WATER TREATMENT TECHNOLOGIES FOR PFAS: CURRENT AND NEXT GENERATIONS

March 31st 2022 – Maine Sustainability and Water Conference

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PFAS in Maine

OUTDOORS > Posted November 23, 2021 | Updated November 24, 2021

Maine issues 'do not eat' advisory for deer harvested near PFAS-contaminated fields in Fairfield area

The state says deer taken in the Fairfield area have high levels of PFAS, the 'forever chemicals' that pose potential health risks.

Maine delegation calls for federal aid for PFAS crisis

(WABI)
By Morgan Sturdivant
Published: Mar. 15, 2022 at 6:12 PM EDT

BANGOR, Maine (WABI) - Maine's congressional leaders are calling for more federal help with the PFAS crisis and say affected Mainers need immediate income replacement while unable to sell their products and longer-term supports to help them recover.

Both Senators Susan Collins, R-Maine, and Angus King, I-Maine, and Representatives Chellie Pingree, D-Maine, and Jared Golden, D-Maine, say they are urging the USDA to fully utilize all existing programs and authorities to provide additional assistance to farms affected by PFAS contamination.

They addressed the USDA secretary in a joint statement. The delegation said in part:

"We cannot overstate how devastating this situation is for the affected farmers and their families. In addition to extreme financial hardship, they are also facing the potential health risks associated with being exposed to these forever chemicals.

Environment and Outdoors

'Complete crisis' as PFAS discovery upends life and livelihood of young Maine farming family

Maine Public | By Kevin Miller
Published February 7, 2022 at 6:30 PM EST

PFAS in Maine: 2022 Outlook: "Every day we are learning more"

The fight against 'forever chemicals' in Maine

PFAS are being found at farms, landfills, and even in wells.

Author: Associated Press
Published: 1:12 PM EST February 19, 2022
Updated: 8:15 AM EST February 21, 2022

MAINE, USA — ***EDITORIAL NOTE: VIDEO CREATED 02-18-2022***

Maine lawmakers are going to consider setting aside more funding to fight "forever chemicals" as an increasing number of farms across the state have been found to be contaminated.

The group of chemicals known as PFAS has been found in hundreds of farm sites where sludge or papermaking waste containing the toxins have been spread. PFAS also are being found in wells and landfills.

PFAS in Maine

BDN BANGOR DAILY NEWS

Old Town landfill shows how tough Maine's 'forever chemical' problem is to solve

by **Sawyer Loftus**
February 14, 2022 Updated February 15, 2022

"Unfortunately, the technology just does not exist at this point in time to effectively remove PFAS from the discharge, from leachate or from wastewater treatment that is discharged," she said. "Casella is willing to spend money when the technology is proven and when it will ultimately enhance the operation and the management of landfill."

Summing up the PFAS Challenge

>4,700 compounds

- A Class of Compounds With Varying Chemical Properties

Ubiquitous

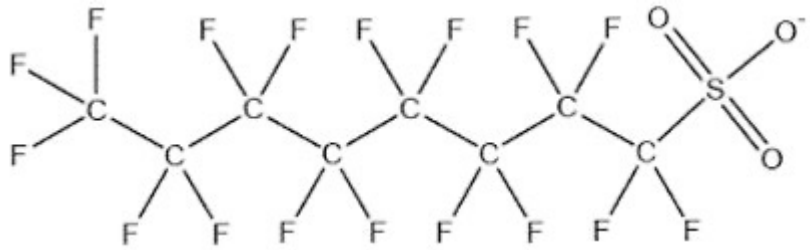
- Found globally and designed to be “indestructible”

Bioaccumulative

- Found far from points of manufacture and stay there

Parts per trillion criteria

- Increasingly low regulatory limits to achieve



Wide Range Molecular Weight

Properties (chain length)

Oleophobic/ Hydrophobic

Thermally resistant

Strongly Electronegative

Negligible relevant volatility

Surfactant characteristics

Polar/ Soluble

The Answer?

Just Treat It

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No 'silver bullet' for PFAS

The PFAS remediation market is potentially huge. But the science, regulation and technology in this area still have a long way to go. Will Hatchett reports

