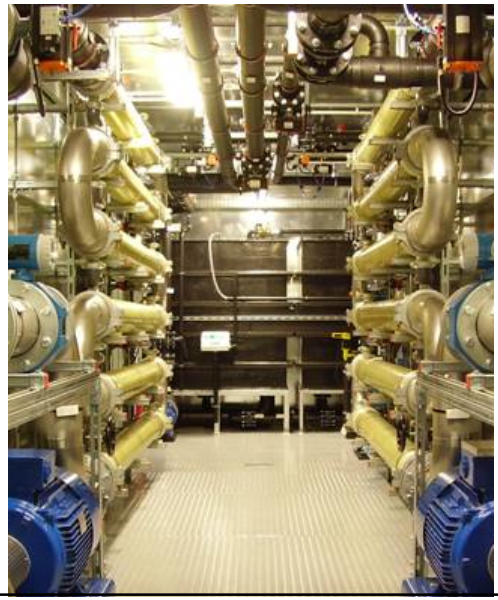
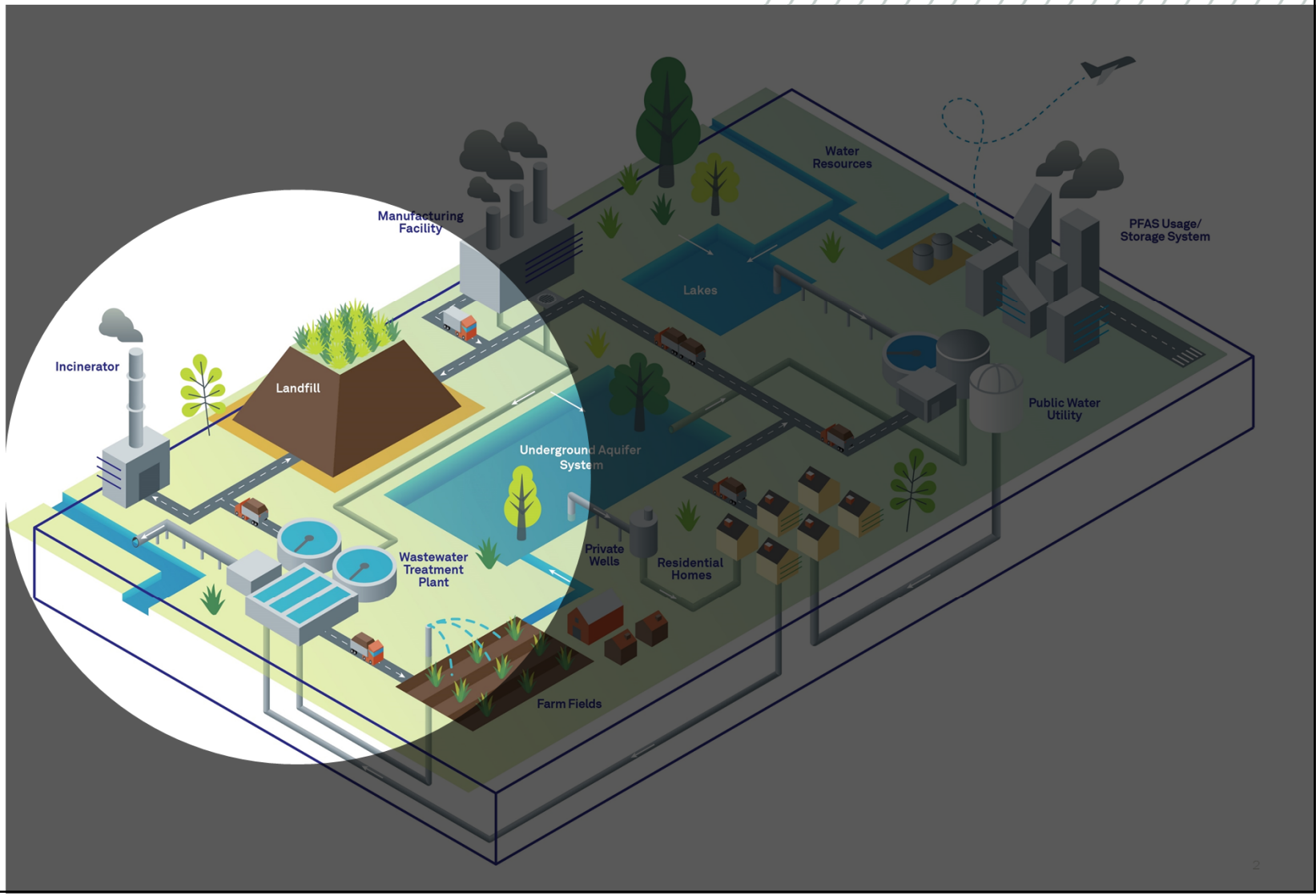
PFAS in Leachate: Characterization, Treatment and POTW Impacts

