AECOM

Evaluation of Destructive PFAS Technologies for Concentrated and Contaminated Treatment Residuals: A Technical Review of Existing Technologies

Presenter: Tim Abbott, PhD

Water/Wastewater Engineering

tim.abbott@aecom.com

Adapted & updated from a report prepared for Health Canada by :

Robbie Venis, PhD
Tim Abbott, PhD
Imad Touahar, P.Eng., M.Sc., M.Sc.A.

Report reviewed by :

Ahmed Elhadidy, PhD, P.Eng.
Chris Curran, PE
Timothy Phelan, P.Eng, PE

Agenda

- Background
- Treatment & Concentration Technologies
- Report for Health Canada & Evaluation Criteria
- Review of Destructive Technologies
- Other Technologies
- Summary & Conclusions

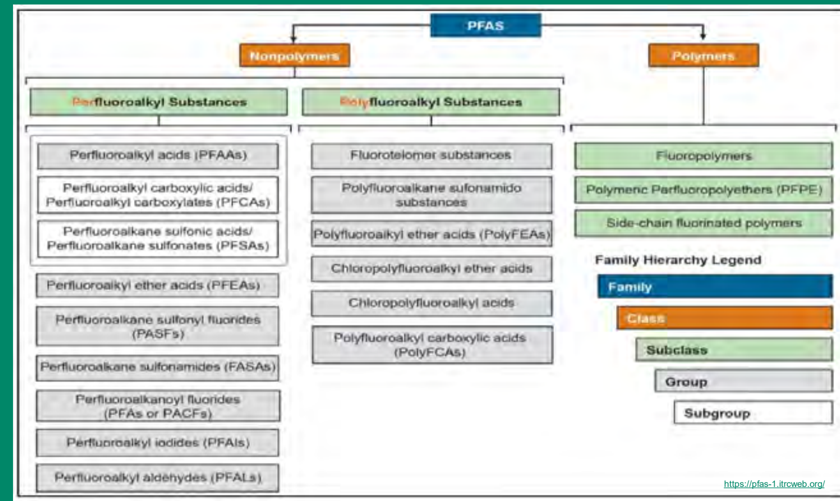
Background

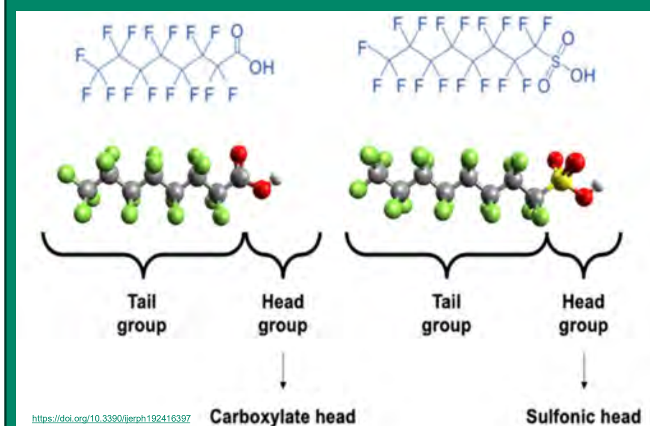
What is PFAS?

- 1000’s of compounds exist
- Characterized by C-F chain length & functional head group (e.g., SO_4, CO_2)
- C-F Bond extremely strong

- Persistent and bioaccumulative
- Often transform between PFAS species (e.g., poly→per, long→short)
- Individual monitoring & evaluation difficult