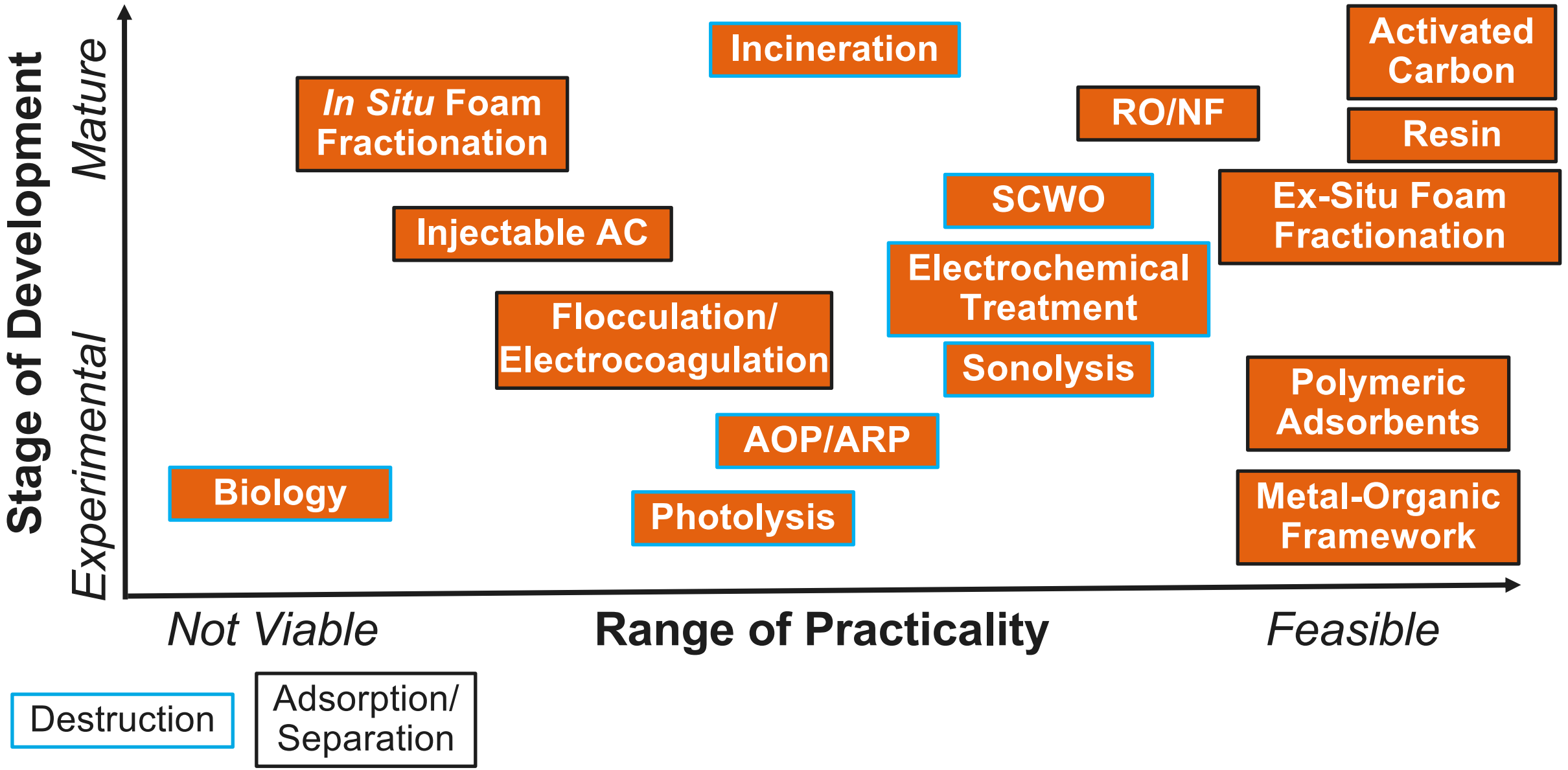
22 September 2020 / Insight, North America, United States

NO SILVER BULLET FOR WASTEWATER TREATMENT OF PFAS

December 1, 2020

Treatment technologies for PFAS are rapidly evolving, but there is no feasible, large-scale treatment that is 100% effective in destroying PFAS or that is cost-effective for ratepayers. Upstream solutions like pollution prevention, product substitution and the like present a holistic, long-term and sustainable solution.

PFAS Water Treatment Technologies



Granular Activated Carbon (GAC)

ARCADIS

Applicability:

- Effectively removes PFOS/PFOA from water (>90%)
- Certain types of carbon appears to perform better (i.e. bituminous)
- Low PFOS/PFOA concentrations; low flow rates with compatible geochemistry (low organics, low hardness, low PFAS, etc.)

Limitations:

- Effectiveness decreases as carbon chain length decreases; manage with longer empty bed contact time (EBCT)
- Competition with other natural organics and other contaminants

GAC in Maine

Kennebunkport and Wells Water District to Remove PFAS with Evoqua's Granular Activated Carbon (GAC) System

May 21, 2018 08:00 AM Eastern Daylight Time

PITTSBURGH--(BUSINESS WIRE)--The Kennebunkport, ME, Kennebunkport & Wells Water District (KKWD) will remove perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS) from its water source using an Activated Carbon System from Evoqua Water Technologies (NYSE:AQUA).

Kennebunkport and Wells Water District to Remove PFAS with @Evoqua 's Granular Activated Carbon System

Tweet this

PFAS is a category of man-made chemicals that have been widely used to make products because of their stain-resistant, waterproof and/or nonstick properties, but are not safe for consumption beyond certain levels.

In 2016 PFOS and PFOA were detected in the Kennebunk River Well (KRW) at levels of 50 parts-per-trillion (ppt). Although the well contained less than the Environmental Protection Agency's (EPA) recommended combined limit of 70 ppt, officials decided against further use of the well without a treatment system for the compounds, and closed the well as a precautionary measure.






Ion Exchange Resin

Applicability:

- Primary Treatment- Adsorption
- Negatively charged ions of PFAS are attracted to the positively charged anion resins
- Lower EBCT than GAC (2 - 5 min); smaller equipment footprints

Limitations:

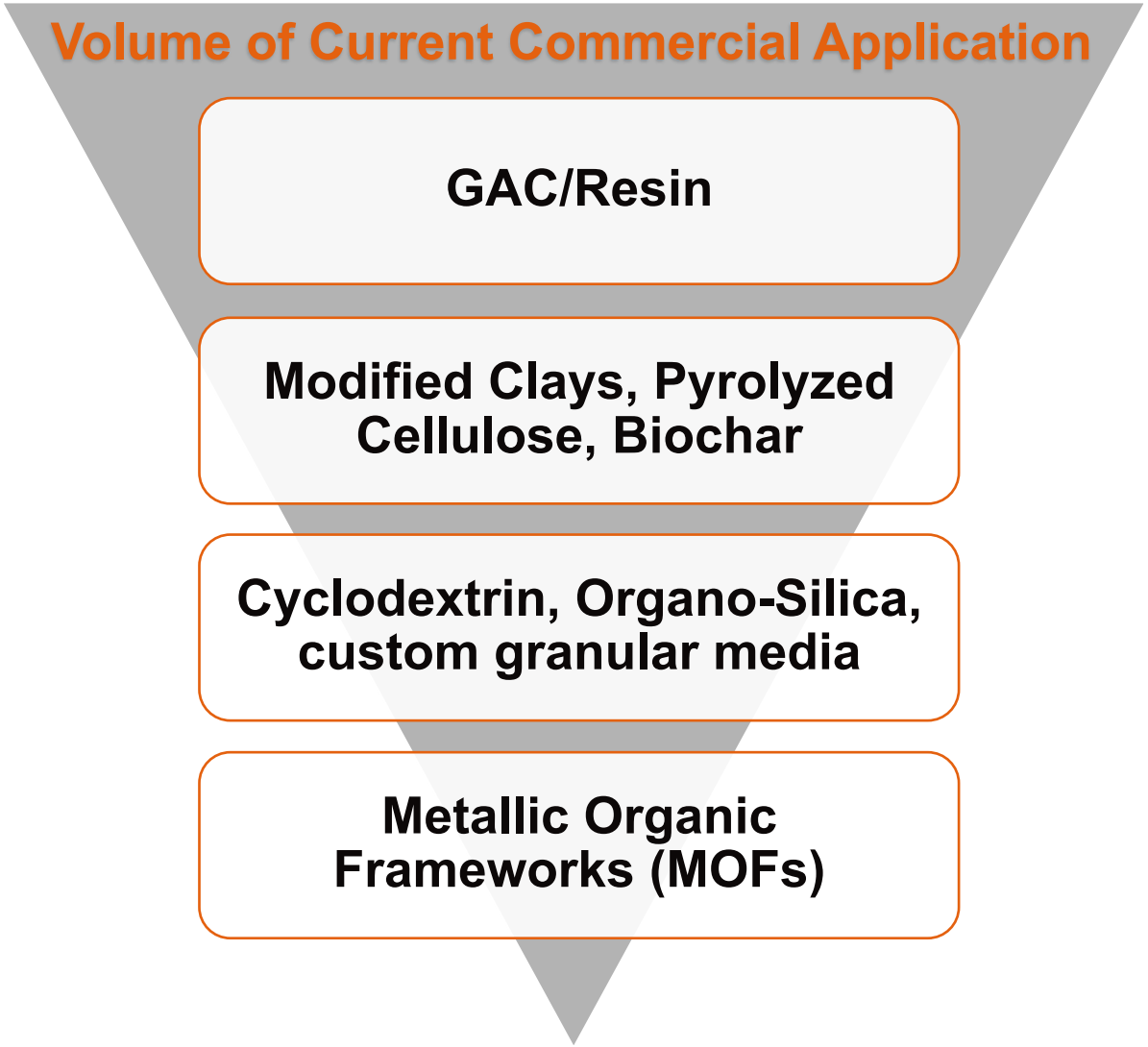
- Rapid Small-Scale Column Testing (RSSCT) not viable for scale-up due to resin properties
- Predictive modeling and/or pilot-scale recommended to gather design parameters
- Extremely sensitive to site-specific geochemistry may require pre-treatment

In this graphic, larger molecules (purple figures) are excluded from entry into the resin due to pore size. Smaller hydrophobic molecules are adsorbed onto the surface (orange figures), while the hydrophilic small molecules (blue figures) freely flow through the structure of the resin.

Source: Purolite, 2017

PFAS-Relevant Adsorbents

- GAC/Resins: Current “de facto” IRM adsorbents
- Modified clays (FluoroSorb®), pyrolyzed cellulose, biochar – available, competing with GAC/resin for PFAS relevance
- Cyclodextrin (CycloPure®), Organo-Silica (PQ-Osorb®), customized granular media (Puraffinity®) – promising but experimental
- MOFs, hydrogels, and two-phase composites – somewhat esoteric still, but huge potential adsorption capacities



