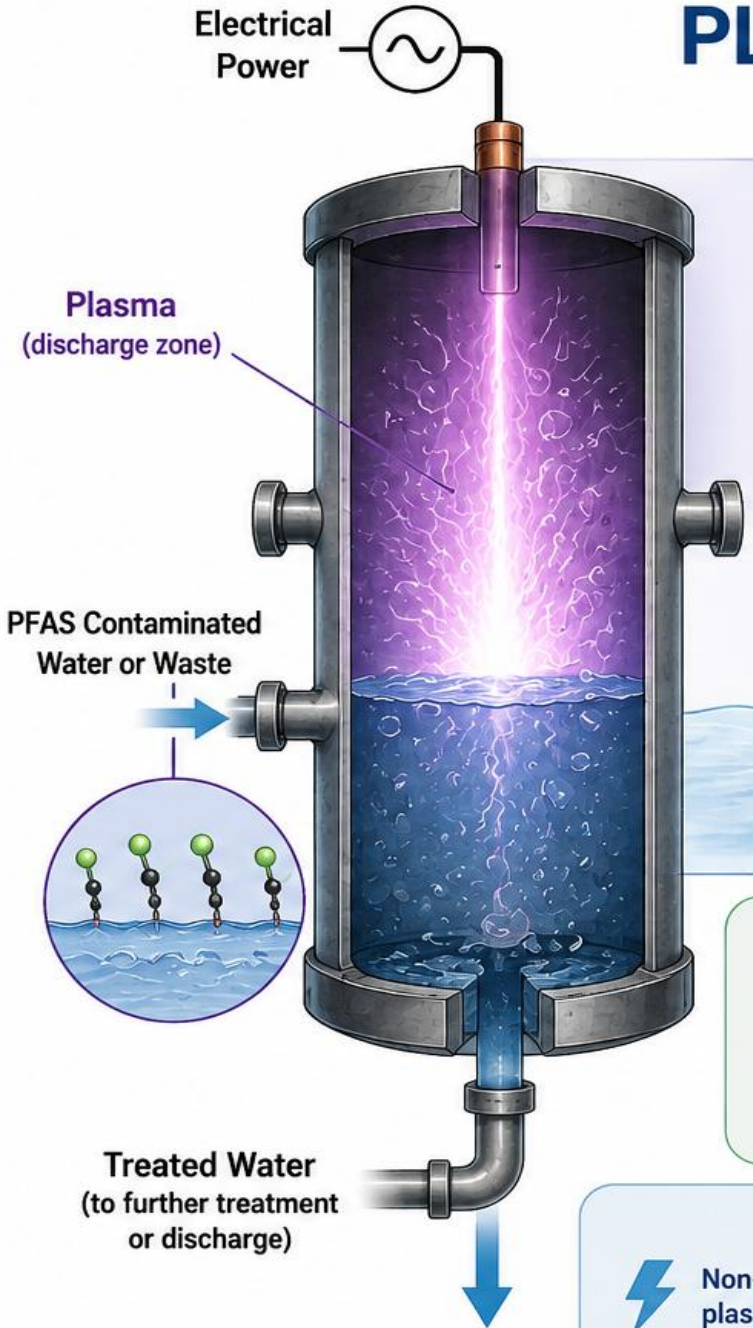
Plasma - It isn't the heat

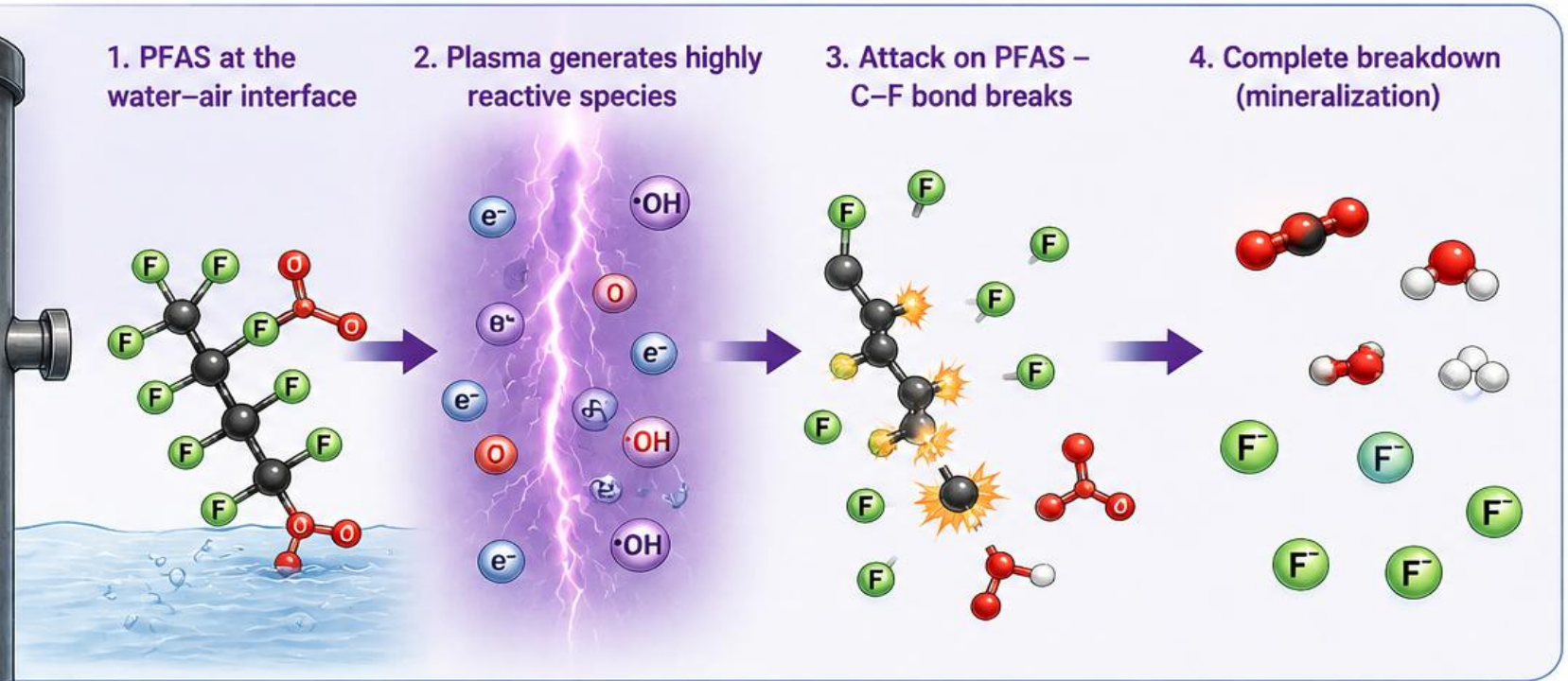


Energy intensive

PLASMA DESTRUCTION OF PFAS

Breaking the Strong Carbon–Fluorine Bond





Products

- **Fluoride** (F^-) (Ion)
- **Carbon Dioxide** (CO_2)
- **Water** (H_2O)
- **Inorganic Salts** (e.g., Na^+, Ca^{2+}, Cl^-, SO_4^{2-})

