→ Jay Surti, Holly Churman, and Steven Brockliss

PFAS across the water cycle

→ Promising management and treatment strategies

Welcome

Introductions

Jay Surti, PE
East Region Biosolids Leader

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Water Treatment and Desalination Service Line Leader - Americas

Steven Brockliss, PE
Senior Project Engineer

Acknowledgements:

– Mallory Griffin, PE – ESWP Membership Chair

Safety moment

↳

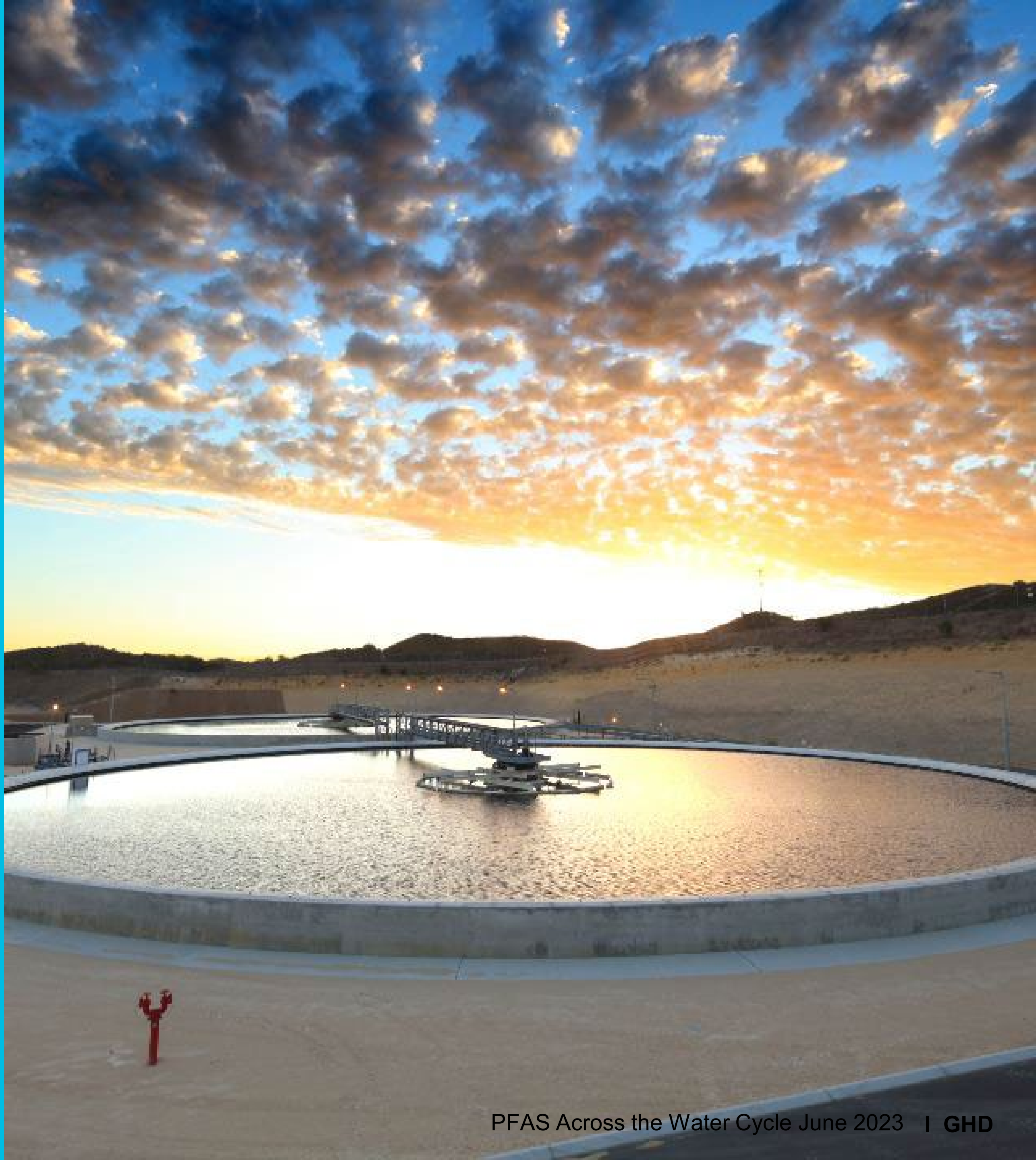
Bench and Pilot Test Safety

- Use of proper PPE is important during all stages of project development and delivery, including bench and pilot studies
- Examples: gloves, hardhat, steel toe boots, safety glasses
- Ensure well-being of staff performing work
- Optimize test outcomes by mitigating potential contamination of water samples

Protect Staff, Optimize Outcomes

Agenda

- Scoping the PFAS challenge
  - Emerging regulations
  - Emerging analytics
- Treatment: Separation and Destruction
  - Potable water
  - Wastewater
- Case studies
- Take aways

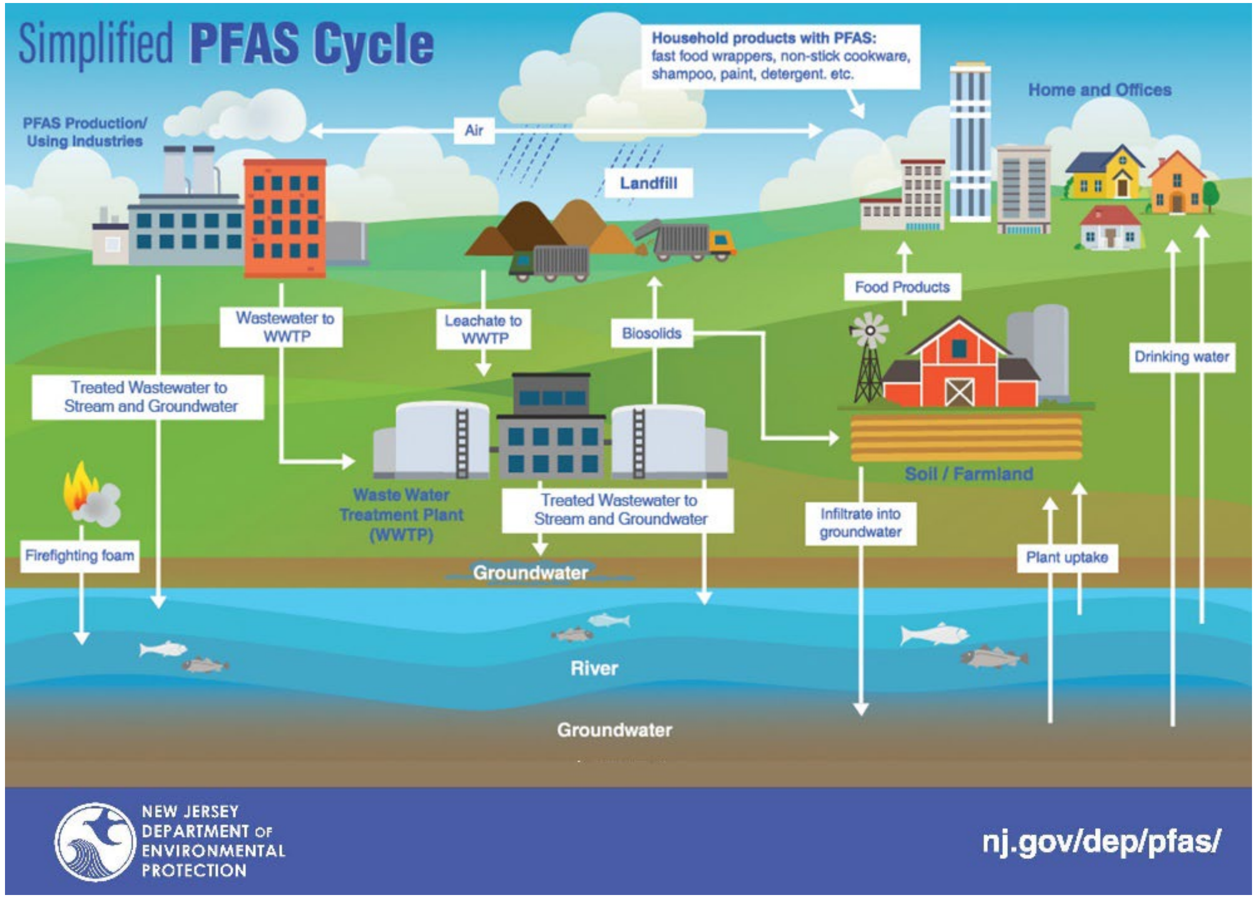


The PFAS challenge

→ Scoping and understanding

Emerging regulations

PFAS exposure and its omnipresence



Federal and state regulations

USEPA has proposed a National Primary Drinking Water Regulation for six PFAS constituents