- Various negative health impacts
- Impacts at very low concentrations



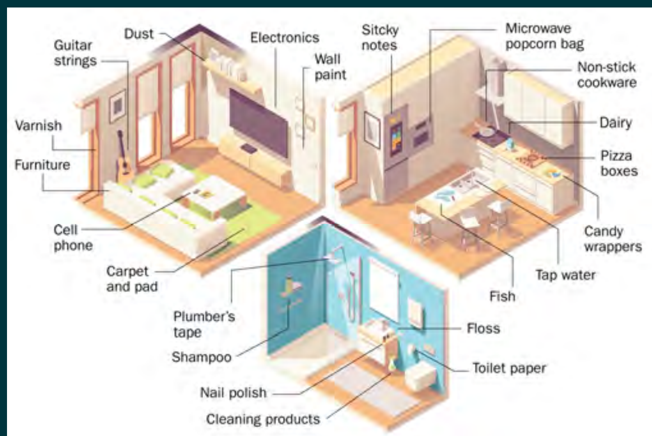


PFAS	Short-Chain	Long-Chain
PFCAs	4-7	8-12
PFSA	4-5	6-12

PFAS Sources and Uses

Food Packaging

Electronics



Houseware and furnishings

https://api.time.com/wp-content/uploads/2023/05/Forever-chemicals-main-image.jpg

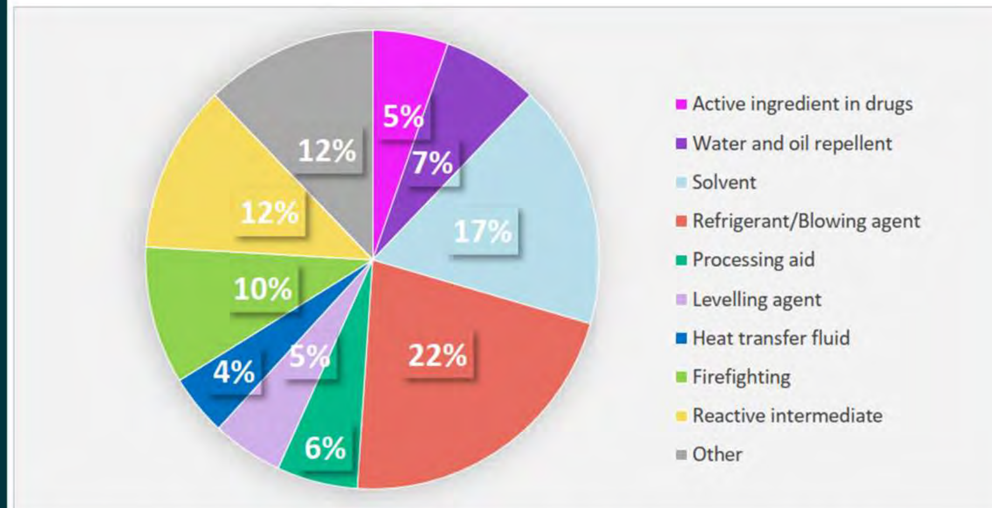
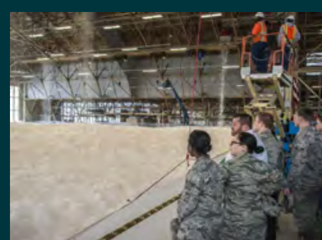


Figure 1. Uses of chemical PFAS notified under the NSNR since 1994. Percentage of total notified uses for notifications.

Chemicals and Pharmaceuticals

Aqueous Film Forming Foam



Defense

Oil & Gas

Transportation

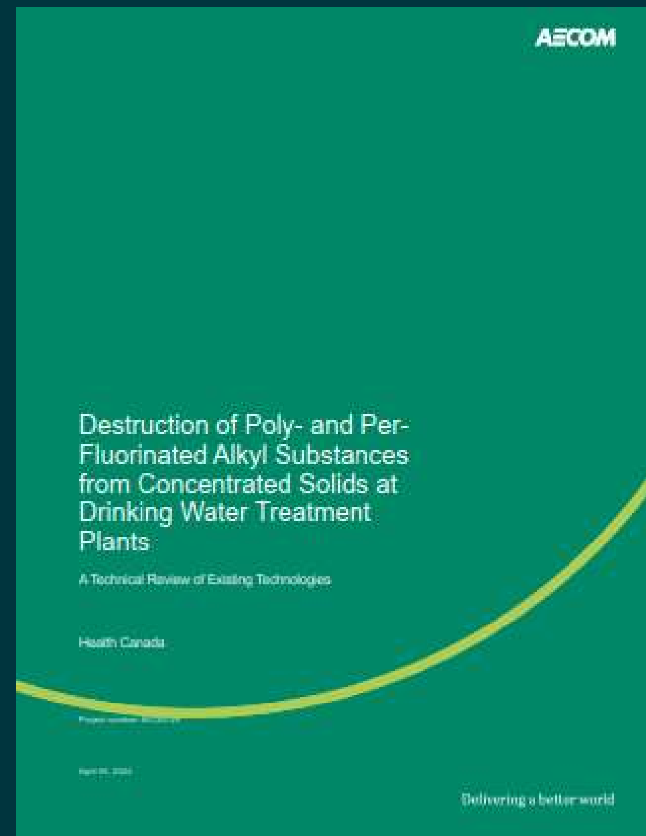
Manufacturing

Health Canada Report

Why is Health Canada interested in PFAS destruction?

What PFAS treatment & disposal approaches are there currently?

What to do with the waste…?


AECOM

Destruction of Poly- and Per-Fluorinated Alkyl Substances from Concentrated Solids at Drinking Water Treatment Plants