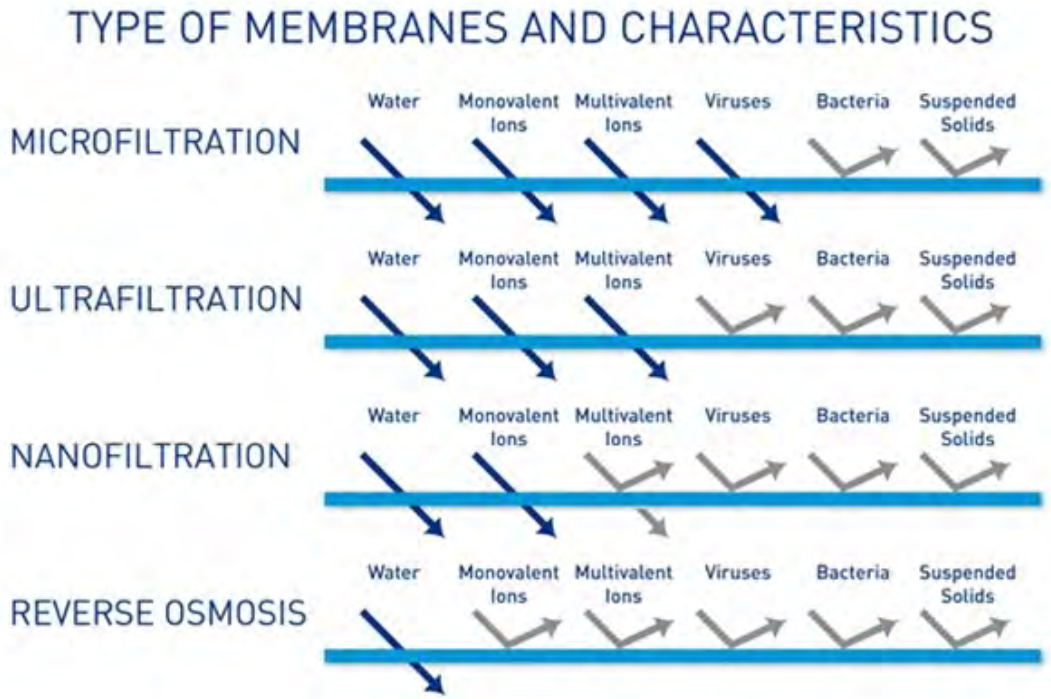
Membranes

Applicability:

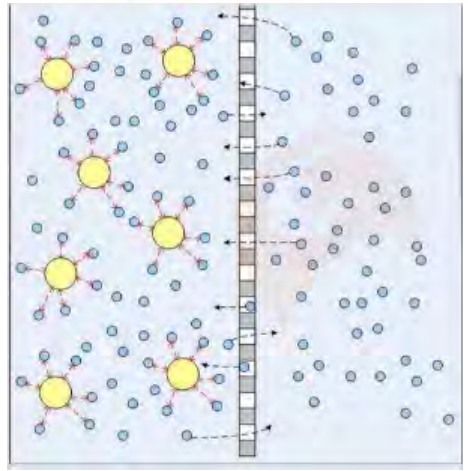
- Most effective removal of long and short chain PFAS
  - Nano-filtration (NF) >95%
  - Reverse Osmosis (RO) >99%
- Inefficient NF removal of short chain PFAS
- Effective for high-quality effluent and re-use applications

Limitations:

- Susceptible to fouling requiring pre-treatment
- Reject ratio can be 10%-35% and impractical for high-capacity systems
- Rejection depends on both the PFAS compound and type of membrane molecular weight cut-off (MWCO)
- Potentially high capital and O&M costs