→ Enforceable standard to address PFAS in drinking water

Maximum Contaminant Levels Proposed:

- PFOA < 4.0 ppt
- PFOS < 4.0 ppt
- Hazard Index (HI) < 1.0
  - Covers PFHxS, GenX, PFNA, PFBS

$$\frac{PFNA}{10} + \frac{PFHxS}{9} + \frac{PFBS}{2000} + \frac{GenX}{10} = Hazard\ Index\ Value$$

Pennsylvania history

- 2013: PFAS challenge identified via USEPA Third Unregulated Contaminant Monitoring Rule (UCMR3)
- 2016: USEPA reduced combined lifetime HAL for PFOA and PFOS to 70 ppt; PA collaborated with federal and local partners to identify sources
- 2023: PA DEP sets MCLs:

Published PA Drinking Water MCLs		
	MCLG	MCL
PFOA	8 ppt	14 ppt
PFOS	14 ppt	18 ppt

Federal Implementation Timeline:

- 2023 Finalize Rule
- 2026 Enforce MCLs
- 2028 Two-year Extension

Published PFAS extraction and analytical methods

Media	Method	Validation status	Analyte list
Drinking water	USEPA 537.1	Multi-laboratory	18 PFAS analytes (including 4 PFAS not included in USEPA Method 533)
Drinking water	USEPA 533	Multi-laboratory	25 PFAS analytes (including 11 not included in USEPA Method 537.1)
Surface water, groundwater, and wastewater	USEPA SW-846 Method 3512	Multi-laboratory	24 PFAS analytes (does not include all PFAS included in USEPA Method 537.1 or 533)
Surface water, groundwater, and wastewater	USEPA SW-846 Method 8327	Multi-laboratory	24 PFAS analytes (does not include all PFAS included in USEPA Method 537.1 or 533)

Emerging biosolids land application regulations

Michigan

- Tiered approach
  - **Tier 3 (PFOS ≥ 150 μg/kg)**
- Cannot be land applied
- Investigate potential sources to develop a source reduction program
  - **Tier 2 (PFOS ≥ 50 μg/kg & <150 μg/kg)**
- Investigate potential sources to develop a source reduction program
- Reduce land application rates to no more than 1.5 dry tons per acre (or submit an alternative risk mitigation strategy)
  - **Tier 1: PFOS > 20 μg/kg & < 50 μg/kg**
- Consider investigating sources and sampling the WWTP effluent for PFAS

Maine

- March 2019: Moratorium on biosolids land application
  - **Testing for PFAS required for all biosolids to be land applied**

Screening concentrations for PFAS in biosolids	
PFOA	2.5 ng/kg
PFOS	5.2 ng/kg
PFBS	1900 ng/kg

- April 2022: Ban on use of all products that contain wastewater biosolids

PFAS treatment

→ Drinking water

Treatment Options

TREATMENT PROCESS	PFOA	PFOS	PFNA	PFHxS	PFBS	HFPO-DA (Gen-X)	PFHpA	PFDA
Aeration	□	□	□		□		□	□
Coagulation / DAF	□	□			□		□	
Coagulation / Flocculation / Sedimentation / Filtration	□	□	□		□		□	□
Anion Exchange	◪	■	■		◪		◪	■
Granular Activated Carbon	■	■	■		■		■	■
Nano Filtration	■	■	■		■		■	■
Reverse Osmosis	■	■	■		■		■	■
MnO_4, O_3, ClO_2, Cl_2, UV, Chloramination	□	□	□		□		□	□

□ *<10% Removal,* ◪ *10 – 90% Removal,* ■ *>90% Removal, No data available for PFHxS or HFPO-DA*

Treatment Selection

- Characterizing water supplies
- Using consistent analytical support to ensure accuracy of data
- Setting well-grounded treatment objectives
- Understanding existing water demand and the condition of available assets
- Having an effective communication plan to engage your community throughout the process
- Supporting technology selection with bench study and pilot-scale data
- Maintaining a rapport with the regulating agency throughout the planning process

Proven Processes

Carbon Adsorption

Granular Activated Carbon

Ion Exchange

Anionic Resin

High Pressure Membrane

Nano-filtration and Reverse Osmosis

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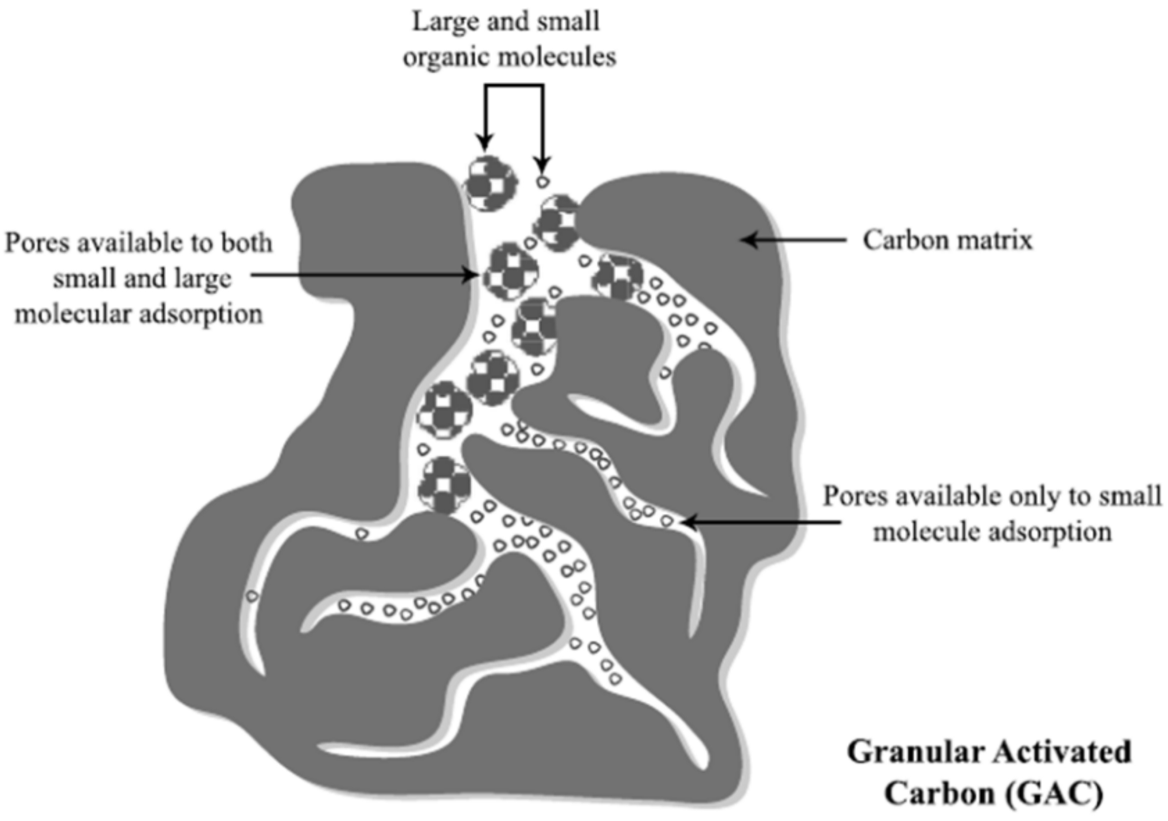
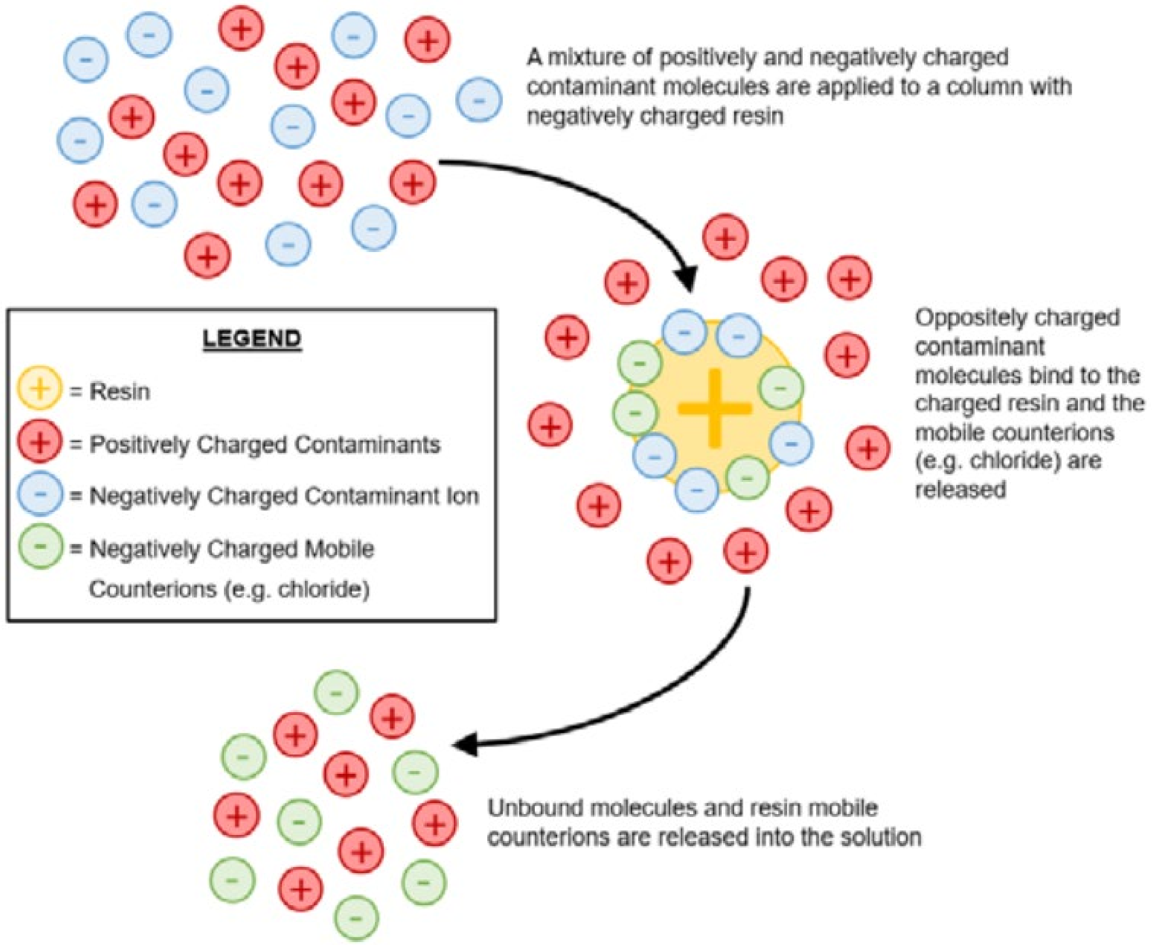
Activated Carbon Adsorption