Key Features

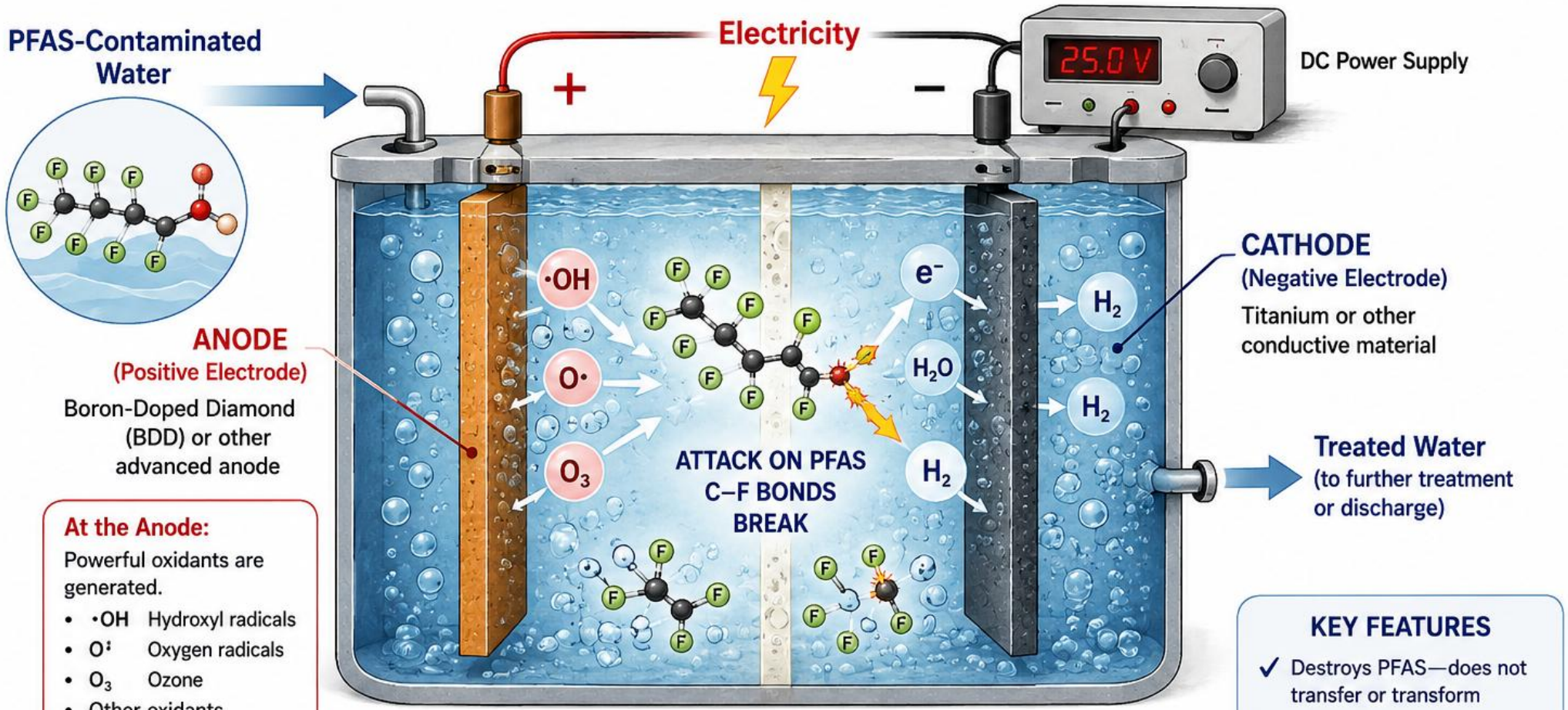
- Non-thermal plasma
- Operates near ambient pressure and temperature
- Highly reactive species break strong C–F bonds
- Effective for water, concentrates, and waste streams
- Destroys PFAS – does not just transfer them

At Joint Base Cape Cod, researchers demonstrated a process that:

1. **Used regenerable ion exchange to treat about 1.2 million liters of PFAS-contaminated groundwater.**
2. **Concentrated the PFAS into only about 45 liters of regeneration waste.**
3. **Treated that concentrated waste using plasma technology.**

ELECTROCHEMICAL DESTRUCTION OF PFAS

Breaking the Strong Carbon–Fluorine Bond



At the Anode:

Powerful oxidants are generated.

- ·OH Hydroxyl radicals
- O· Oxygen radicals
- O_3 Ozone
- Other oxidants

RESULTS: PFAS DESTROYED

Fluoride (Ion)	Carbon Dioxide (CO_2)	Water (H_2O)	Inorganic Salts (e.g., Na^+, Ca^{2+}, Cl^-, SO_4^{2-})

KEY FEATURES

- ✓ Destroys PFAS—does not transfer or transform
- ✓ Operates at ambient temperature
- ✓ Effective for concentrated PFAS waste streams
- ✓ No combustion or air emissions

Early-Life Exposure to "Forever Chemicals" Linked to Childhood Intestinal Inflammation