A Technical Review of Existing Technologies

Health Canada

Delivering a better world

Concentration & Transfer Technologies

PFAS Separation Treatment Technology – *Concentrate* PFAS

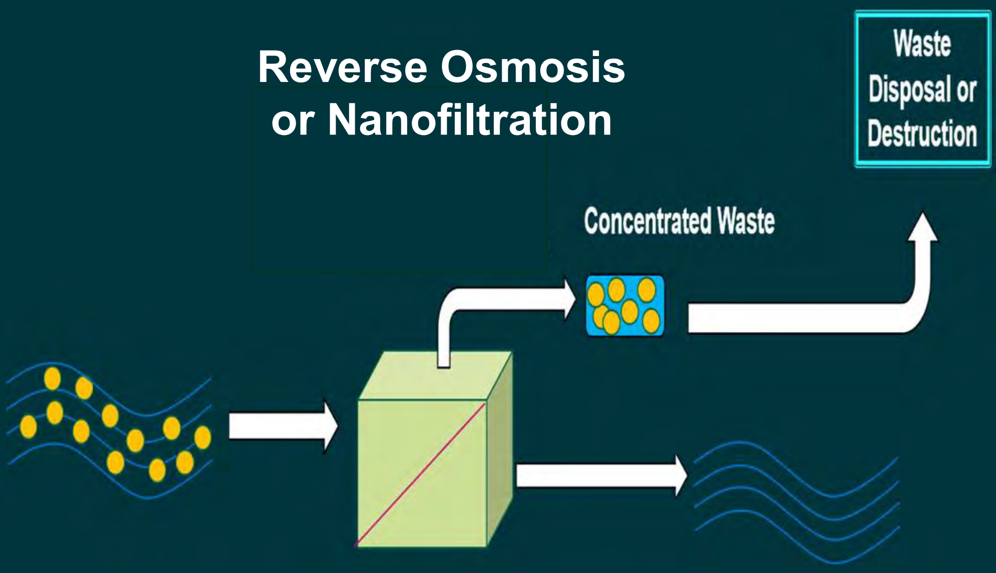
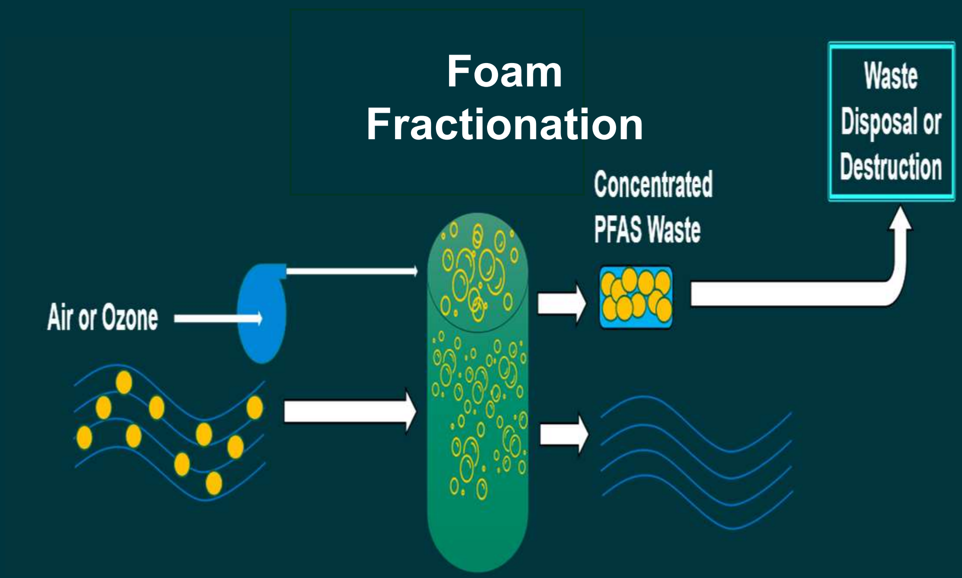


Image Source: WEHRLE-WERK AG

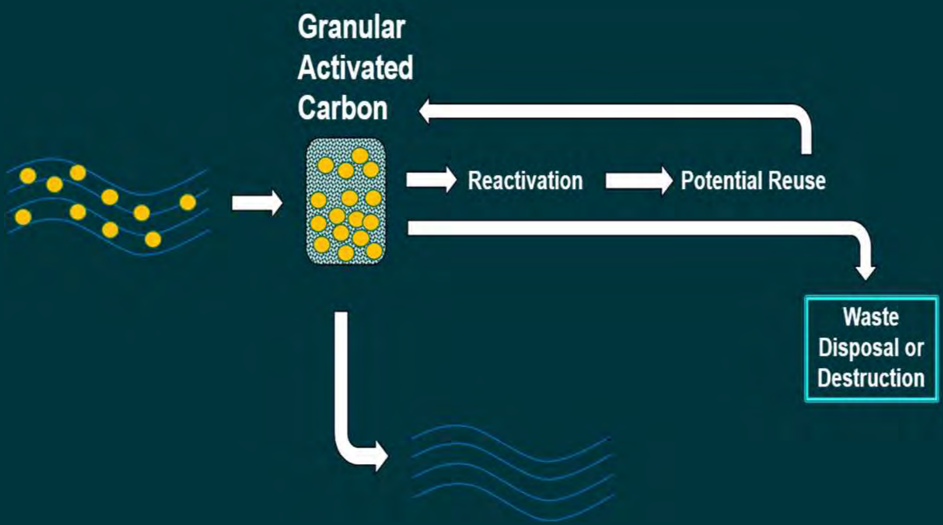
PFAS Separation Treatment Technology – *Concentrate* PFAS