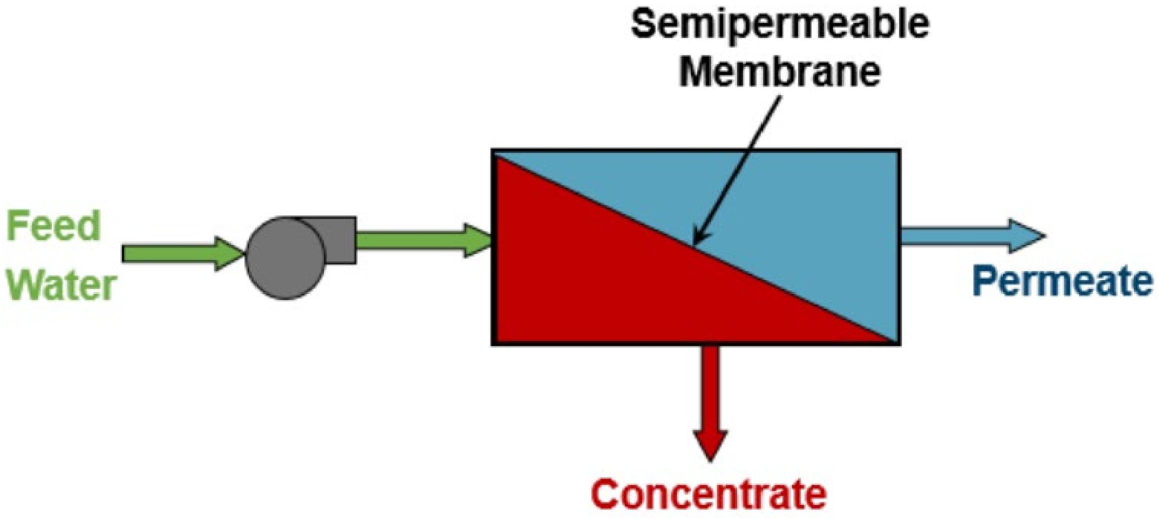
- Good PFAS removal
- Secondary water quality benefits
- Backwash wastewater must be disposed of
- Carbon will need to be reactivated or incinerated
- GAC can be retrofitted to existing sand filters
- O&M costs for media replacement

Ion Exchange



- Reliable treatment process
- Some secondary water quality benefits
- PFAS-selective resins are available
- Increased resin use depending on water chemistry
- O&M costs for resin replacement

High Pressure Membranes



- Best PFAS removal
- Secondary water quality benefits
- Concentrate disposal will be challenging
- Pre-treatment will be required
- Post-membrane treatment may be required
- High energy needs relative to other processes
- High capital and O&M costs

Comparison

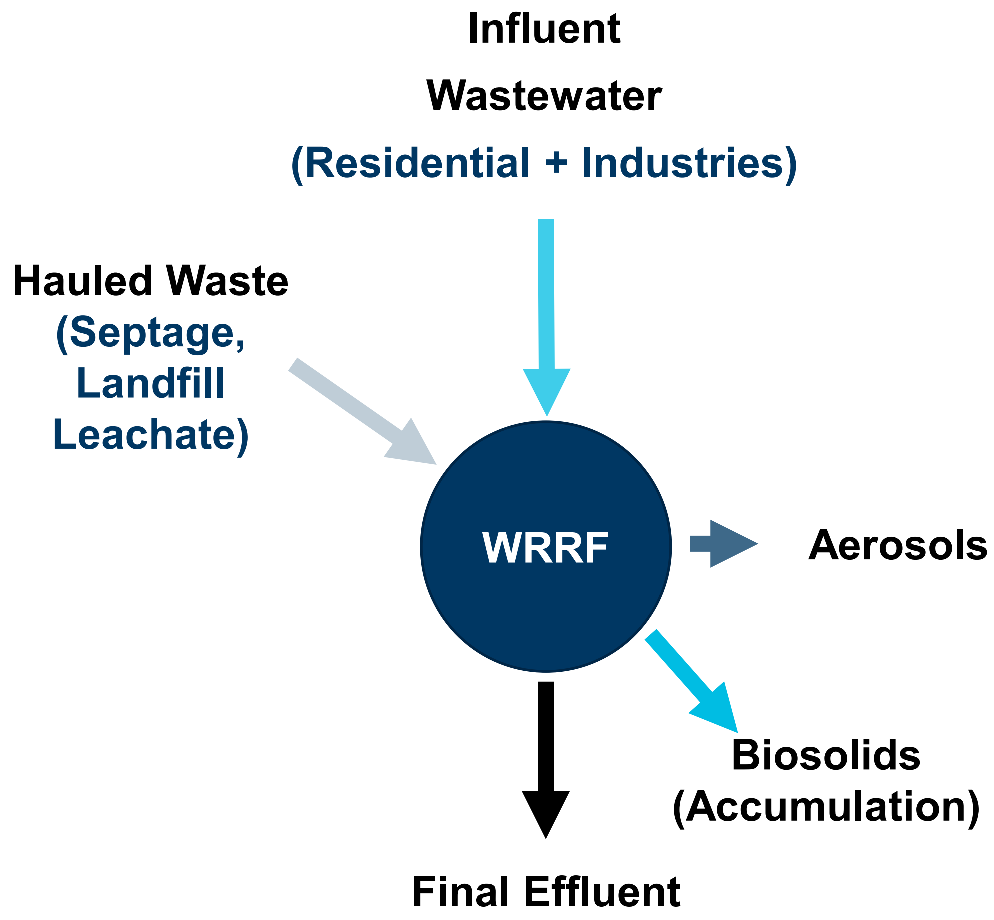
Treatment Technology	Relative Cost	Short Chain Removal	Long Chain Removal	Waste Stream	PFAS Endpoint
GAC Adsorption	Moderate to High	< 96%	40% - 96%	Backwash Water	Carbon Media
Ion Exchange	Moderate to High	< 95%	55% - 97%	N/A	Exchange Resin
Membrane Filtration	High	> 99%	> 99%	Concentrate Stream	???