April 6, 2022 | Jeff Allen, P.E. | JAllen@BrwnCald.com | 651.468.2061

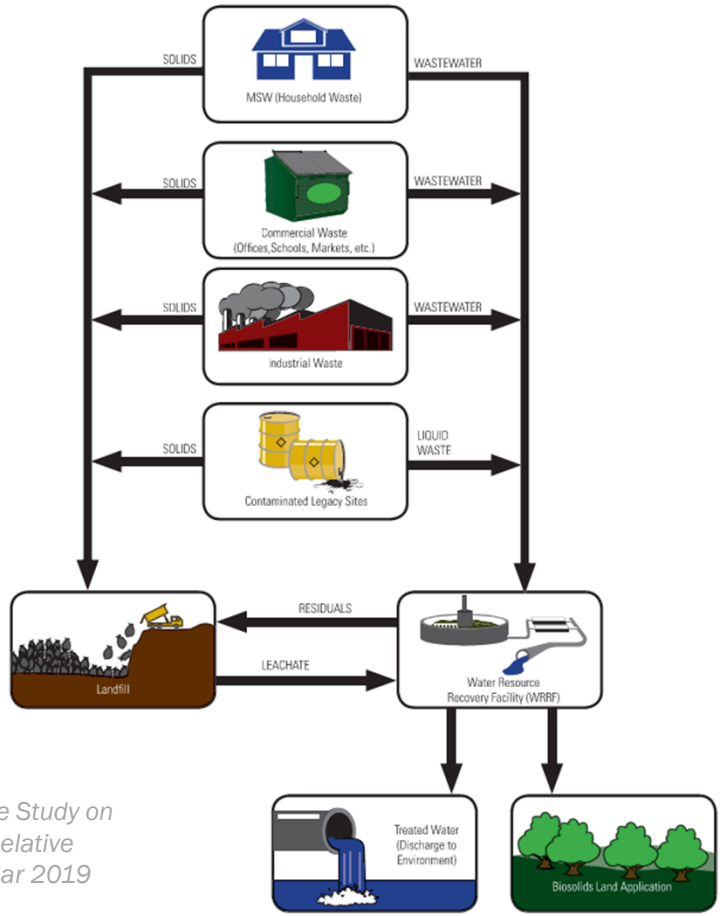



PFAS impact the entire water cycle

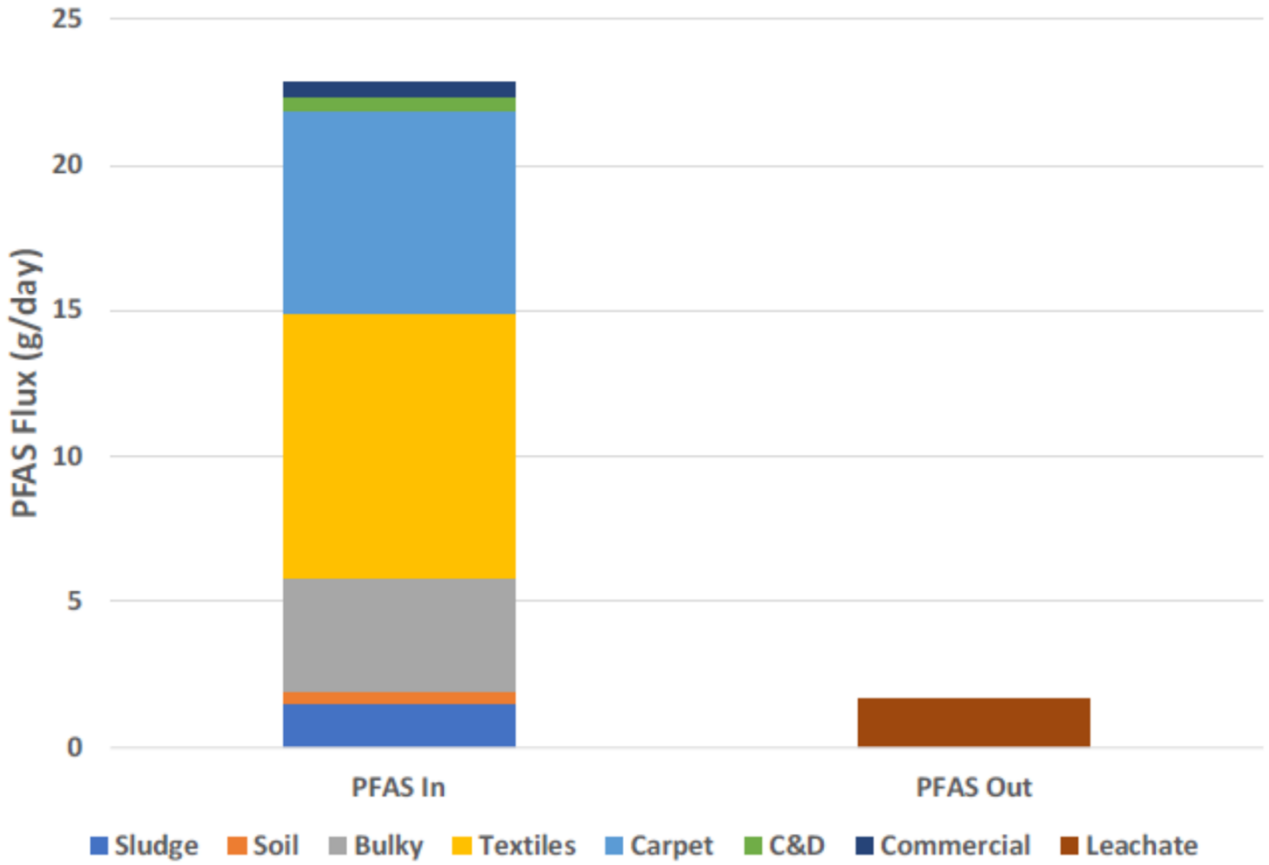


Landfills and POTWs are PFAS Bedfellows



Michigan Waste & Recycling Association, Statewide Study on Landfill Leachate PFOA and PFOS Levels and Relative Influence on WRRF Influent, Technical Report, Mar 2019

Estimated PFAS Flux Through Landfill



PFAS Waste Source Testing Report, Coventry Vermont, Sanborn, Head & Associates, Oct 2019

PFAS-Containing Landfill Wastes

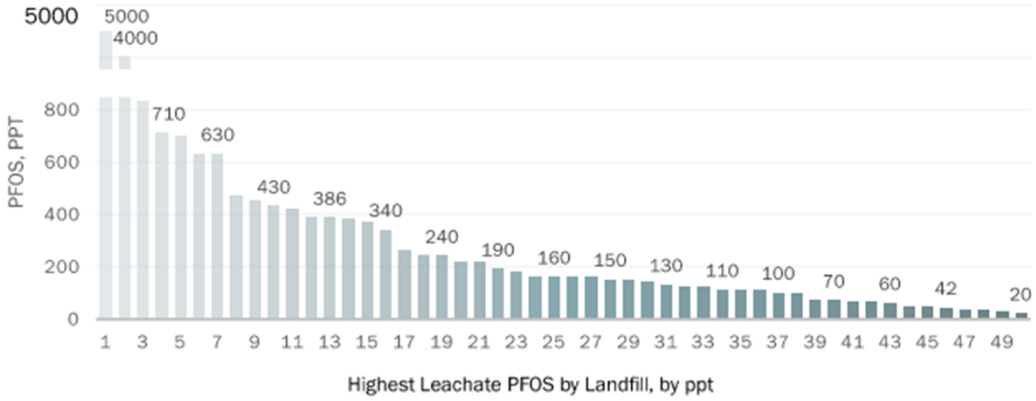
- Non-stick cookware
- Stain-resistant/water-repellant fabrics (clothing, furniture, carpet)
- Grease/water-resistant paper products (food and beverage)
- Cosmetics, lotions
- POTW biosolids
- Aqueous film forming foam (discarded product or fire debris)
- Industrial

Michigan Waste & Recycling Association, Statewide Study on Landfill Leachate PFOA and PFOS Levels and Relative Influence on WRRF Influent, Summary Report, Mar 2019

PFAS Concentrations in Leachate | Michigan

Sources of PFOS to WWTPs in Michigan

Industry/Category/Type	Total Number Evaluated	Number (%) Sources of PFOS by Type	Range Effluent PFOS exceeding screening level of 12 ppt
Landfills	56	49 (88%)	13-5,000



Michigan EGLE, Identified Industrial Sources of PFOS to Municipal Wastewater Treatment Plants, Aug 2020

Michigan vs. Worldwide PFOA and PFOS Leachate Concentrations Ranges

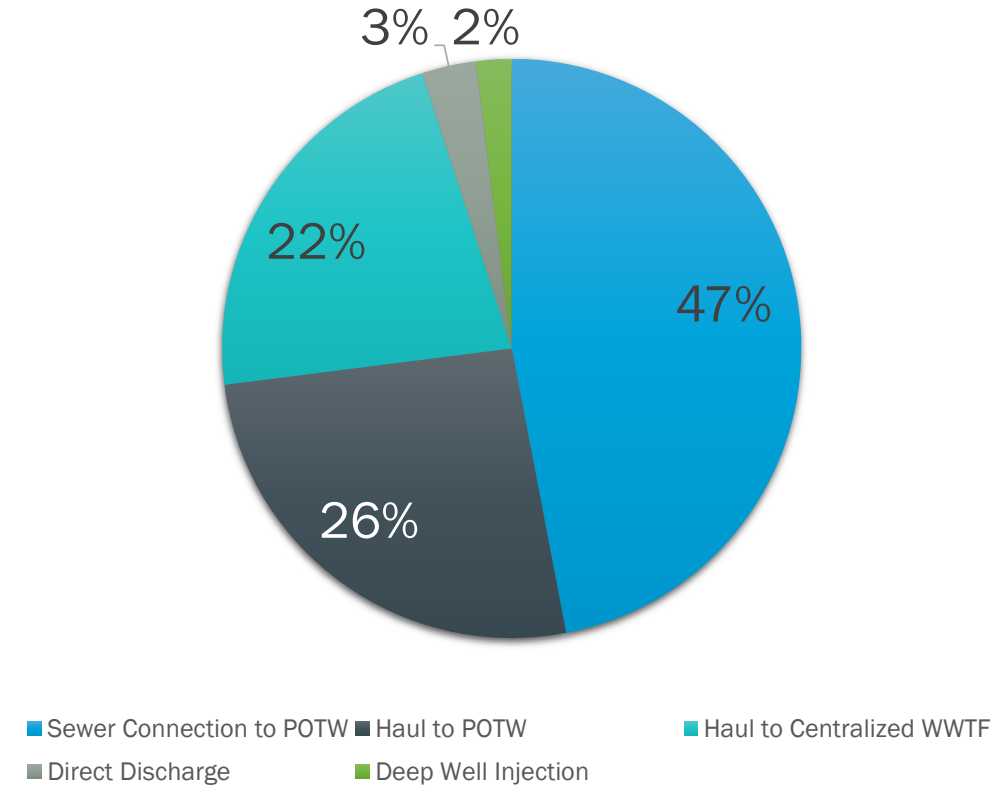
Region	PFOA (ppt)	PFOS (ppt)
Michigan	16 to 3,200	9 to 960
United States	30 to 5,000	3 to 800
Europe	ND to 1,000	ND to 1,500
Australia	17 to7,500	13 to 2,700
China	281 to 214,000	1,150 to 6,020
Worldwide Range	**ND to 214,000**	**ND to 6,020**

Michigan Waste & Recycling Association, Statewide Study on Landfill Leachate PFOA and PFOS Levels and Relative Influence on WRRF Influent, Technical Report, Mar 2019

Leachate Disposal Options

- Direct discharge to receiving stream (full on-site treatment)
- Discharge to an off-site wastewater treatment facility
  - POTW or centralized WWTF
  - With or without on-site pretreatment
  - Direct sewer connection or truck hauling
- Zero discharge (e.g., evaporation)
- Deep well injection