Image Source: Environmental Science & Engineering Magazine



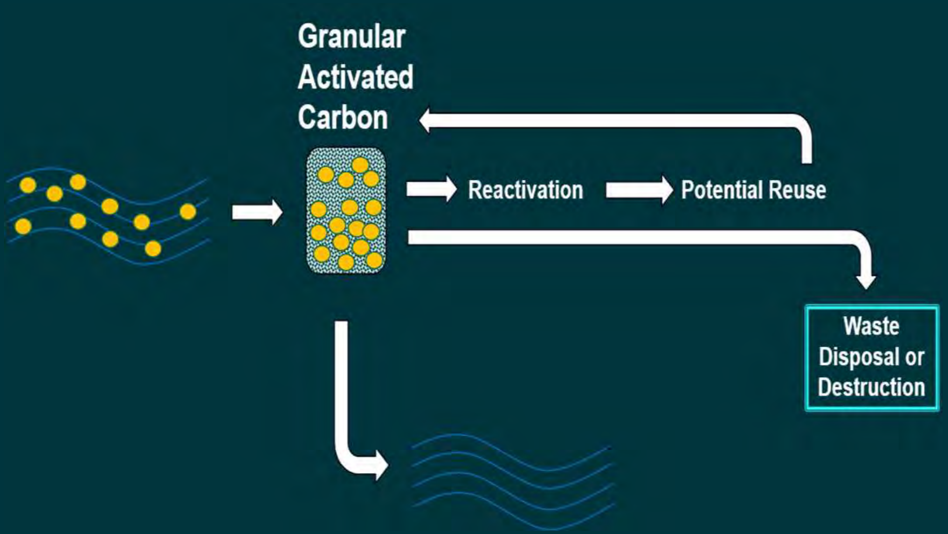
PFAS Separation Treatment Technology – *Transfer* PFAS