Promising management and treatment strategies

→ **Wastewater and biosolids**

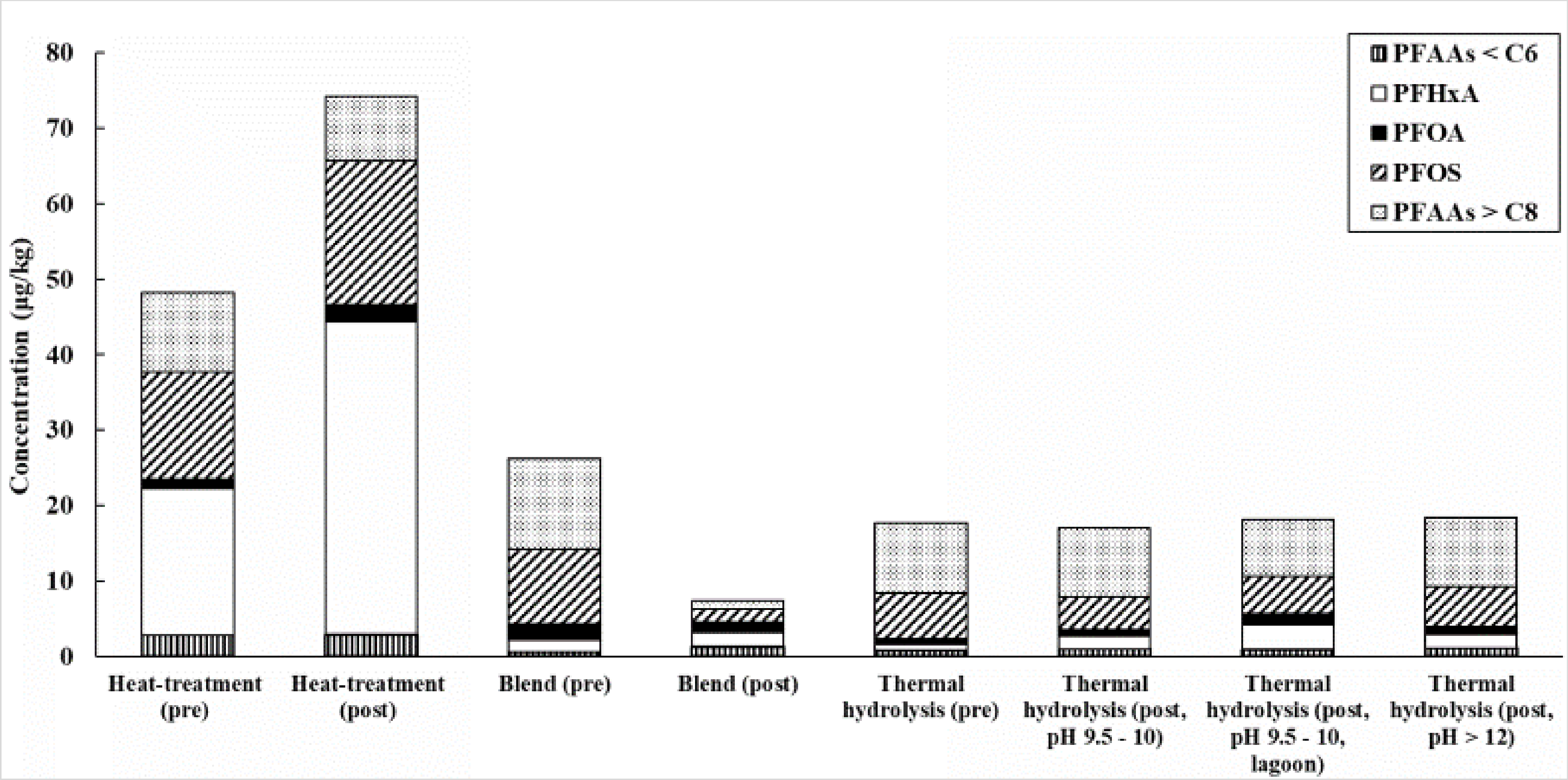
Fate of PFAS in wastewater & biosolids

- PFAS are not in a stable condition, changing between dissolved and particulate phase
- Lighter PFAS compounds stay in the liquid phase
- Heavier PFAS compounds accumulate in biosolids
- Industrial waste and imported waste streams significant contributors of PFAS



Fate of PFAS through solids treatment process

Total PFAA Concentrations (µg/kg, dry wt.) for the < 2 mm Fraction of Fertilizers Pre- and Post-Treatment.



Source: Per- and Polyfluoroalkyl Substances in Commercially Available Biosolids-Based Fertilizers: The Effect of Post-Treatment Processes; by Rooney Kim Lazcano, Chloe de Perre, Michael L. Mashtare and Linda S. Lee. Presented at the WEF/IWA Residuals and Biosolids Conference 2019.

Michigan – Source control achievements

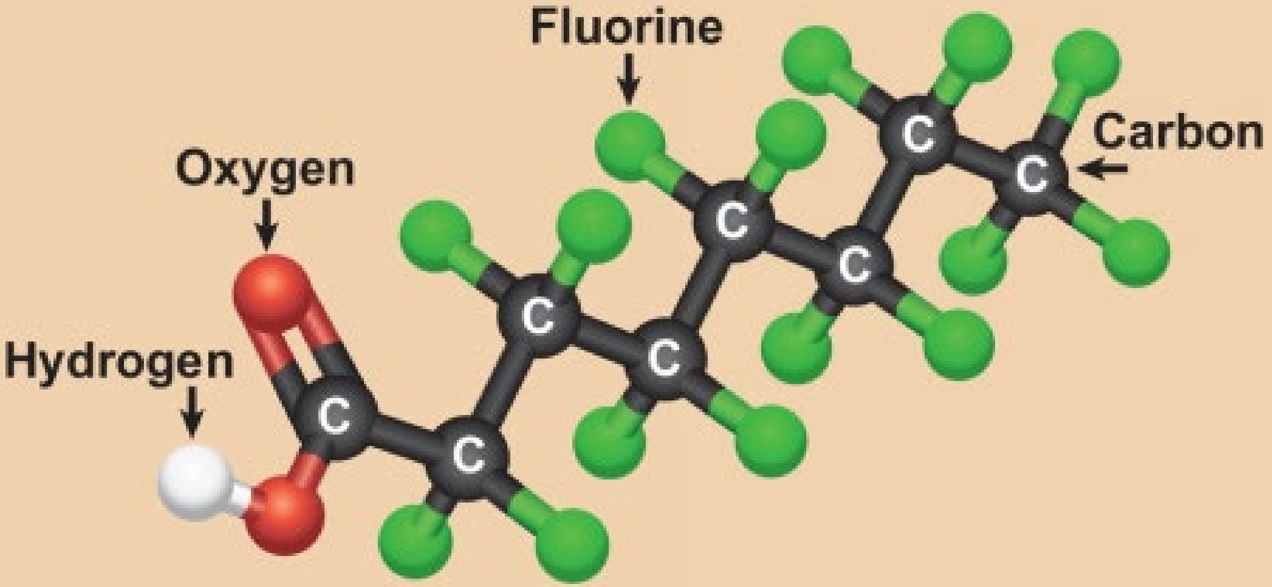
→ Substantial PFOS Reduction in WRRF Effluent after source control initiatives