Statewide Leachate Disposal Methods
(Percentage based on gallons treated)



Michigan Waste & Recycling Association, Statewide Study on Landfill Leachate PFOA and PFOS Levels and Relative Influence on WRRF Influent, Technical Report, Mar 2019

PFAS Prevalence in Leachate

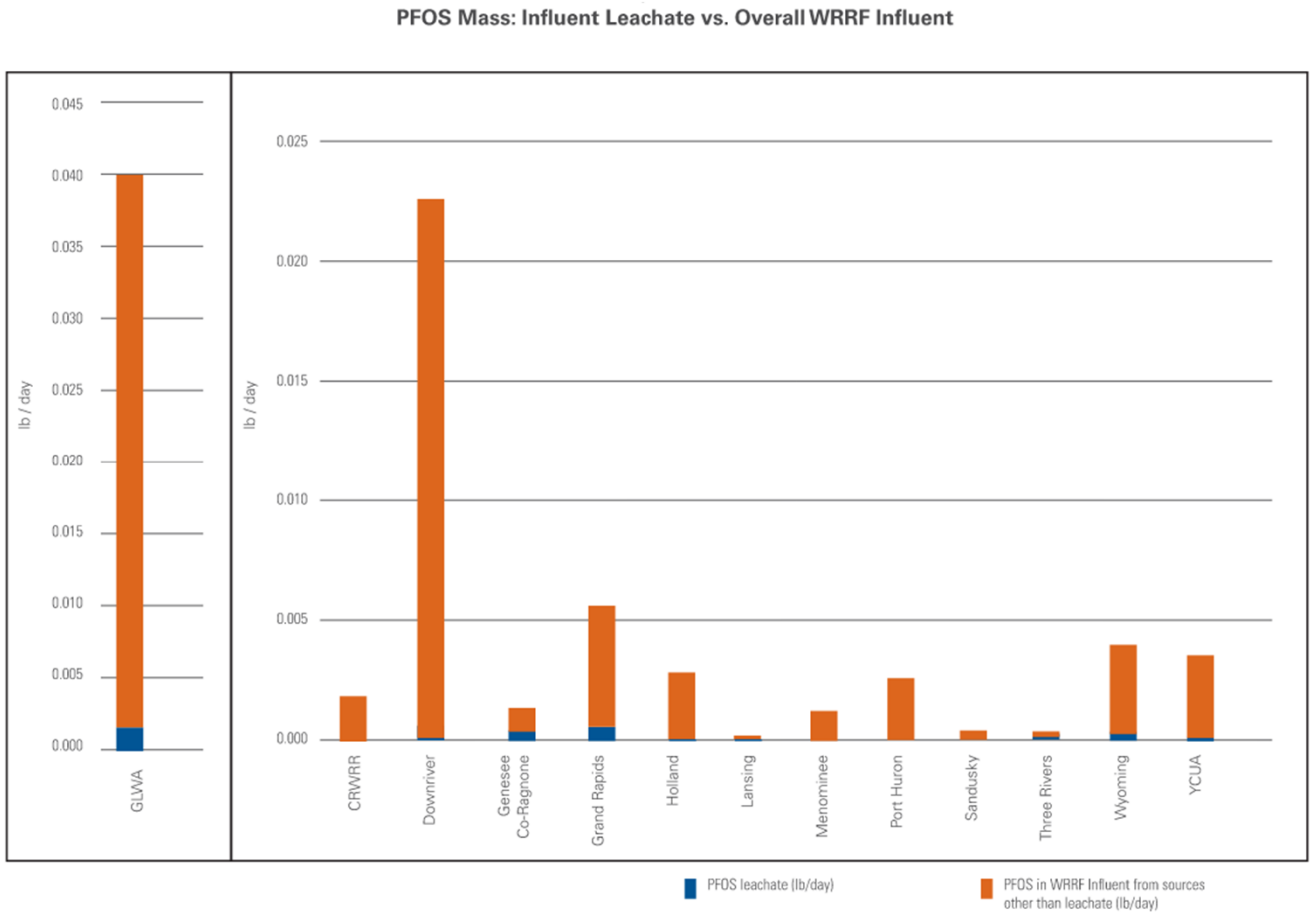
- 18 Landfills
- 95 Samples
- 70 PFAS Compounds

Group 1 Compounds (Detected in 50% of Samples)		
PFBA	3:3 FTCA	MeFBSAA
PFPeA	5:3 FTCA	MeFPeSAA
PFHxA	7:3 FTCA	MeFHxSAA
PFHpA	PFBS	MeFHpSAA
PFOA	PFPS	MeFOSAA
PFNA	6:2 FTSA	EtFPeSAA
PFDA	PFHxS	EtFHxSAA
6:2 FTCA	PFOS	EtFOSAA
8:2 FTCA	8:2 FTSA	

Lang, Johnsie R., et al. "National estimate of per-and polyfluoroalkyl substance (PFAS) release to US municipal landfill leachate." Environmental science & technology 51.4 (2017): 2197-2205.

Leachate PFAS Contribution to POTW Influents

Michigan Data For PFOS



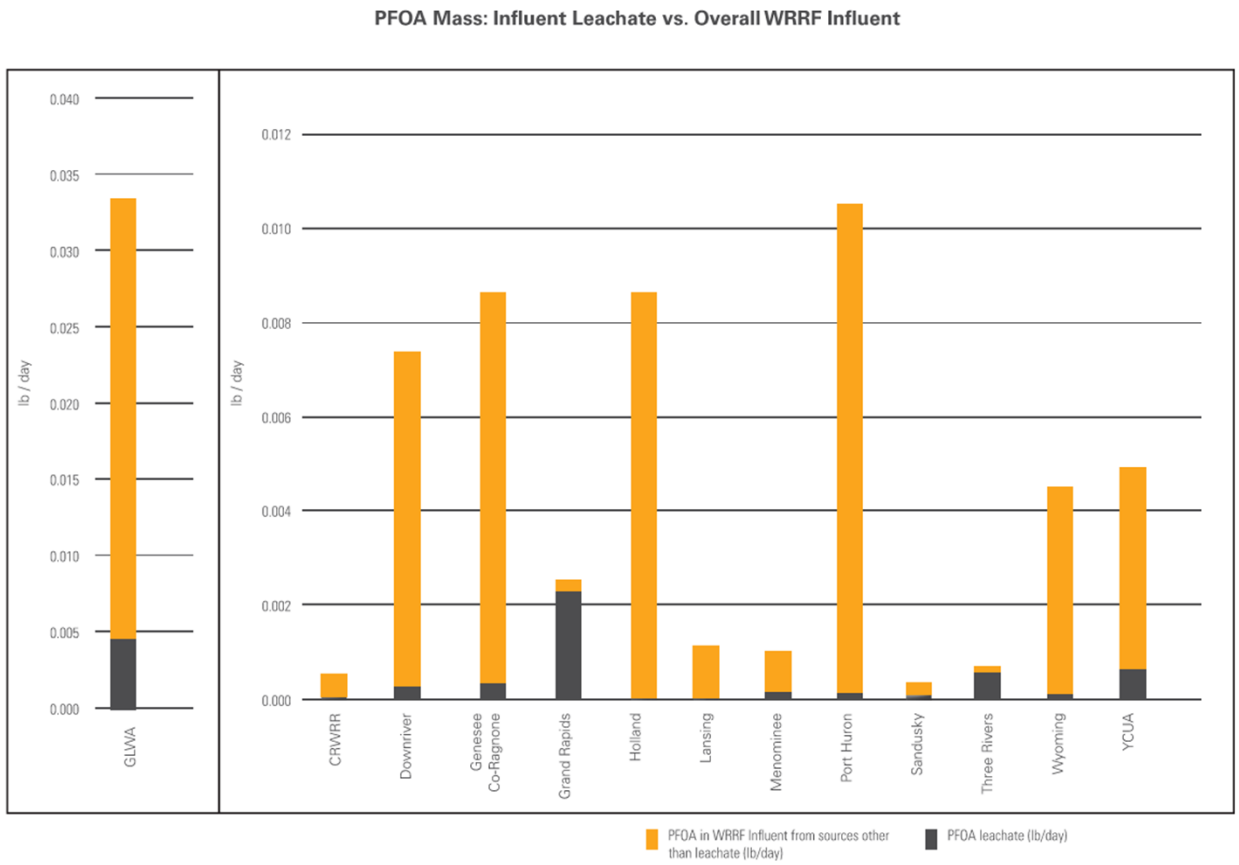
Michigan Waste & Recycling Association, Statewide Study on Landfill Leachate PFOA and PFOS Levels and Relative Influence on WRRF Influent, Technical Report, Mar 2019

Leachate PFAS Contribution to POTW Influents

Michigan Data For PFOA

"The data collected during this study indicate that leachate provides a relatively minor contribution to the overall PFOA and PFOS concentration in most WRRF influent; non-leachate sources of PFOA and PFOS contribute greater mass to WRRF influent than leachate.