Activated Carbon

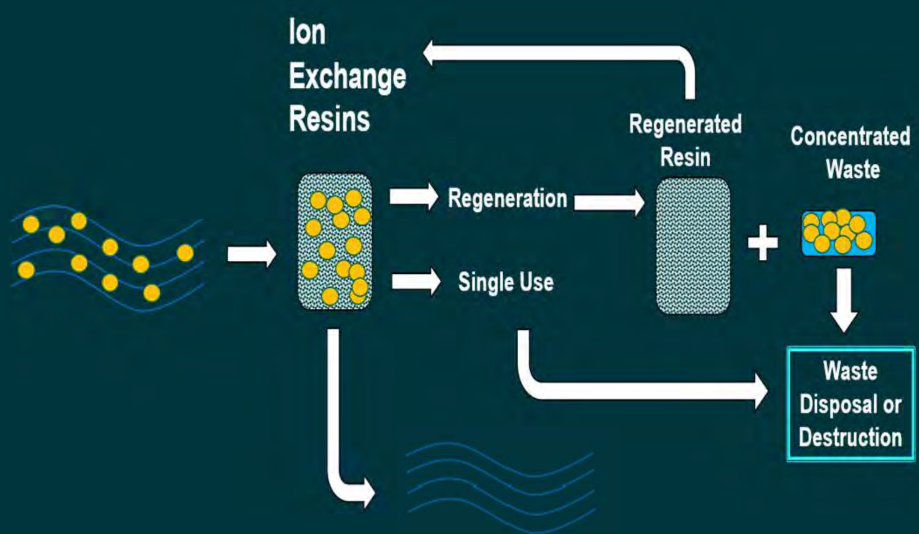


PFAS Separation Treatment Technology – *Transfer* PFAS

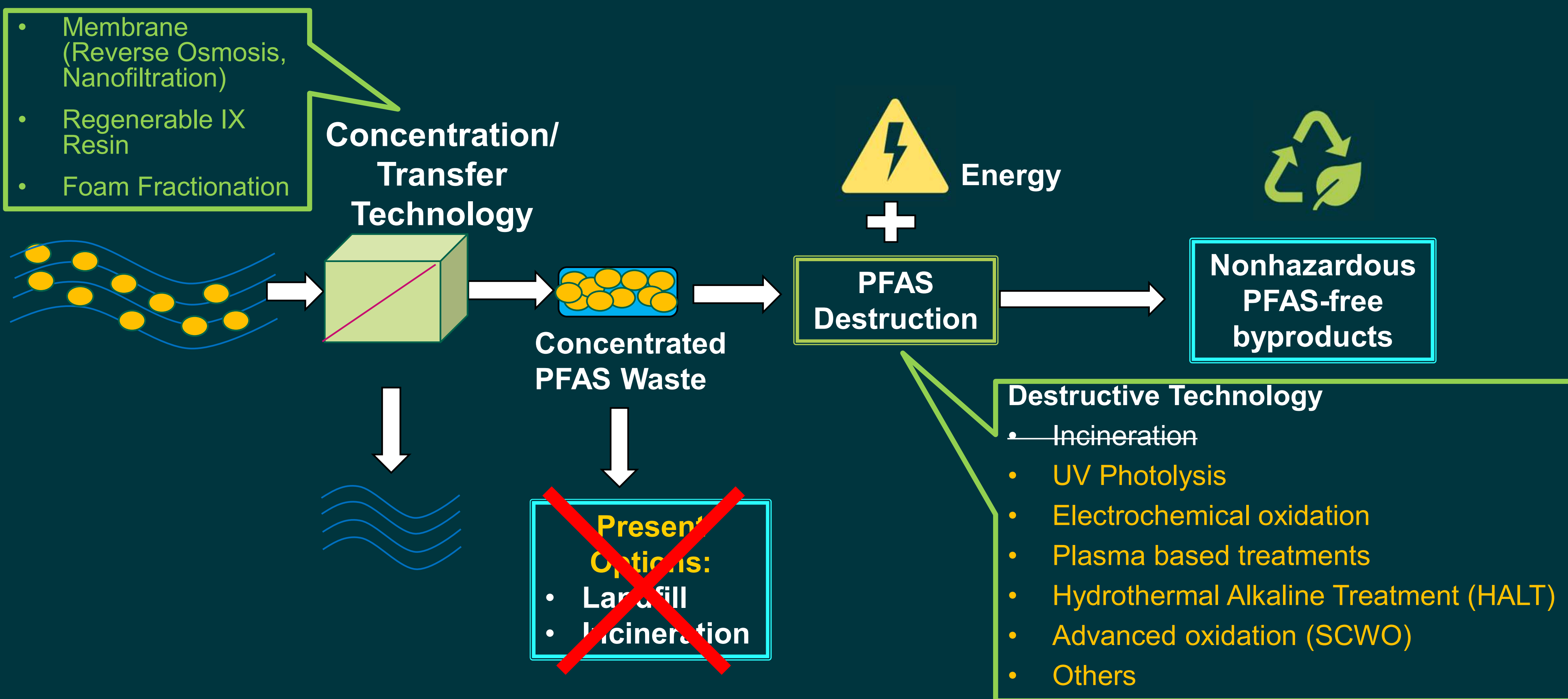
Activated Carbon



Ion Exchange



Treatment Approach – Add Destruction for PFAS-free Solution



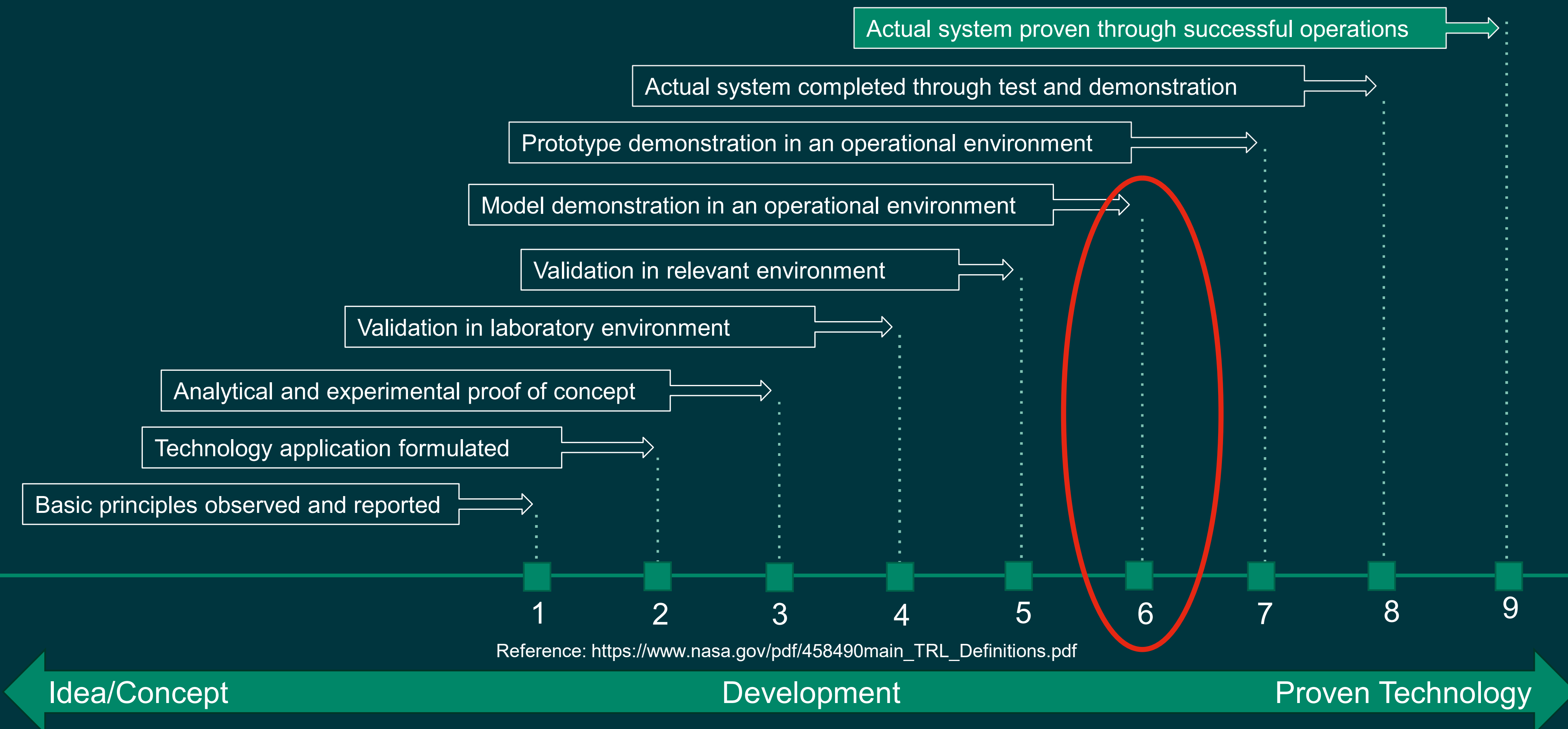
Evaluation of Treatment Technologies

Destructive Technologies Review

What criteria were used?

How were technologies evaluated?

Technology Readiness Level (TRL)



PFAS Destruction: Lines of evidence checklist*

- ✓ Decrease in target PFAS concentrations in context of mass balance
- ✓ Treatment mechanism consistent with previous studies
- ✓ Transformation products identified and quantified

*Reference: SERDP ER18-16, Nov. 2021, Lines of Evidence and Best Practices to Assess the Effectiveness of PFAS Remediation Technologies

Treatment Technologies

Destructive Treatment Technology – UV Light Based-Treatments

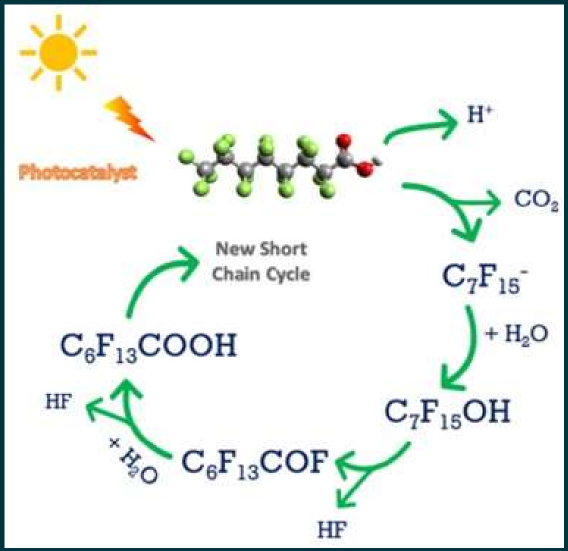


Image credit: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9778349/

- UV + catalyst/photosensitizer work together to break down PFAS sequentially
- Atmospheric pressure & room temperature
- More efficient at higher concentrations