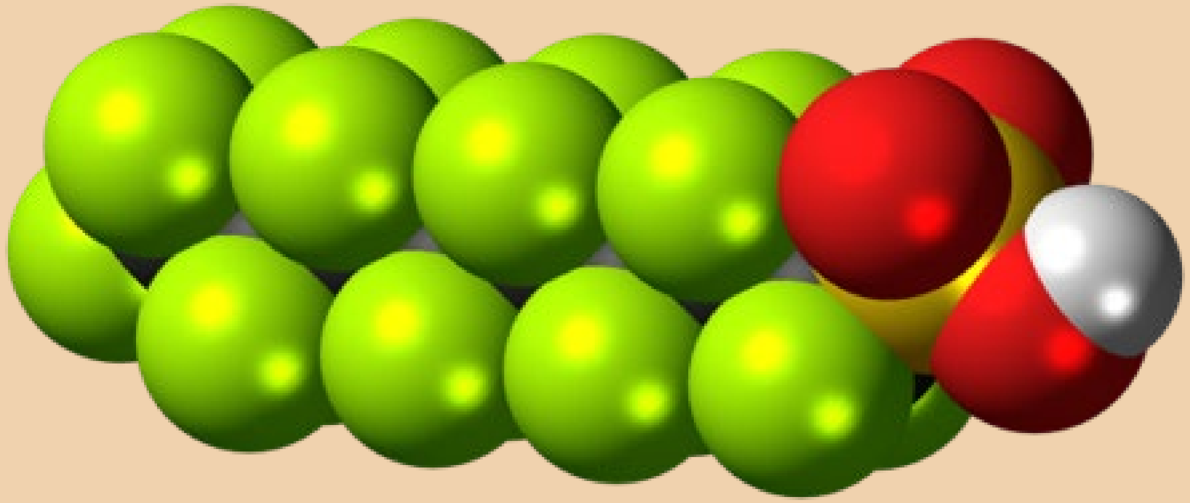
Municipal WWTP	PFOS, Effluent (ppt, most recent**)	PFOS Reduction in Effluent (highest to most recent)	Actions Taken to Reduce PFOS
Lapeer	<18*	99%	Treatment (GAC) at source (1)
Wixom	17*	99%	Treatment (GAC) at source (1)
Port Huron	15*	99%	Elimination of PFOS source (2)
Howell	4	97%	Treatment (GAC/resin) at source (1)
Bronson	12	97%	Treatment (GAC) at source (1)
Ionia	25*	95%	Treatment (GAC) at source (1)
Kalamazoo	5	88%	Treatment (GAC) at sources (2), change water supply
K I Sawyer	13*	95%	Eliminate leak AFFF, some cleaning
GLWA (Detroit)	37*	23%	Treatment (GAC) at sources (9)

*Greater than Michigan's Water Quality Standard of 12 ppt

**Data (rounded) received as of June 26, 2020

Source: Michigan IPP Initiative, Identified Industrial Sources of PFOS to Municipal Wastewater Treatment Plants. Aug 2020



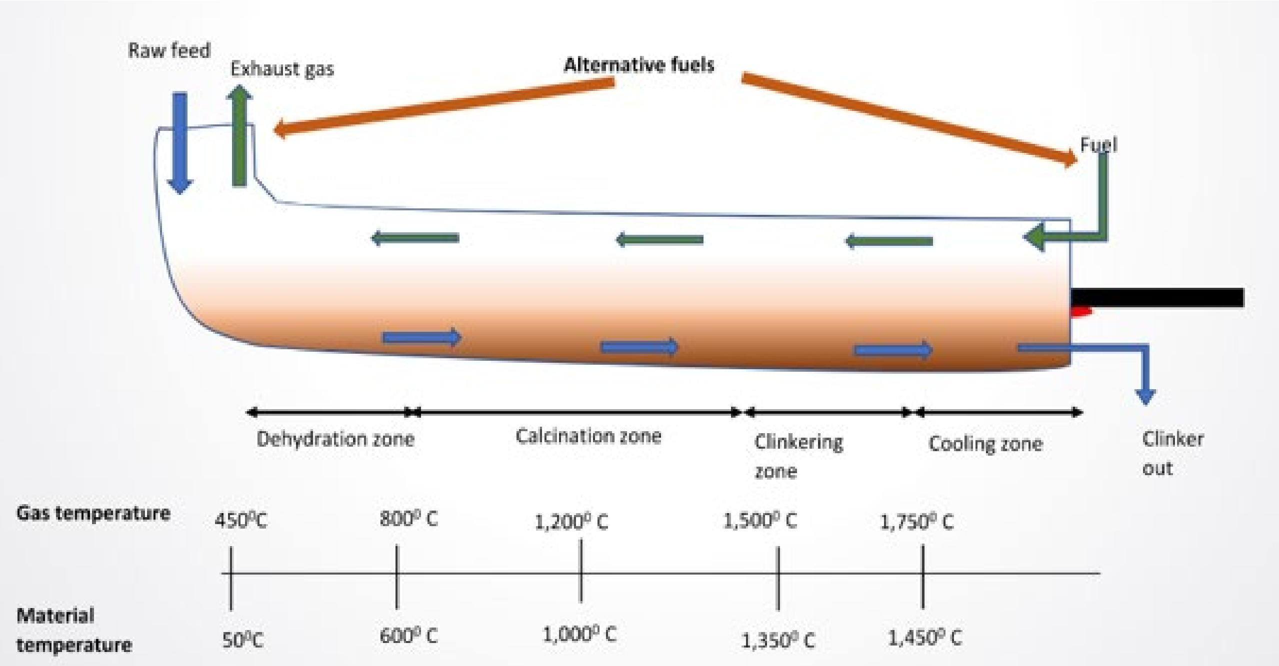


Treating PFAS – Tough to crack!

- Terminal PFAAs are extremely **stable** compounds
- Strong **C-F bond**, and **carbon shielding**
- **Thermal destruction** (mineralization) require temperatures greater than 1,000◦C (1,832◦F).
- **Chemical hydrolysis, oxidation and reduction** is challenging due to the **fluorine effect!**

Thermal Combustion (Incineration)

- 3Ts (time, temperature and turbulence)
- Concerns with PFAS incineration
  - Products of Incomplete Combustion (PICs)
  - Shorter chain PFAS, partially fluorinated PFAS
  - Secondary pollution concerns
  - HF corrosion concerns. Post-incineration treatment required



Sewage sludge as co-fuel for cement kilns

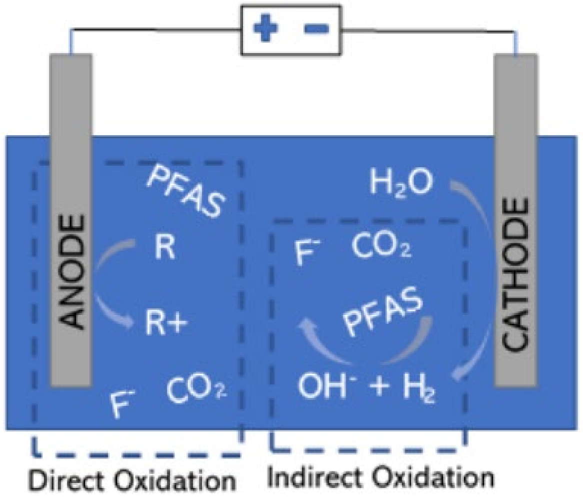
- Temperatures: 1,400ºC to 2,000 ºC
- Calcium catalyzes PFAS destruction
- Long residence time: 20 – 30 mins (solids), 6 – 10 seconds (gas)

Promising PFAS destruction technologies

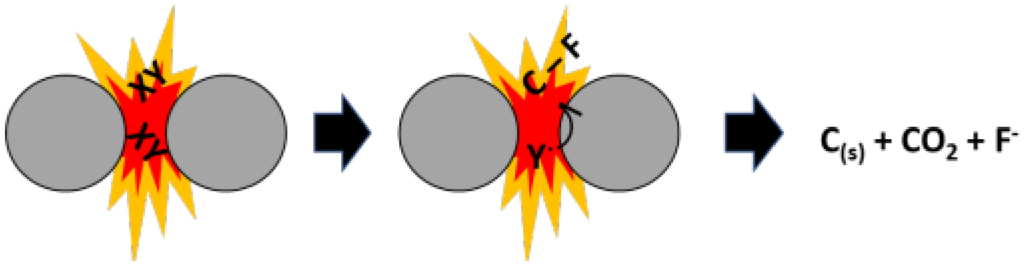
United States Environmental Protection Agency