Michigan Waste & Recycling Association, Statewide Study on Landfill Leachate PFOA and PFOS Levels and Relative Influence on WRRF Influent, Technical Report, Mar 2019



PFAS Fate and Transport in a POTW

Physical partitioning

The unique biological and chemical stability of PFAS makes them difficult to be removed through conventional wastewater treatment processes. Instead, PFAS are partitioned into biosolids during wastewater treatment.

Chemical transformation

In the meantime, some polyfluorinated precursor compounds can transform into shorter-chain perfluorinated compounds (e.g., PFOS and PFOA) via conventional wastewater treatment processes.

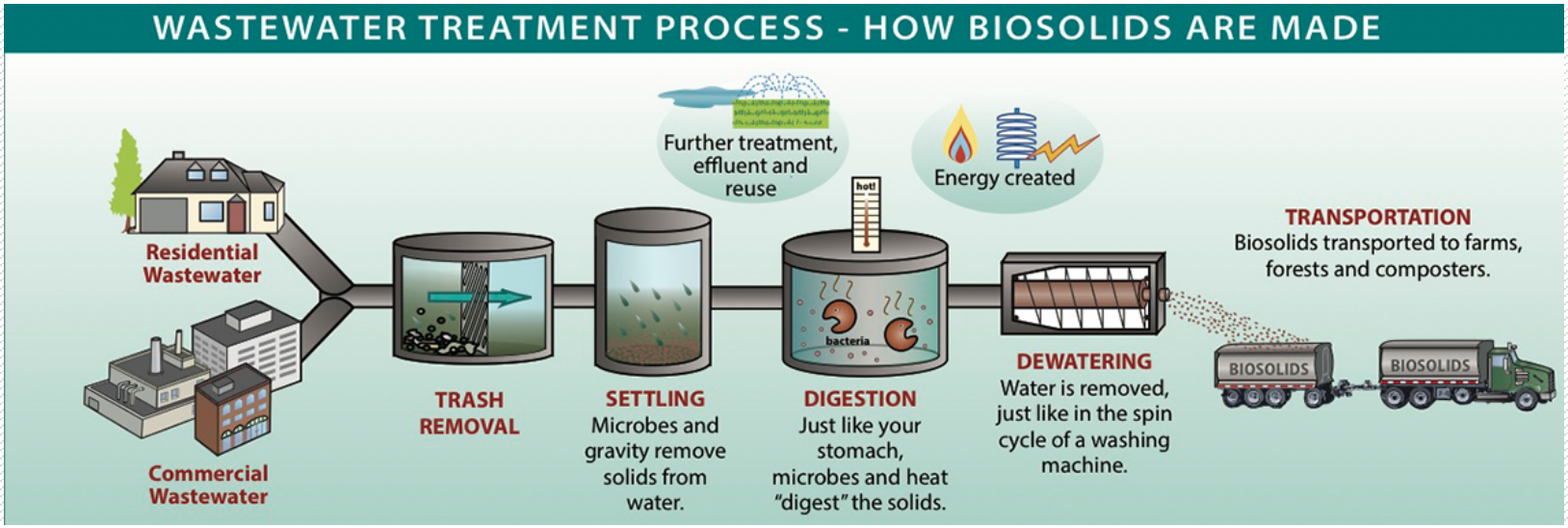


Figure by Northwest Biosolids

Summary of PFAS in Wastewater Influents and Effluents

1

Ubiquity and persistence of PFAS in the environment ensure **PFAS loading to WWTPs over the long-term** → PFOA and PFOS are the most **ubiquitous** but **not necessarily** the most **abundant**

2

Leachate composition likely reflects consumer products and has a similar PFAS profile to WWTP influent

3

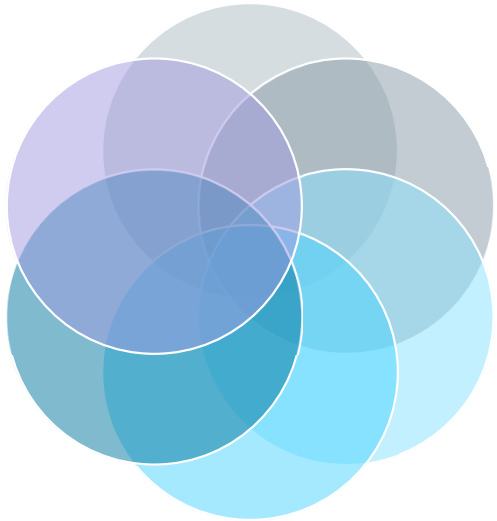
Polyfluorinated precursors in fluorotelomer-based surfactants and polymers can degrade into PFAAs

4

PFAS removal by conventional wastewater treatment is **negligible**
Most removal is assumed to be through **partitioning to wastewater solids**

5

WWTP sludge composition suggest a small contribution to leachate PFAS



USGS Study of Three Landfill-POTW Systems

- 73 PFAS Compounds
- Analyzed Leachate, POTW Influent, POTW Effluent

System	Leachate Flow Contribution to POTW	Leachate Total PFAS Load to POTW
A	0.095%	1.0% (10X)
B	0.24%	3.5% (14X)
C	11.7%	167% (14X)

Masoner, Jason R., et al. "Landfill leachate contributes per-/poly-fluoroalkyl substances (PFAS) and pharmaceuticals to municipal wastewater." Environmental Science: Water Research & Technology 6.5 (2020): 1300-1311.

USGS Study | Top PFAS Compounds in Leachate

Compound	System A	System B	System C
PFHxA	4,200 (4.7%)	8,300 (4.3%)	3,600 (420%)
FPePA (3:3 FTCA)	2,800 (8.8%)	4,600 (6.6%)	1,200 (250%)
FHEA (6:2 FTCA, 6:2 FTA)	2,400 (ND)	<25 (ND)	<25 (ND)
MeFBSAA	2,400 (4.6%)	3,700 (2.7%)	650 (120%)
PFBS	1,600 (12%)	1,900 (3.9%)	2,200 (800%)
PFHpA	1,400 (2.5%)	6,500 (4.5%)	2,300 (430%)
6:2 FtS	1,200 (0.2%)	220 (2.1%)	240 (48%)
FOEA	960 (ND)	600 (ND)	<25 (ND)
PFHxS	720 (6.2%)	4,100 (6.6%)	1,200 (1,000%)
MeFPeSAA	680 (ND)	7,600 (ND)	790 (190%)
PFOA	370 (0.3%)	4,800 (0.8%)	3,700 (55%)
PFOS	360 (ND)	890 (3.3%)	860 (460%)
MeFOSAA	230	920	140
EtFPeSAA	120 (ND)	930 (ND)	72 (ND)
PFDA	110 (ND)	120 (ND)	600 (390%)
5:3 PFPeA	<10 (ND)	2,000 (ND)	1,400 (ND)

- Concentrations in ng/L
- Values in parentheses are the % mass load contribution to POTW influent
- ND signifies compound not present in POTW influent sample
- Table sorted by System A descending concentrations
- Blue shaded values are the top 5 compound for the corresponding landfill
- PFNA not a top compound

USGS Study | Top PFAS Compounds in POTW Influent

Compound	System A	System B	System C
PFOA	1,100	1,400	790
6:2 FTS	740	25	58
PFHxA	85	470	100
6:2 diPAP	79	63	<50
PFUdA	62	<10	<10
PFHpA	54	350	62
MeFBSAA	49	330	63
FPePA (3:3 FTCA)	30	170	56
8:2 diPAP	26	30	35
FHUEA	17	<25	<25
PFBS	13	120	32
PFHxS	11	150	14
PFOS	<10	66	22
MeFHxSAA	<10	58	<10
MeFPeSAA	<10	<10	48