- **Media:** Liquids & concentrates
- **Effectiveness**:
  - Data shows rapid destruction of PFOS, less for PFOA
  - Trials show 95% defluorination
  - Promising, ongoing evaluation

Destructive Treatment Technology – UV Based-Treatments

Image Credits: ClariosTech
Enspired Solutions

- **Advantages:**
  - Potential real-time monitoring of progress
  - Can run overnight/unstaffed
  - Potential to recover catalysts
- **Disadvantages:**
  - Energy intensive
  - Competition from other organic matter & influenced by liquid characteristics (TDS, UVT, etc.)
  - Limited removal of some PFAS forms & incomplete removal
  - Difficult to recover catalyst
- TRL 6

Destructive Treatment Technology - Electrochemical Oxidation

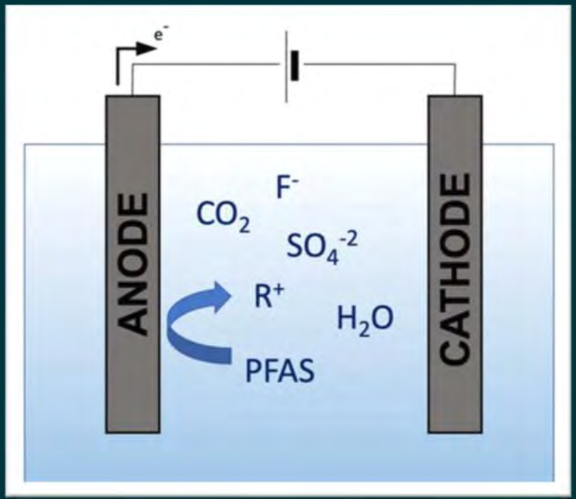


Image credit: https://www.mdpi.com/1660-4601/19/24/16397

- Electrical current between anode and cathode creates oxidizing conditions
- Atmospheric pressure & room temperature
- Destroys PFAS via sequential, non-selective defluorination
- Electrode chemistry varies – affects durability, costs
- **Media:** Liquids & concentrates
- **Effectiveness**:
  - Reductions of 99% or more
  - Promising, ongoing evaluation