Source: Pentair

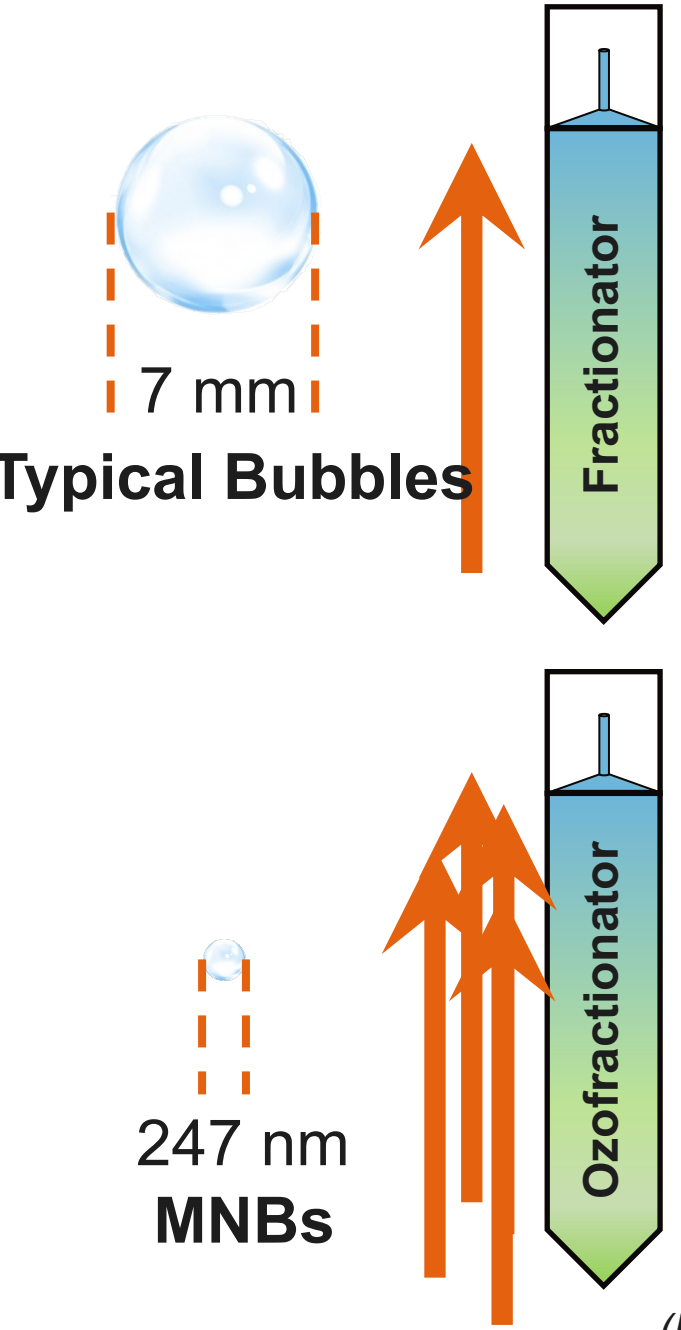


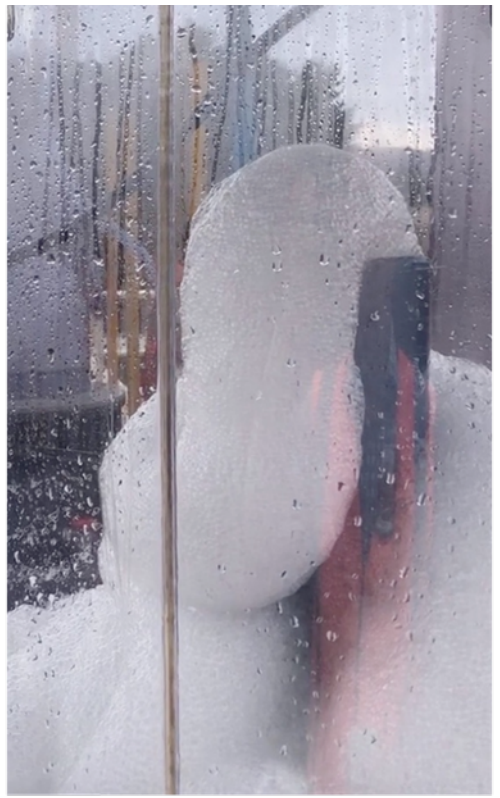
NF/RO Membranes

Source: Suez Titan Series Data Sheet- For Visualization

Foam Fractionation

- Fractionation uses bubbles to separate PFAS from the aqueous solution
- Gases (air and ozone) can vary to optimize bubble surface area and stability and create micro-nano-bubbles (MNBs) ranging from 10s nm to 10s µm
- Volume of foam target is less than 1% of the raw influent (will vary depending upon initial water quality)
- Potential for significant cost savings in disposal volumes

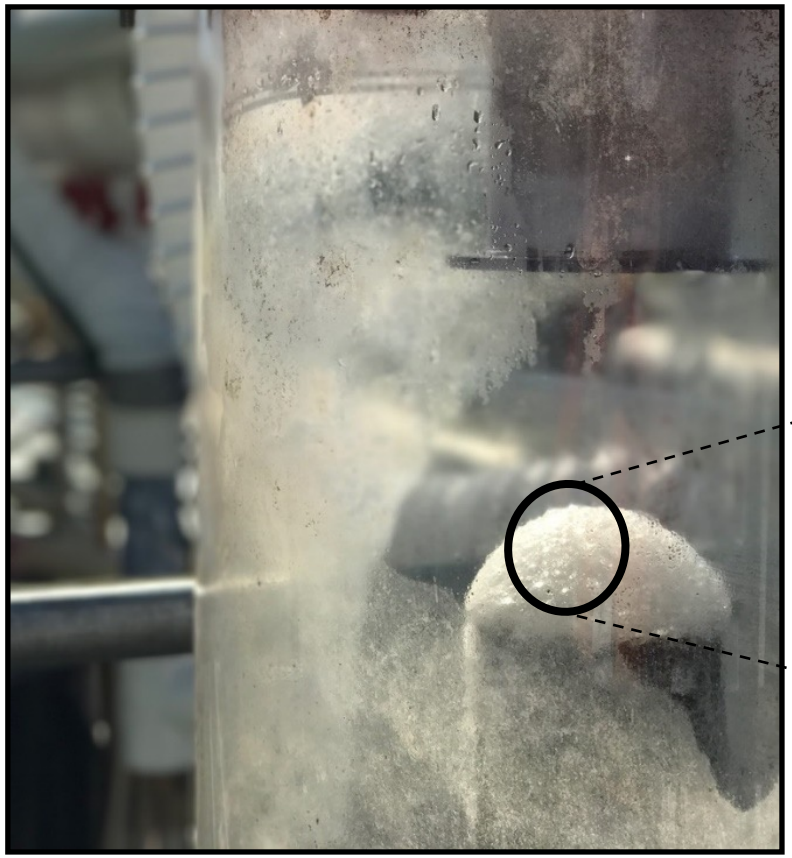




Target Structural Collapsing Foam – Optimized Fractionate Flow

(Hu and Xia 2018)