- Concentrations in ng/L
- Purple shaded compound values not detected in corresponding leachate
- Green shaded compound values outside the top 10 leachate compounds
- Table sorted by System A descending concentrations
- PFNA <10 ng/L

USGS Study | Top PFAS Compounds in POTW Effluent

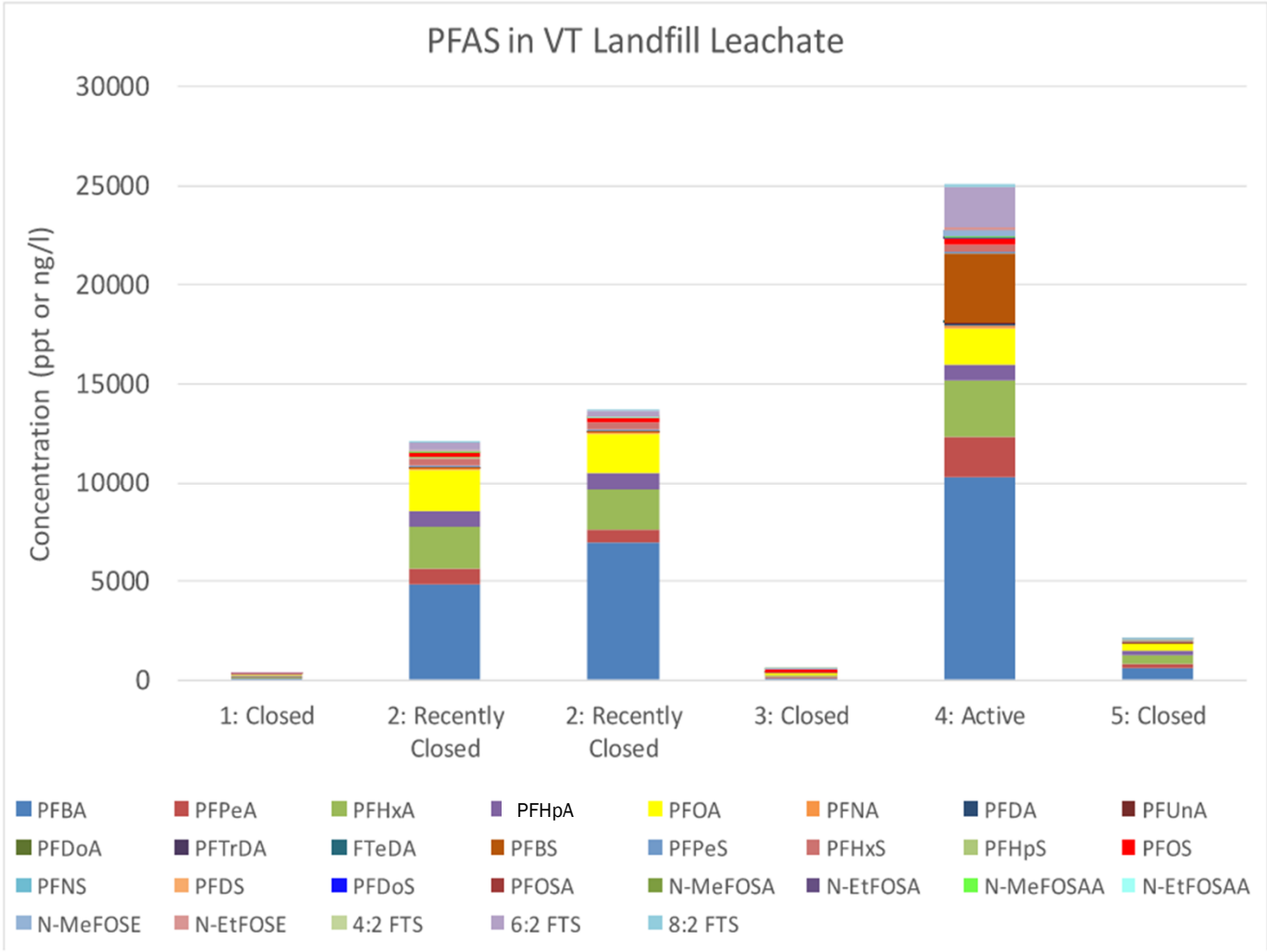
Compound	System A	System B	System C
PFOA	1,150 (5%)	1,200	740
PFHxA	120	260	84
PFPeA	88	<10	120
PFHpA	63 (17%)	200	43
MeFBSAA	55 (12%)	53	<10
8:2 diPAP	24	<10	<10
PFDA	21	<10	<10
PFBS	21 (62%)	51	54 (69%)
6:2 FtS	20	<10	<10
8:2/10:2 diPAP	13	<10	<10
PFHxS	10	54	29 (107%)

PFOS, PFNA <10 ng/L in all three effluents

- Concentrations in ng/L
- Purple shaded compound values not detected in corresponding influent
- Orange shaded compound values higher than corresponding influent (percent increase in parentheses)
- Table sorted by System A descending concentrations

Top PFAS Compounds

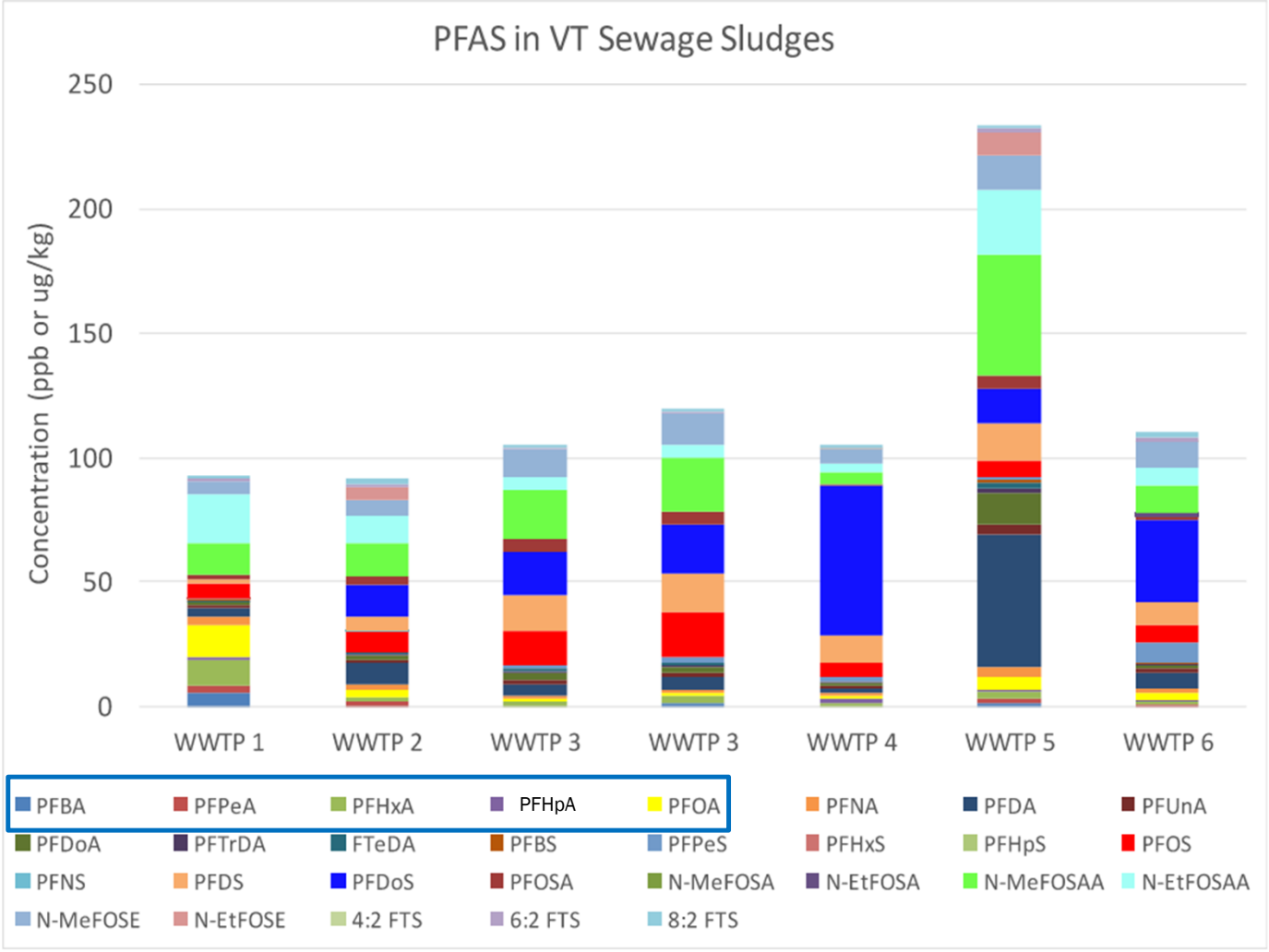
- PFBA
- PFPeA
- PFHxA
- PFHpA
- PFOA



Courtesy Stephen Zemba, 2019, Sanborn, Head and Associates. Inc.