Destructive Treatment Technology - Electrochemical Oxidation

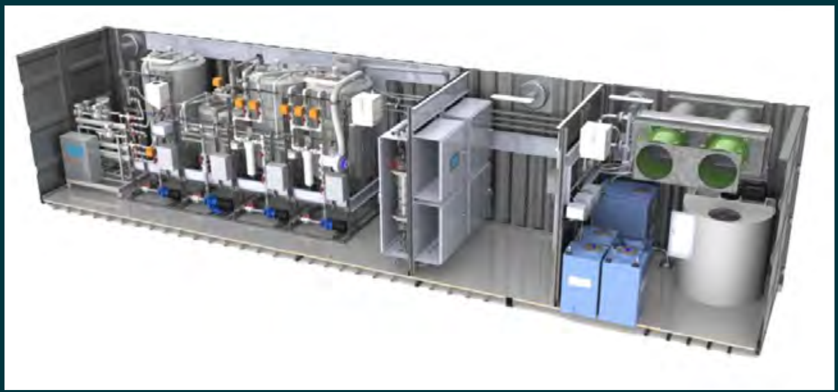


Image credit: Axine Water Technologies

- **Advantages:**
  - Relatively low energy requirements
  - Easy to operate
  - Relatively small footprint & scalable
  - Demonstrated efficacy at scale
- **Disadvantages:**
  - Most efficient at high PFAS concentrations
  - Competitive organics must be managed
  - Potential intermediate compounds & perchlorate generation
- TRL 8-9

Destructive Treatment Technology - Water-Based Cold Plasma

Image credit: https://www.serdp-estcp.org/projects/details/790e2dda-1f7b-4ff5-b77e-08ed10a456b1/er20-5355-project-overview

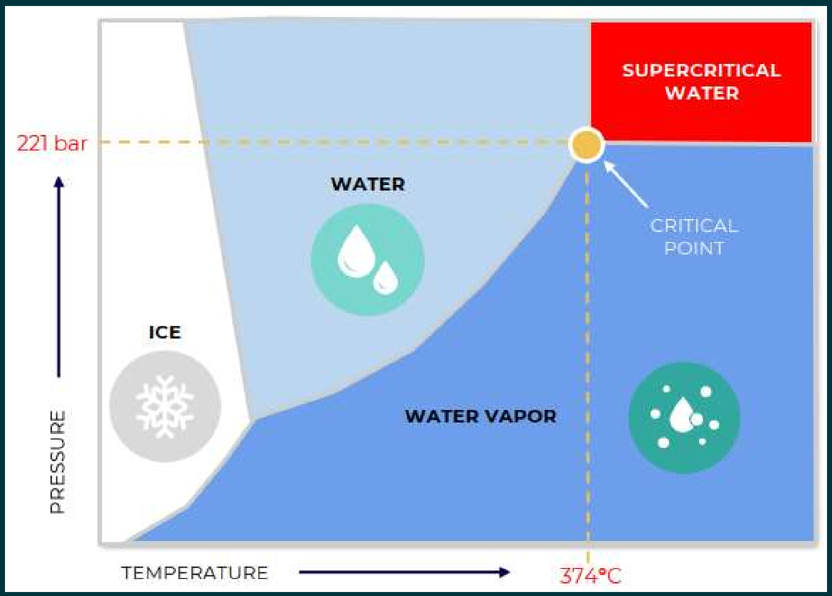
- High voltage electrical discharge converts water into plasma
- Gas is bubbled bringing PFAS to the surface where it reacts
- No additional chemicals required
- **Media:** Liquids & concentrates only
- **Effectiveness**:
  - Varies:
    - Demonstrated reduction in long-chain and precursors >99%
    - Less effective against short chain PFAS
  - May not completely mineralize all PFAS, ongoing research

Destructive Treatment Technology - Water-Based Cold Plasma

Image credit: https://www.serdp-estcp.org/projects/details/790e2dda-1f7b-4ff5-b77e-08ed10a456b1/er20-5355-project-overview

- Advantages:
  - Low amounts of scaling/fouling
  - Removals unimpacted by TOC levels
- Disadvantages:
  - Limited removal of short-chain PFAS (may require a surfactant)
  - May not completely mineralize all PFAS
  - High energy input esp. at high conductivities
- TRL 7-8