PFAS Innovative Treatment Team (PITT)

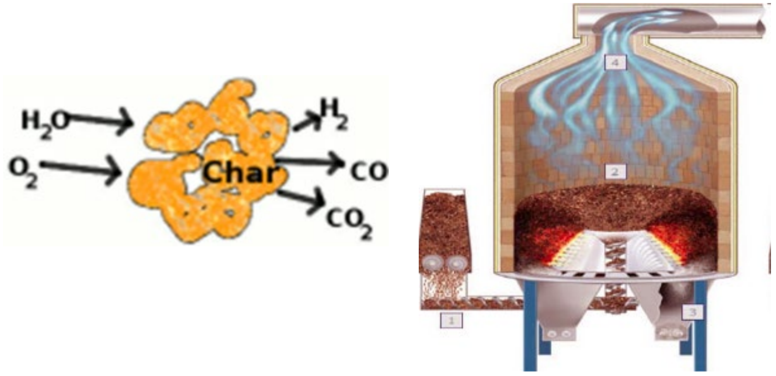
Electrochemical Oxidation



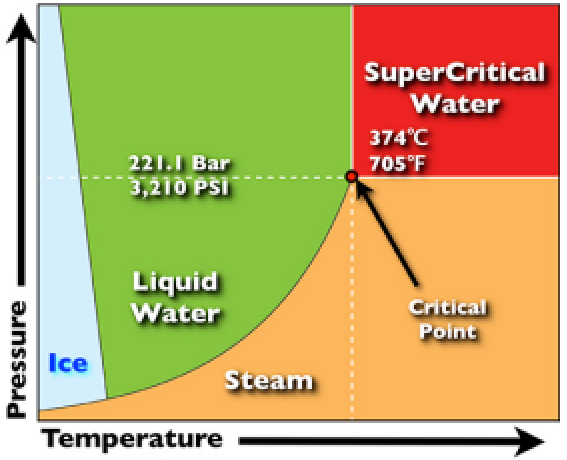
Mechanochemical Degradation



Pyrolysis and Gasification



Supercritical Water Oxidation



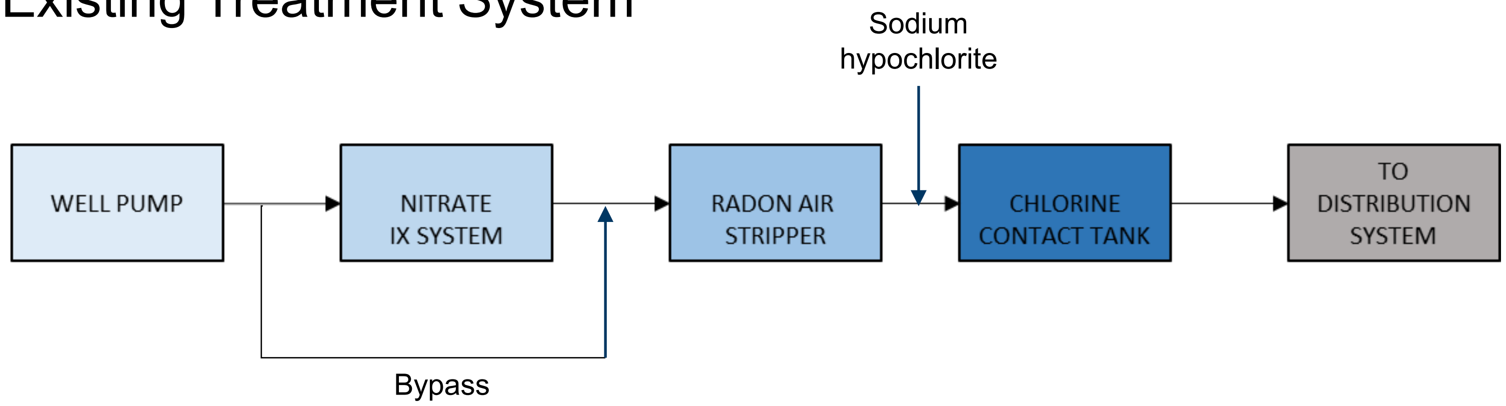
Case study 1

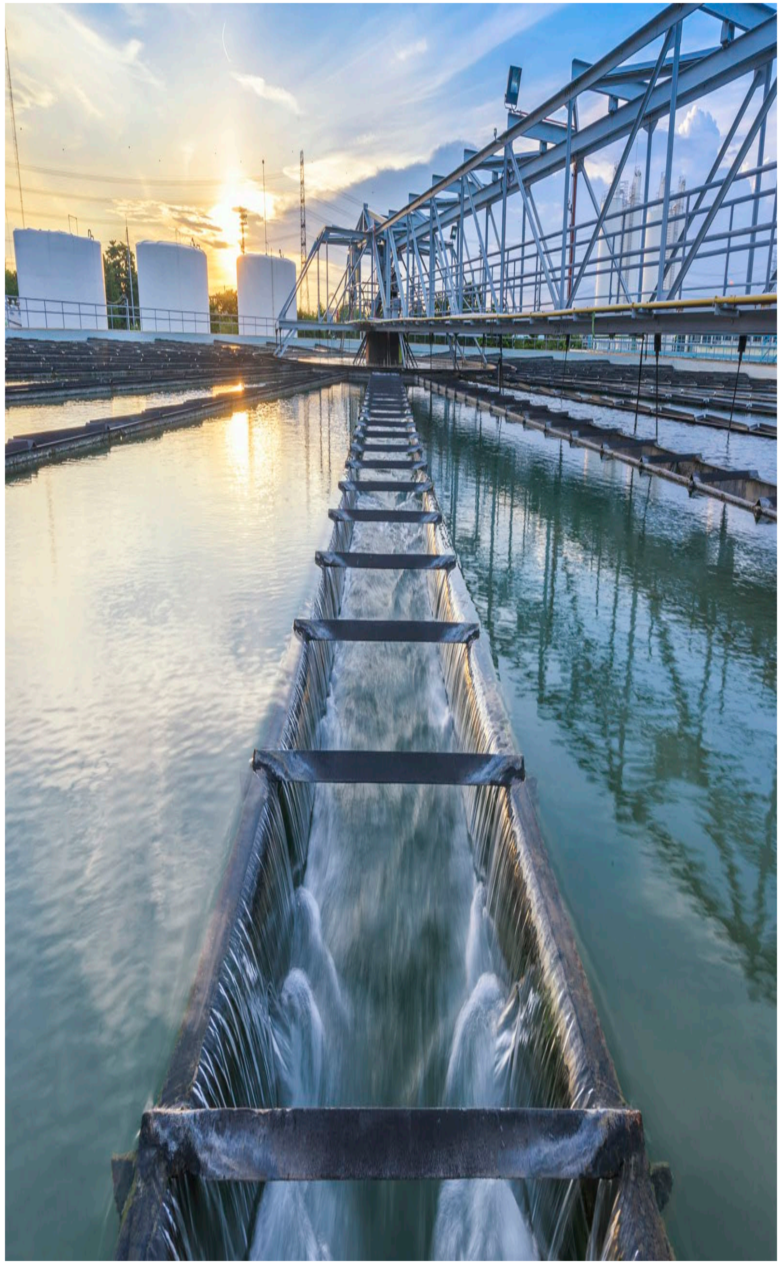
→ **Treatability of PFAS contaminated groundwater for potable use**

Project background

- Finished water samples were taken at a private client's drinking water treatment plants for the 18 PFAS analytes included in EPA Method 537.1. Results from production well were above the EPA health advisory of 70 ppt for Perfluorooctanoic acid (PFOA) and Perfluorooctane sulfonate (PFOS) either separately or in combination. The client decided to keep this production well offline until a treatment plan is in place.