Each POTW has landfill leachate as an influent source.

The prevalent leachate compounds are not prevalent biosolids compounds (PFBA, PFPeA, PFHxA, PFHbA, PFOA)



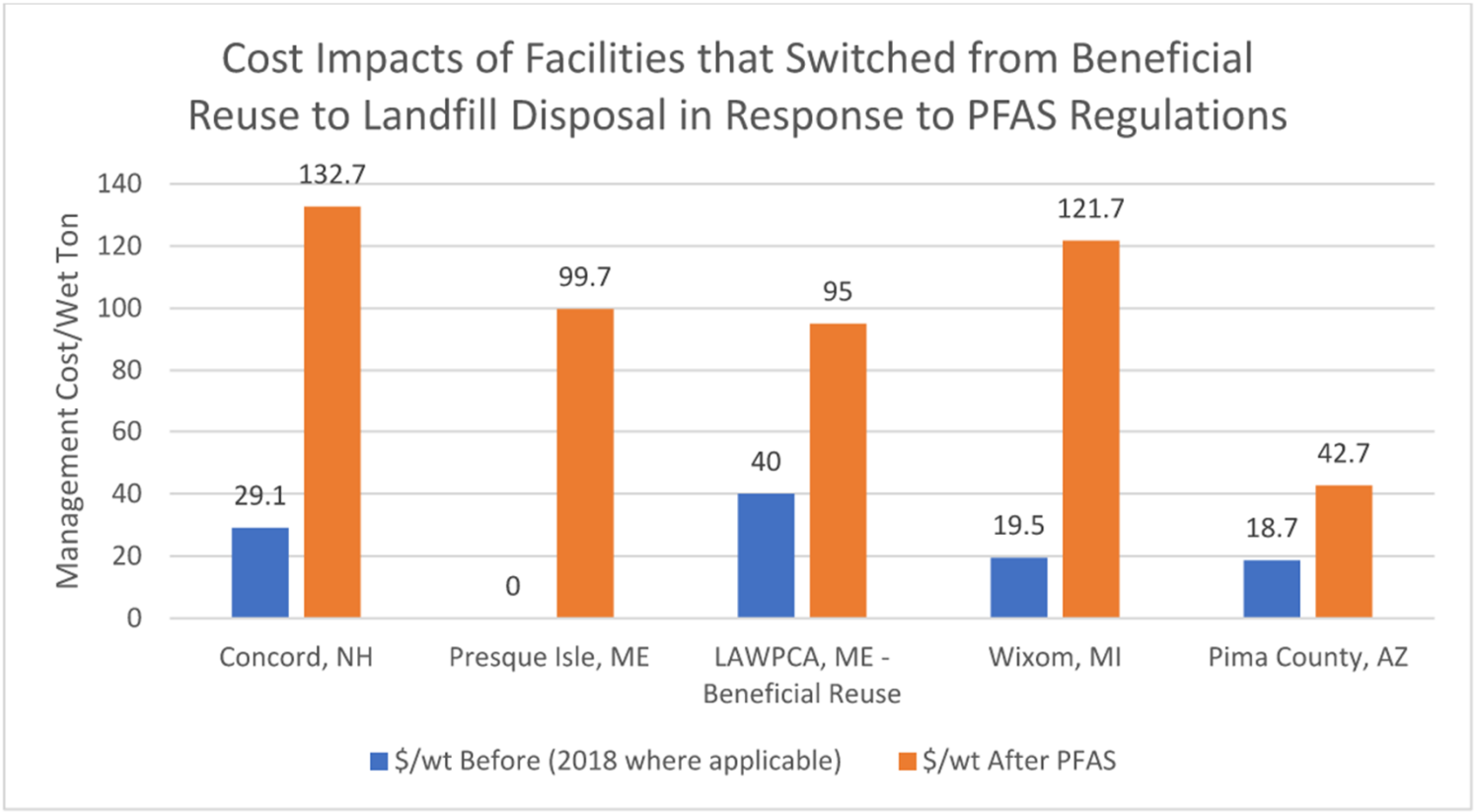
Courtesy Stephen Zemba, 2019, Sanborn, Head and Associates. Inc.

Landfill Acceptance of POTW Biosolids

- PFAS concerns with land application and incineration of biosolids is pushing more POTWs to landfill disposal
- Landfill capacity is limited in some regions
- The amount of biosolids that can be received at a given landfill may be constrained by the physical characteristics
- Landfill operators are concerned with the PFAS content of the biosolids and leachate quality impacts

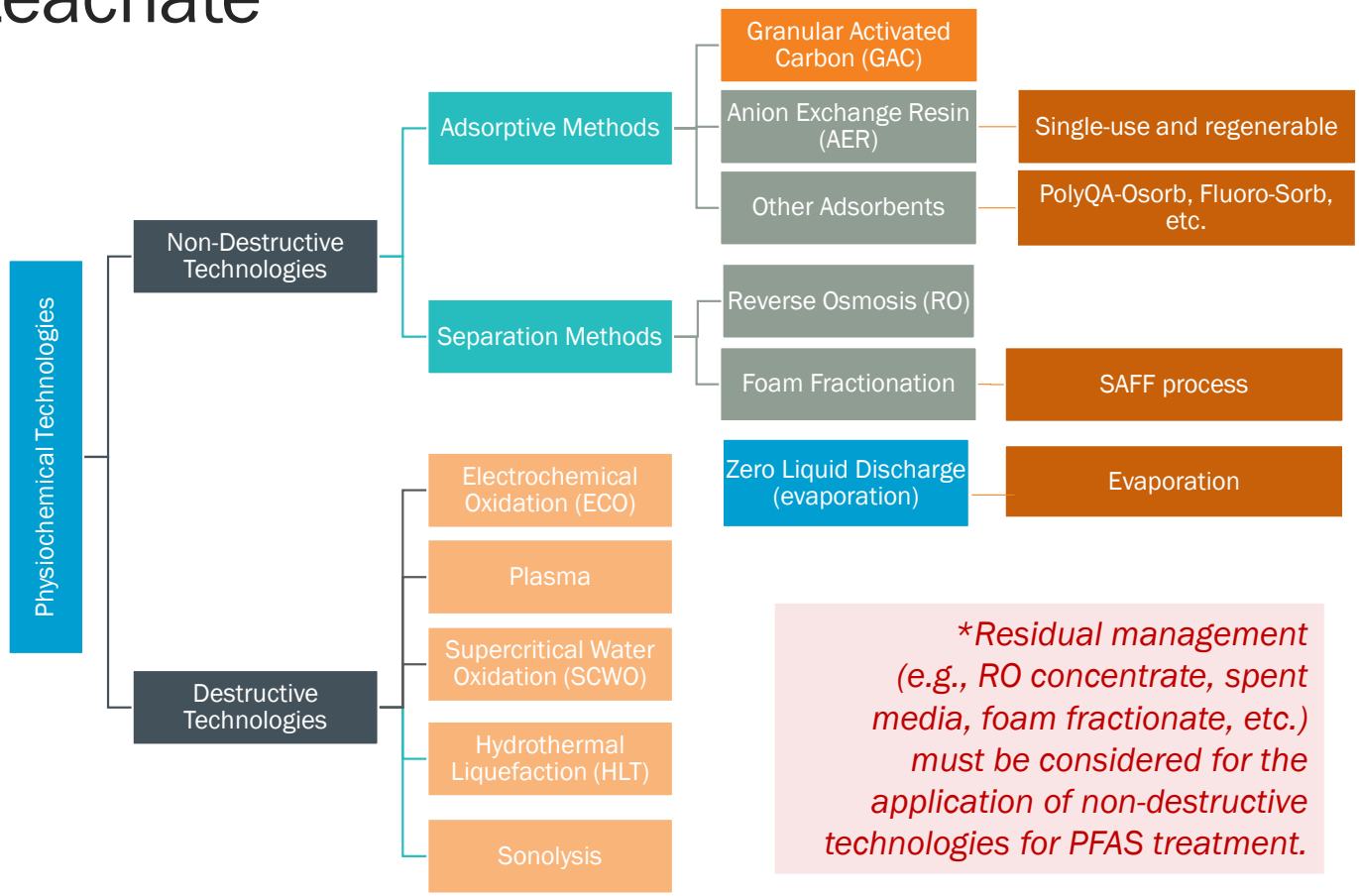
Adapted from "PFAS in Wastewater, Biosolids and Implications for Solid Waste Management," Ned Beecher, NEBRA, EBC New England, Nov 2019