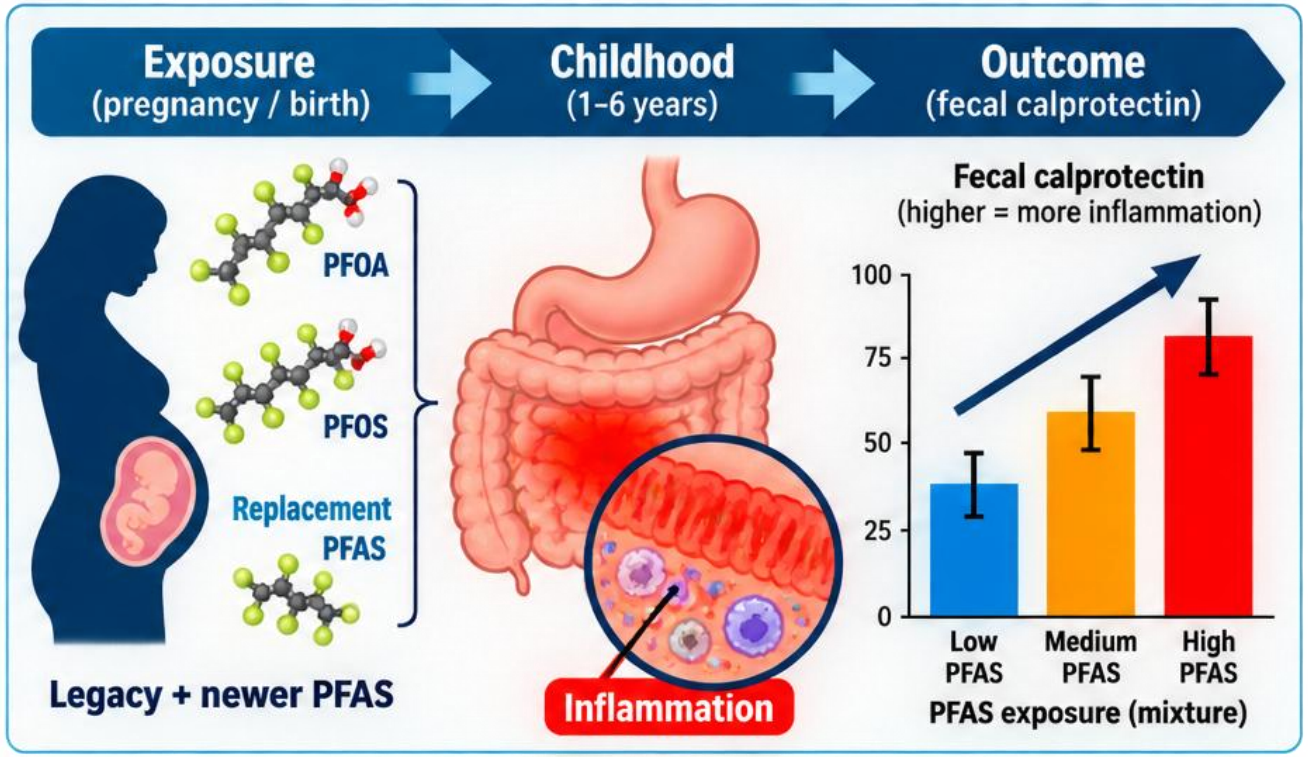
Midya et al. | *Clinical Gastroenterology and Hepatology* | Published online July 10, 2026

Key Findings:

1. **Three birth cohorts**
   New York (2) and Mexico City (1).
   Measured PFAS in maternal blood (pregnancy), cord blood, or newborn dried blood spots.

2. **Higher PFAS-mixture exposure linked to higher fecal calprotectin**
   from ~1–6 years, with similar association later in childhood.

3. **Included legacy + newer PFAS**
   Untargeted analysis: both legacy (e.g., PFOA, PFOS) and replacement PFAS associated with inflammation.



Important: Association, not causation.
Elevated fecal calprotectin indicates intestinal inflammation — not Crohn"s disease or ulcerative colitis.

Takeaway:

Replacing PFOA/PFOS doesn't eliminate concern — newer PFAS can also affect the gut.

Midya et al. (2026). *Clinical Gastroenterology and Hepatology.* https://doi.org/10.1016/j.cgh.2026.06.035

Mount Sinai News (2026) | PMID: 42431496

Supported by experimental animal studies (e.g., PFOS, 2023)

Questions



MASSTC
The Massachusetts Alternative Septic System Technology Center

CLEAN WATER CENTER
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HEALTH & ENVIRONMENT
COUNTY OF BARNSTABLE
MASSACHUSETTS
WASTEWATER DIVISION