Destructive Treatment Technology – Supercritical Water Oxidation (SCWO)



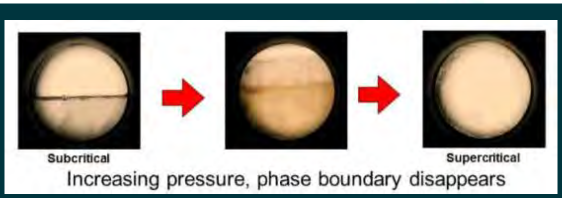


Image credit: 374Water

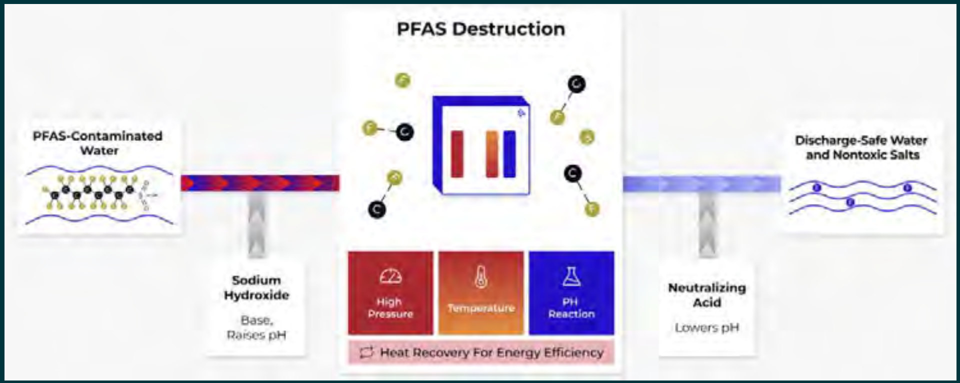
- Supercritical - high temperature (374°C) & pressure (221 bar/3200 psi) process
- Injects air or oxidant
- Produces inert gases, water, & minerals/salts
- **Media:** Liquids & solids (slurry)
- **Effectiveness**:
  - Highly effective
  - Demonstrated to reduce PFAS concentrations by >99.9%
  - Promising, ongoing evaluation

Destructive Treatment Technology – Supercritical Water Oxidation (SCWO)

Source: https://www.bluetechforum.com/wp-content/uploads/1.-374Water-BlueTech-Case-Study-Rev1.pdf

- Advantages:
  - Generates inert by-products
  - Potential for energy recovery
  - Good mass balance
- Disadvantages:
  - High pressure & temperature operation
  - Potential for scaling & corrosion
  - May require supplemental energy (depending on feedstock)
- TRL 9

Destructive Treatment Technology – Hydrothermal Alkaline Treatment (HALT)



Source: https://www.aquagga.com/ourtech

- High:
  - Temperature (350°C)
  - Pressure (165 bar/2400 psi)
  - pH (14)
- Requires 1-5 M caustic soda (NaOH)
- Produces inert gases, water, & minerals/salts
- **Media:** Liquids & solids (slurry)
- **Effectiveness**:
  - >99% of total PFAS
  - May remove other resistant contaminants

Destructive Treatment Technology – Hydrothermal Alkaline Treatment (HALT)

Source: www.aquagga.com

- **Advantages:**
  - Works with high solids & salinity
  - Flexible conditions
  - Effective degradation of many PFAS forms
  - Good mass balance
- **Disadvantages:**
  - High temperature & pressure process
  - Scaling & corrosion
  - Chemical handling & cost
  - Output may require neutralization
- TRL 8

Other Destructive Treatment Technologies & Summary

- Other Technologies for Solids Only
  - Incineration
    - 800 - 900°C
    - Full air
  - Pyrolysis
    - 200 – 600°C
    - No air
  - Gasification
    - 600 - 1,000 °C
    - Limited air
  - Thermal Plasma
    - 3,000 - 10,000 °C
    - No/limited air

Treatment Technology	Solids	Liquid	TRL
UV Based-Treatment	✕	✓	6
Electrochemical Oxidation	✕	✓	8 – 9
Water-Based Cold Plasma	✕	✓	7 – 8
HALT	✓	✓	8
SCWO	✓	✓	9

- Future/Emerging Technologies
  - Sonolysis
  - Electron beam (E-beam)
  - Bacteria, enzymes, and fungi
  - Others

Conclusions

- ✓ No single technology can be universally applied to all types of PFAS waste streams.
- ✓ Technology selection should be site-specific and context dependent.
- ✓ Further advances in existing technologies and the development of novel innovations, is both required and expected.
- ✓ More research and development are needed to improve the performance, reliability, scalability, and affordability.

Questions?

Tim Abbott, PhD

Water/Wastewater Process Engineering

tim.abbott@aecom.com

Imad Touahar

PFAS Lead, Canada

imad.touahar@aecom.com

AECOM

Delivering a
better world