Cost Impacts of Landfilling Biosolids



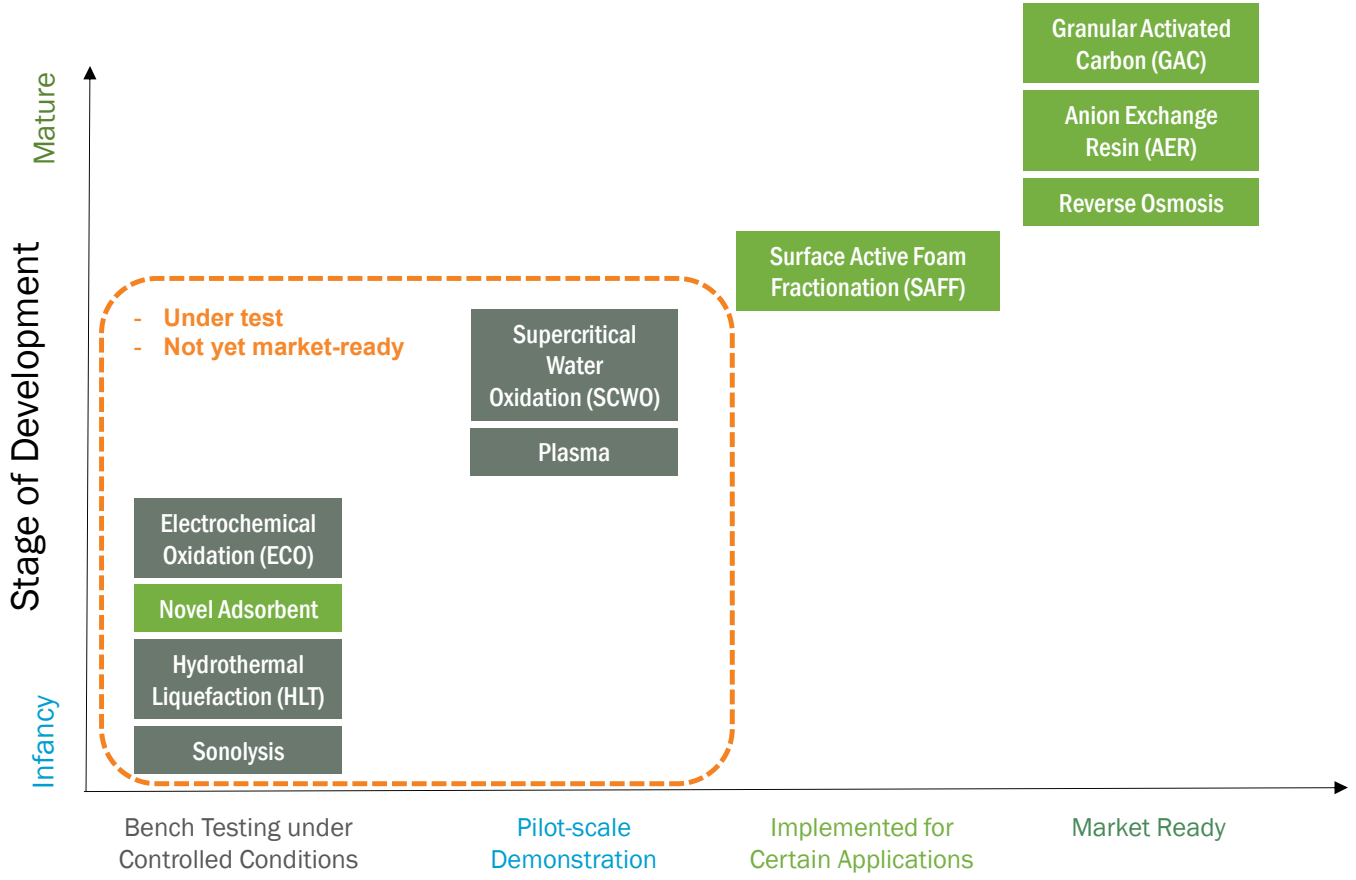
Cost Analysis of the Impacts on Municipal Utilities and Biosolids Management to Address PFAS Contamination, CDM Smith, Oct 2020

Non-Destructive and Destructive Treatment Technologies for Landfill Leachate

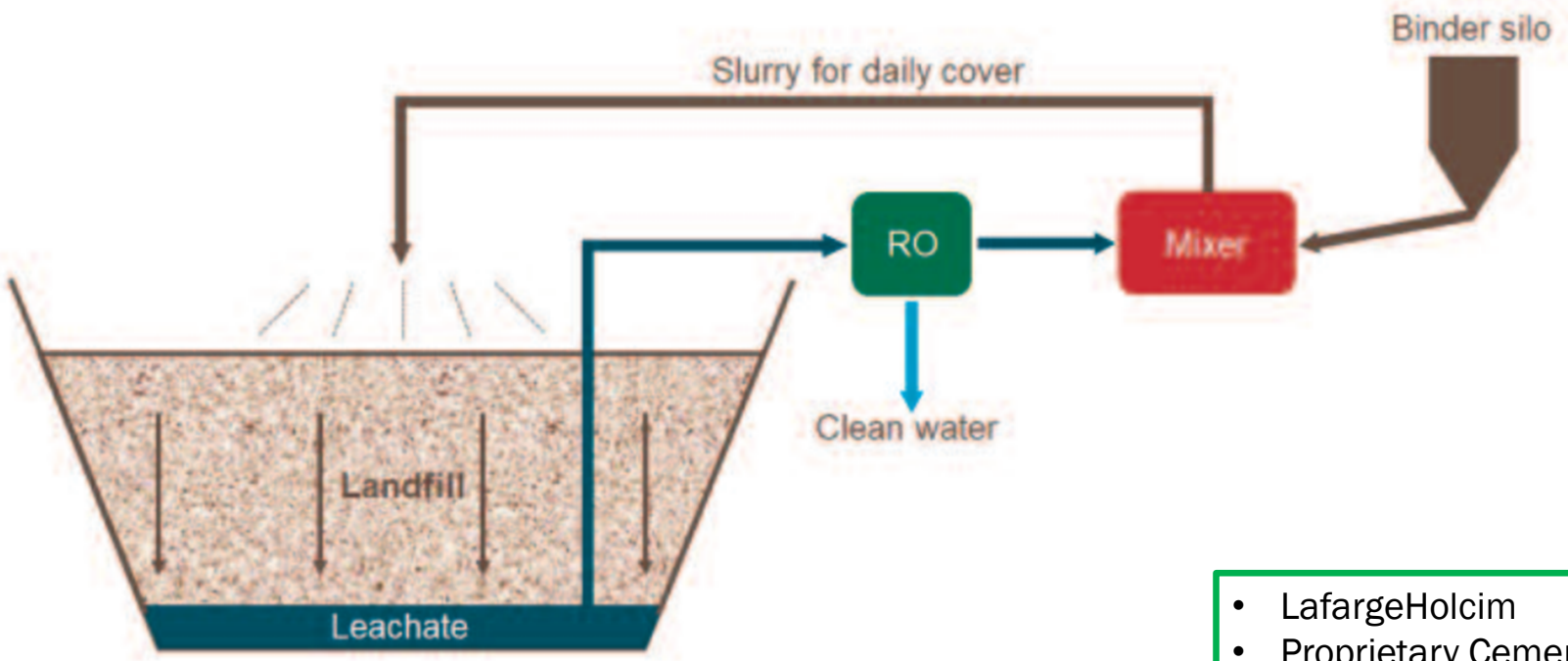


**Residual management (e.g., RO concentrate, spent media, foam fractionate, etc.) must be considered for the application of non-destructive technologies for PFAS treatment.*

Destructive Technologies Are Not Mature Yet



Immobilization of Leachate Concentrate



- LafargeHolcim
- Proprietary Cement Binder

Vermont Landfill Case Study

VERMONT PFAS INVESTIGATION AND RESPONSE

The Vermont Agency of Natural Resources is working with the Vermont Department of Health to continue to identify sources and reduce the use, release and public exposure of per and polyfluoroalkyl substances (PFAS) in Vermont.