Fractionation



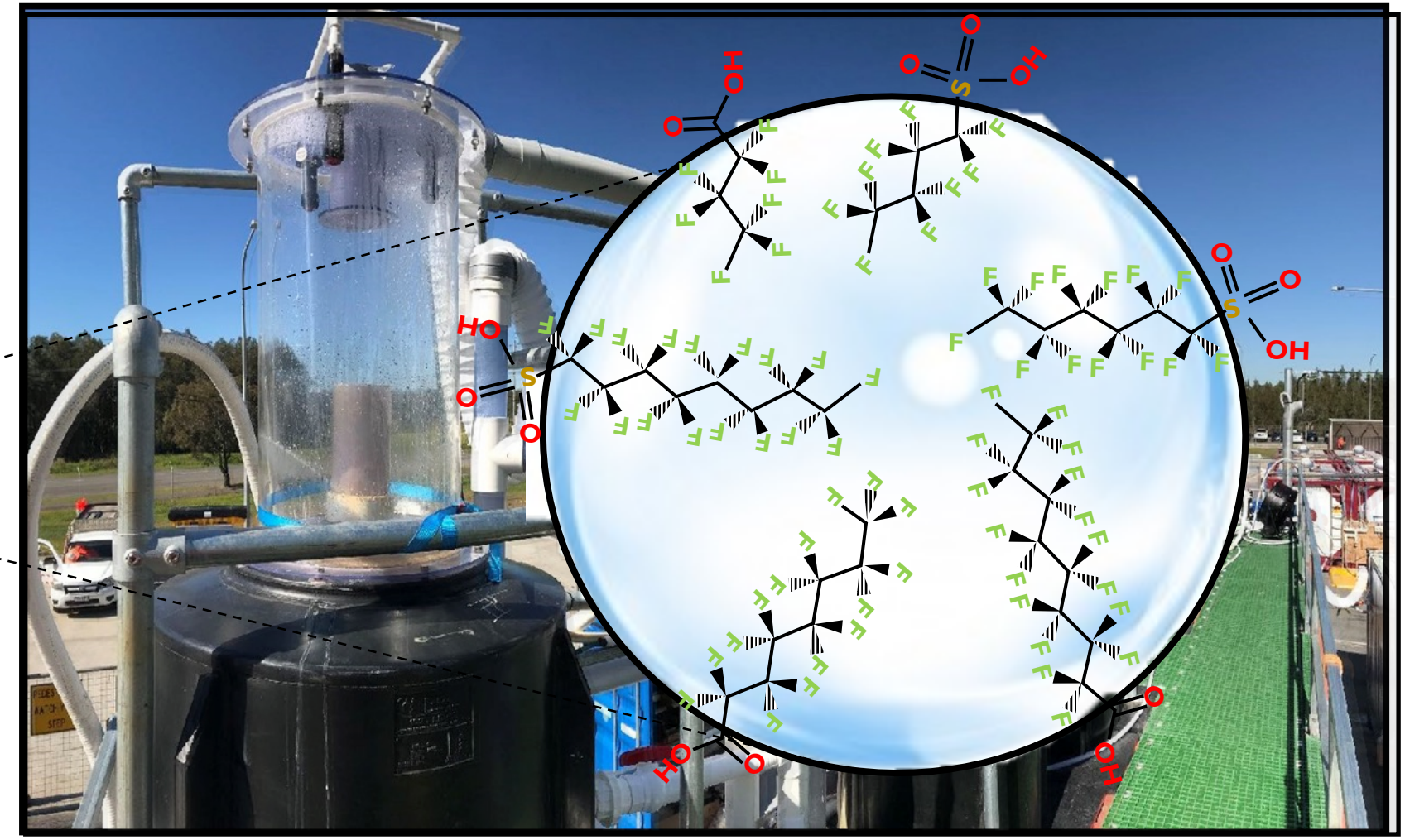


Photo Source: Evocra 2017

Fractionation Becoming More Commercially Available

ARCADIS

Portable Fractionation Pilot System

ARCADIS evocra

Model PFAS 0250

Working in partnership with Australian firm, Evocra, Arcadis has made fractionation technology for PFAS treatment available in North America with its portable fractionation pilot system, the "PFAS 0250". This technology can reduce waste generated through PFAS treatment and, as a result, reduce overall waste disposal costs. Previous full-scale systems have produced water with greater than 99% removal of targeted PFAS.

Fractionation is a separation technology that uses micron-sized gas bubbles to remove contaminants, such as Poly- and Perfluoroalkyl substances (PFAS) from water. It can also work in conjunction with other water treatment systems to reduce PFAS waste. PFAS molecules have hydrophilic and hydrophobic properties attracting them to the gas-liquid interfaces present in fractionation as the injected gas bubbles move through water. Bubbles interact with PFAS and other constituents and are discharged as foam fractionate.

Fractionation is effective as a stand-alone technology for low- to medium-flow rate applications and as an integral part of a treatment train for minimizing waste disposal costs by further reducing the volumes of high-concentration waste streams from membrane exclusion and filtration technologies. The volume reduction of a contaminant-impacted waste stream can be up to 99.5% with fractionation, reducing disposal costs significantly. Any residual levels of PFAS can still be removed via traditional media polishing processes, increasing bed-life and operational efficiency.

Standard Specifications

3 Fractionation Columns
1 Concentrating Column
4 Feed Pumps (one for each reactor)
4 Recirculation Pumps (one for each reactor)
8 Venturis for Gas Injection (2 per reactor)
1 Treated Water Transfer Pump
1 System Return Pump
1 Hydrocyclone for solids management
4 Retention Tanks
2 Foam Fractionate Tanks
Ozone Generator with Oxygen Concentrator and Ozone Destruct Unit
Automated Controls and HMI
pH, ORP, Conductivity, DO, Pressure Monitoring

Available Options

2 Media Polish Connections for Treated Water
2 Chemical Dosing Connections (acid/caustic)
Influent/Effluent Storage Tanks

- Anson Madison Sanitary District in Maine

AMSD PFAS Treatment System

- PFAS is not treated via standard wastewater secondary treatment technology
- Additional tertiary treatment is necessary
- Proposed at AMSD - Foam fractionation system followed by activated carbon

MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION www.maine.gov/dep

Supercritical Water Oxidation

- Demonstrated effectiveness within the radiological industry
- Viability for PFAS under development, particularly concentrated waste streams