- Existing Treatment System





Data analysis

- Some PFAS removal is achieved by the existing nitrate IX system, but it is not sufficient to meet EPA's Health Advisory Limit.
- Influent nitrate measured during GHD's sampling was 5.7 mg/L which is just above the finished water quality target concentration of 5 mg/L. If levels drop below 5 mg/L, the nitrate IX system could be fully bypassed.

- 90% of Nitrate and Sulfate Removed
- 55% PFOS Removal
- 67% PFHxS Increase

Treatment alternatives

Alternative	Option Description	Stream Treated	Advantages	Disadvantages
1	PFAS specific IX	Nitrate IX effluent plus bypass	Existing nitrate IX process remains unchanged	Nitrate loading on PFAS IX will shorten life. PFAS potentially present in nitrate IX regen.
2	IX	Nitrate IX effluent	Low nitrate sulfate loading on PFAS IX extending the time to breakthrough	Nitrate IX may require modification. PFAS potentially present in nitrate IX regen.
3	IX	Raw Water	Eliminate nitrate IX resin treatment and regen. Repurpose vessel with new PFAS IX process	PFAS resin will remove nitrate for the first 500 to 1,000 BV of operation.
4	GAC	Raw Water	PFAS removed prior to Nitrate IX, so no potential for PFAS in IX regen. Existing nitrate IX process remains unchanged.	Radon adsorption would make the GAC a radioactive waste.
5	GAC	Radon Stripper Effluent	PFAS removed prior to Nitrate IX, so no potential for PFAS in IX regen.	PFAS potentially present in Nitrate IX regen

RSSCT test results

Media Type	Sample Location	EBCT	PFOA + PFOS
IX Resin 1	Raw Water	12 mins	~2 ppt
	Nitrate IX Effluent Plus Bypass	2 mins	~21 ppt
IX Resin 2	Raw Water	3 mins	~10 ppt
GAC 1	Nitrate IX Effluent Plus Bypass	10 mins	ND

Alternative comparison

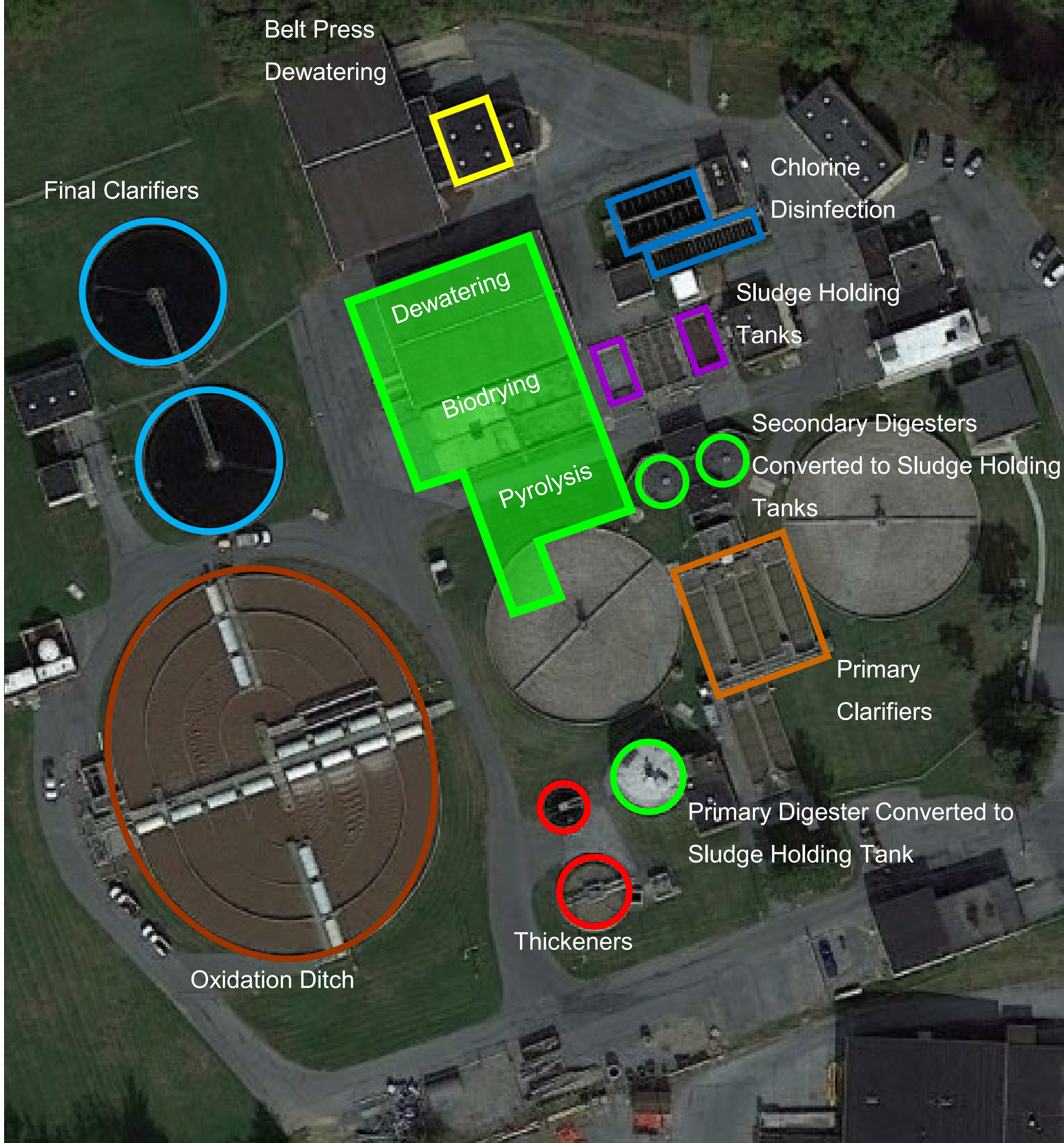
- Manufacturer performance projections vs. treatability testing
- Process flow schematics
- Site layout and footprint requirement
- Cost estimate

Case study 2

→ **Biosolids pyrolysis**

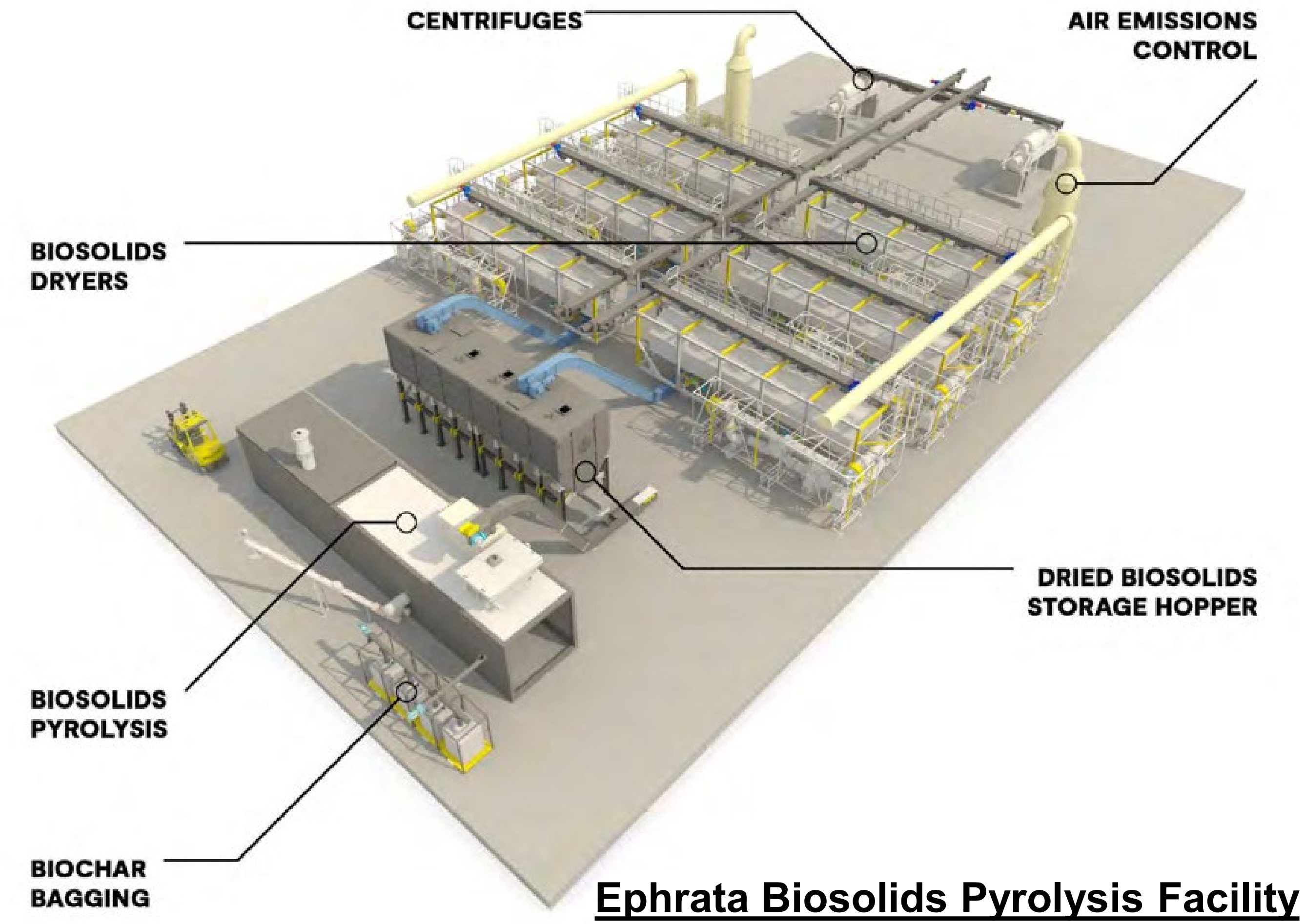
Ephrata Borough Authority (EBA) WWTP # 1