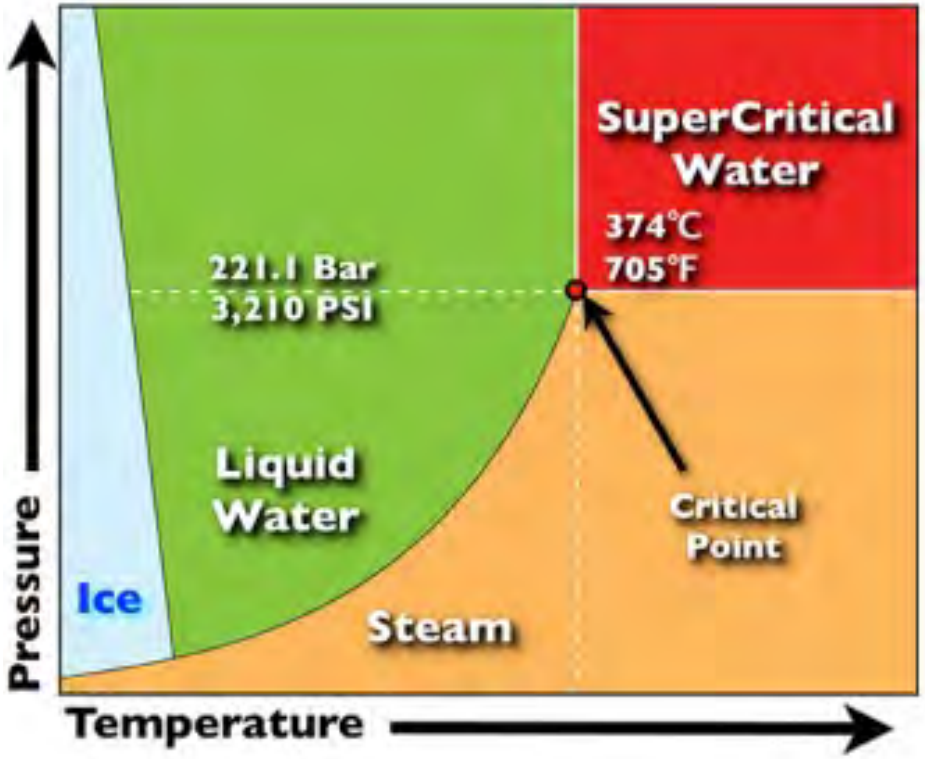
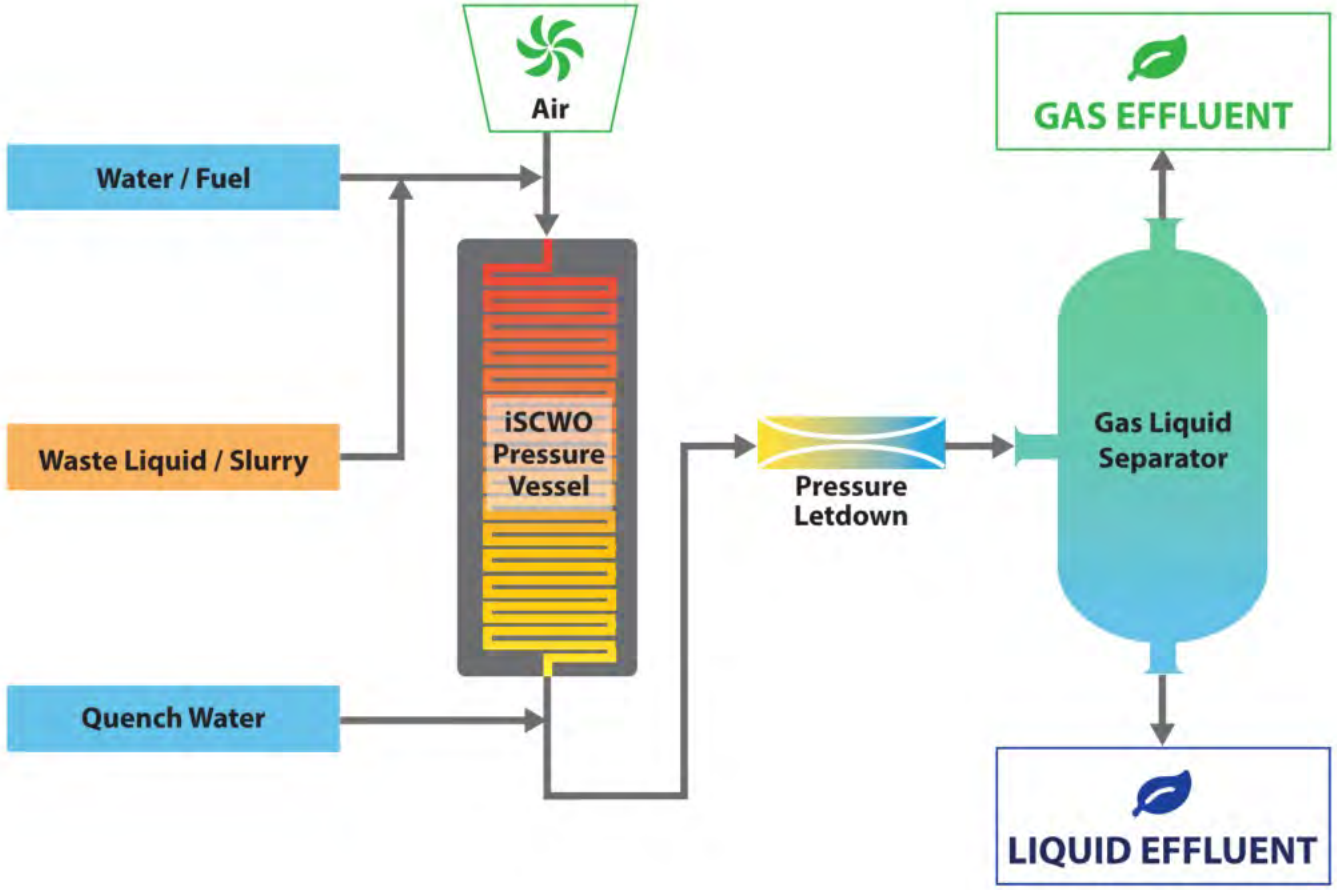