- 3.8 MGD rated, current flow 2 MGD
- Liquids treatment:
  - Primary treatment
  - Oxidation ditch secondary treatment
  - Anaerobic digestion
  - Chlorine disinfection



Anaerobic digestion vs. pyrolysis

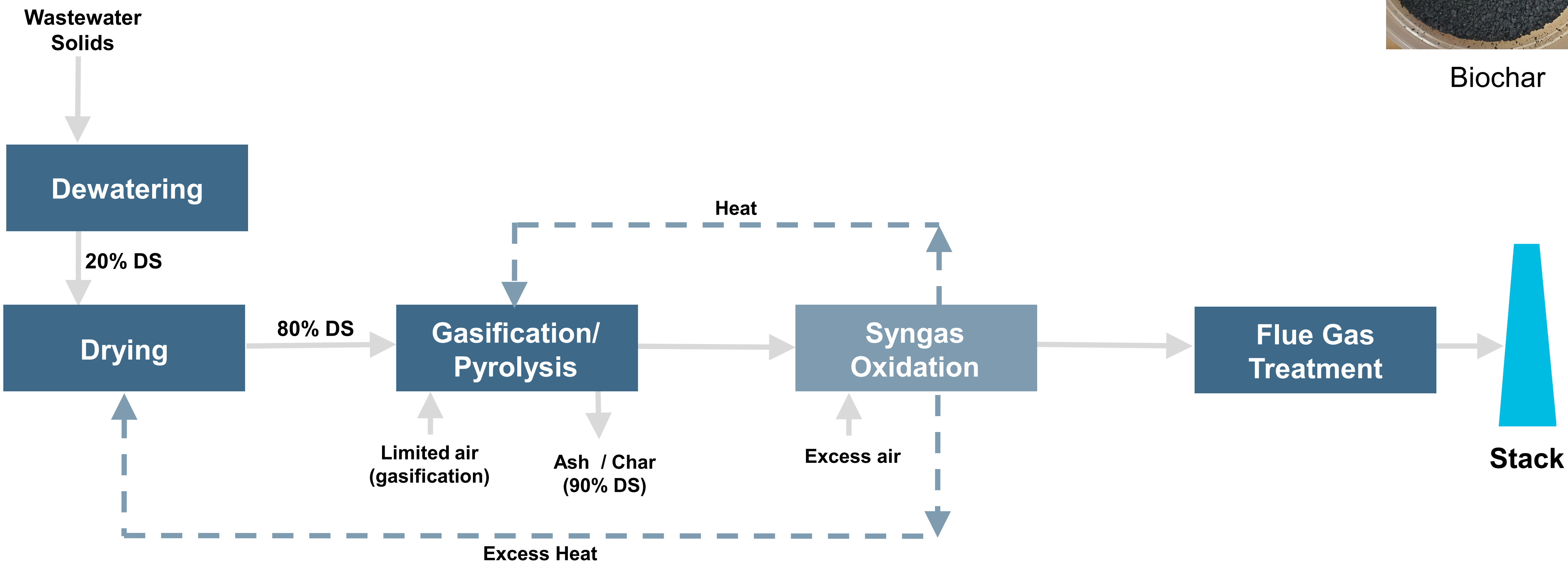
Biosolids pyrolysis benefits compared to anaerobic digestion	
Constructability	Less disruptive to plant operations
Sequencing	Less sludge hauling during construction
Overall cost (NPV basis)	Less
Sludge storage	More (repurpose digesters)
Internal plant nutrient recycle loads	None
Mass of product going offsite	Significantly less
Quality of product	Higher compared to dewatered cake
PFAS risk	Mitigated for biosolids



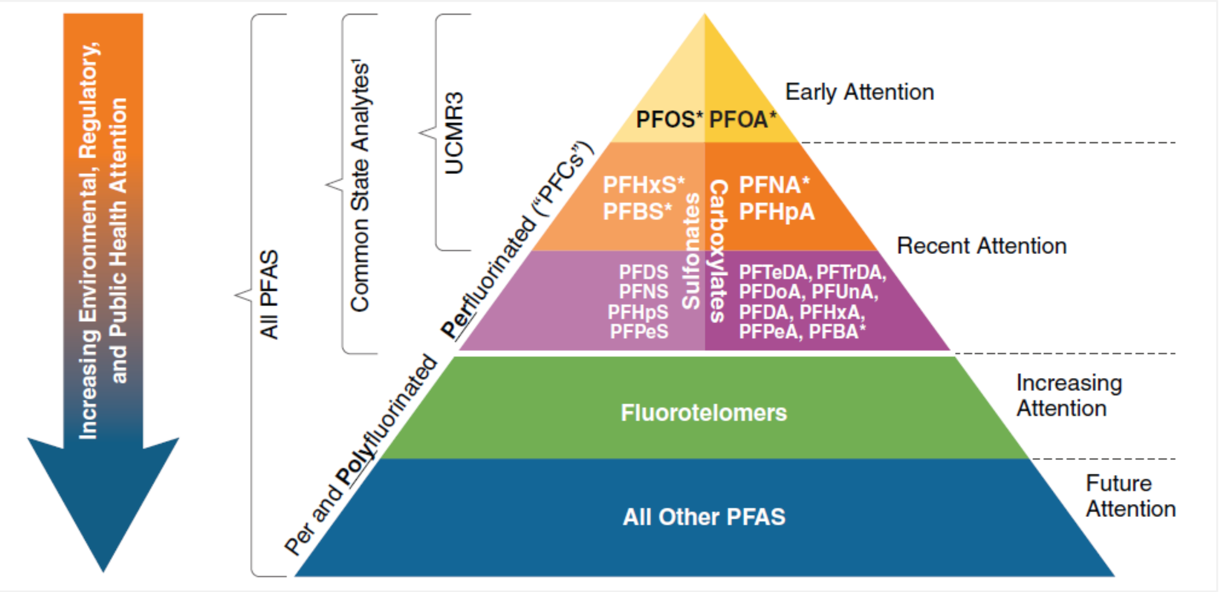
Ephrata Biosolids Pyrolysis Facility

Pyrolysis and gasification

Biochar



Take aways



– Characterize PFAS throughout operations, including water, wastewater, biosolids and spent media

– Evaluate existing treatment systems and ability to remove and/or treat PFAS

– Treatability trials to develop PFAS removal (separation) and destruction solutions

– Investigate source control opportunities

– Adaptive planning in light of the regulatory uncertainty to reduce risks

– Evaluate alternative approaches for managing biosolids, especially if biosolids are land applied

– Stakeholder communications and transparency

* Thank You

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