Image credit:
Jonathan Kamler
EPA Brief

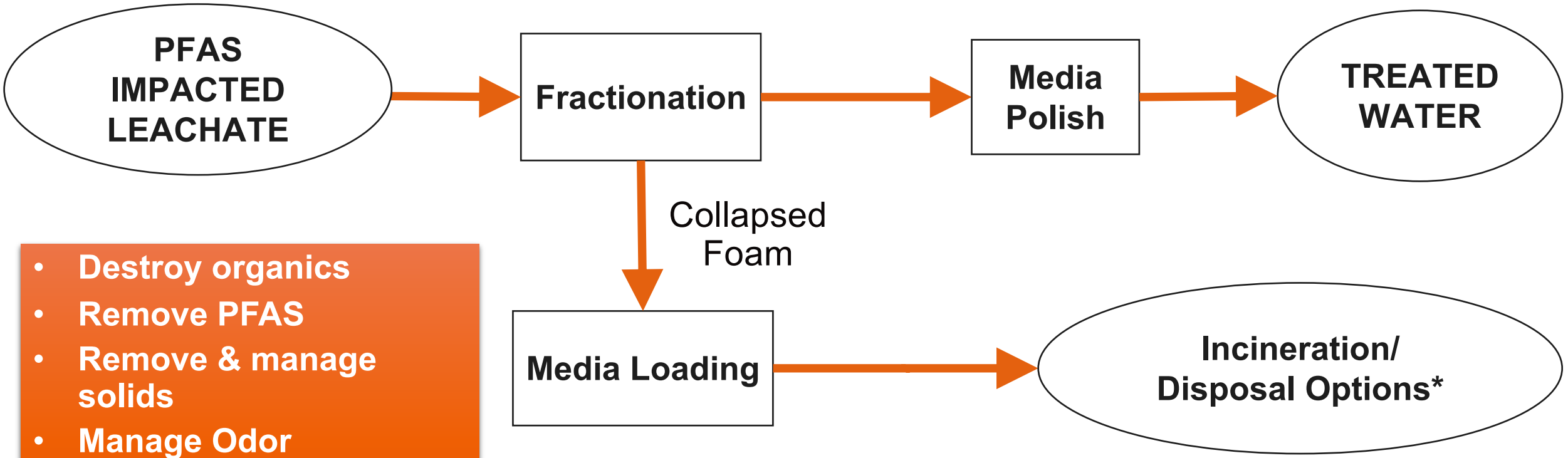


Conceptual Demonstration:

https://www.ga.com/hazardous-waste-destruction

Graphic and demonstration reproduced from General Atomics (with permission)
(McDonough et. al 2022)

Example of PFAS Treatment Train



- Destroy organics
- Remove PFAS
- Remove & manage solids
- Manage Odor
- Extend Media Polish Performance
- Reduce Waste Disposal Volumes and Cost

*Other Alternatives i.e. Supercritical Water Oxidation

Research and Development Pipeline

- Sub-micron powdered activated carbon (SPAC) Ceramic Membrane Filtration (CMF)
- Synthetic Adsorbents (Osorb / PQ-Osorb)
- Destruction of PFAS
  - Sonolysis
  - eBeam
  - Electrochemical Destruction
- PFAS Cleaning Agents and Solvents
  - Arcadis FluoroFighter™

Source: Arcadis

OCTOBER 22, 2021 | PRESS RELEASE

Arcadis launches new cleaning agent to remove PFAS from fire suppression systems

Research and Development Matters

bb AWARDS 2016 WINNER

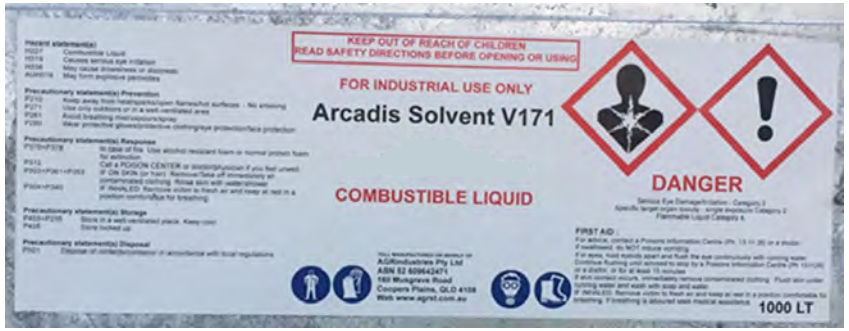
Commercialization of TOP Assay

SERDP DOD • EPA • DOE

BAA

ESTCP

DoD research and development projects (academic/industrial partners)



Innovative and first to market solutions in collaboration with partners

2016 → 2022

Contributions to the academic/industrial literature

PFAS Liquid Treatment Quick Take-Aways

- PFAS defy conventional remediation engineering
  - do not bio**degrade**
  - nearly impractical to chemically **oxidize**
  - has minimal removal through **phase changes**
  - **energy-intensive** to destroy
- Current state of the practice is a **combination** of treatment technologies
- Goal is to **concentrate** PFAS for energy-intensive destruction

ADSORPTION | **SEPARATION/ CONCENTRATION** | **DESTRUCTION**

Thank You!

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