Studies and Reports

- Poly- and Perfluoroalkyl Substances Inputs to Wastewater Treatment Facilities (2022) Weston & Sampson
- Review of Conceptual Leachate Treatment Scoping Study New England Waste Services of Vermont (NEWSVT) (2020) Civil & Environmental Consultants, prepared for Vermont DEC.
- Poly- and Perfluoroalkyl Substances at Wastewater Treatment Facilities and Landfill Leachate (2020) Weston & Sampson
- PFAS Waste Source Testing Report for New England Waste Services of Vermont (2019) Sanborn Head & Associates
- Conceptual Leachate Treatment Scoping Study for New England Waste Services of Vermont (NEWSVT) Landfill (2019) Brown and Caldwell
- PFAS Background in Vermont Shallow Soils (2019) University of Vermont, Sanborn Head & Associates

Press Releases

- Department of Environmental Conservation Releases Reports on PFAS Chemicals (2020)

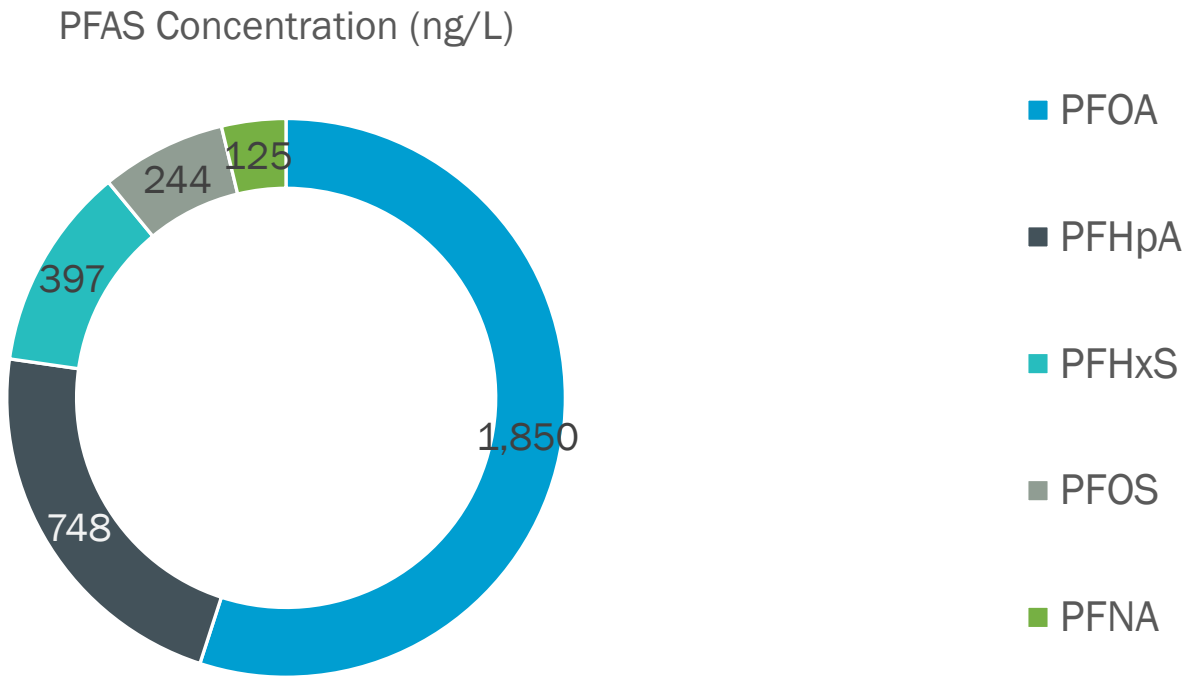
Fact Sheets

- General Information on PFAS Factsheet
- The Act 21 PFAS Law Factsheet
- The Department of Health PFAS and Drinking Water Factsheet
- The Drinking Water Testing for Well Owners Factsheet
- The Department of Health Drinking Water Testing Factsheet
- Interstate Technology & Regulatory Council (ITRC) PFAS Factsheets

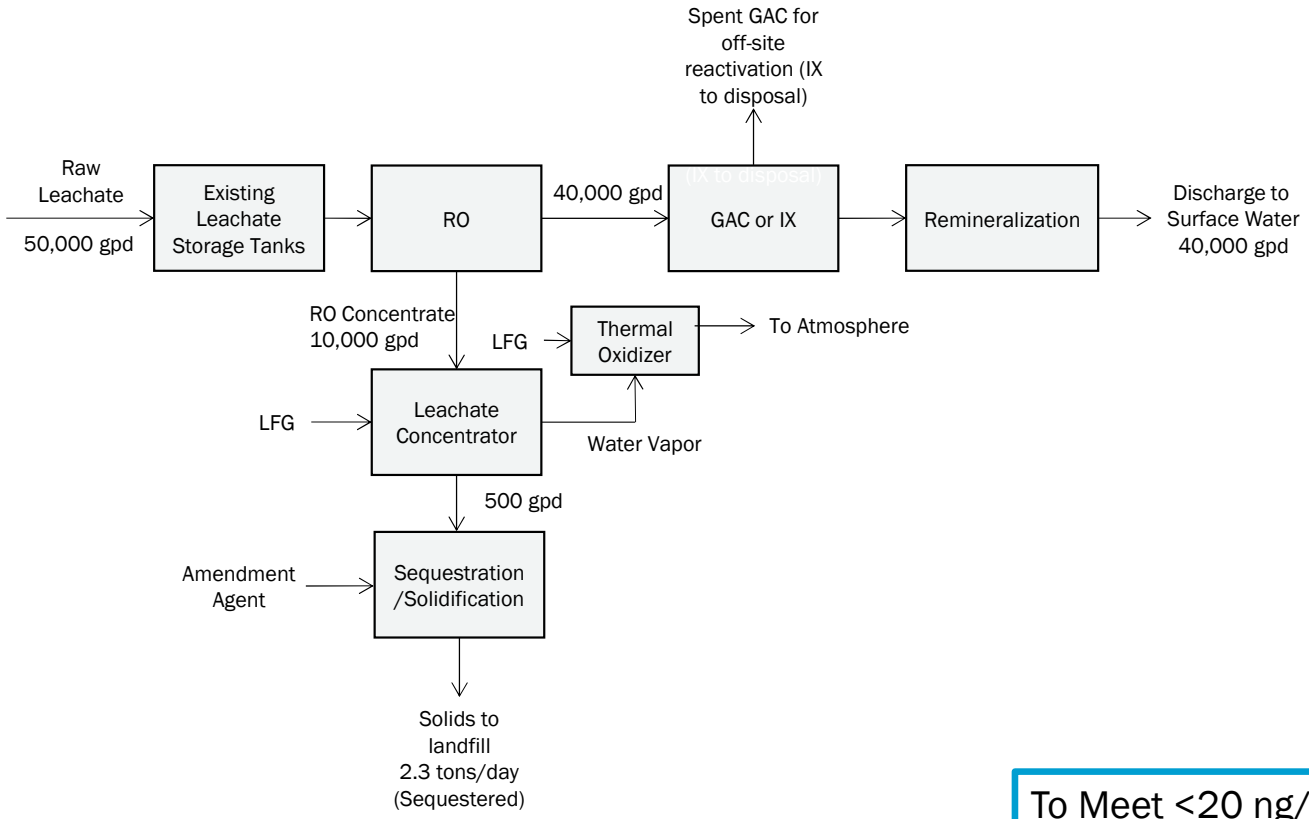
https://dec.vermont.gov/pfas

VT Case Study Raw Leachate (VT5 Compounds)

>99.4% PFAS removal required to meet direct discharge standard (<20 ng/L)



Example: Direct Discharge Leachate Treatment



To Meet <20 ng/L “VT 5” PFAS Limit

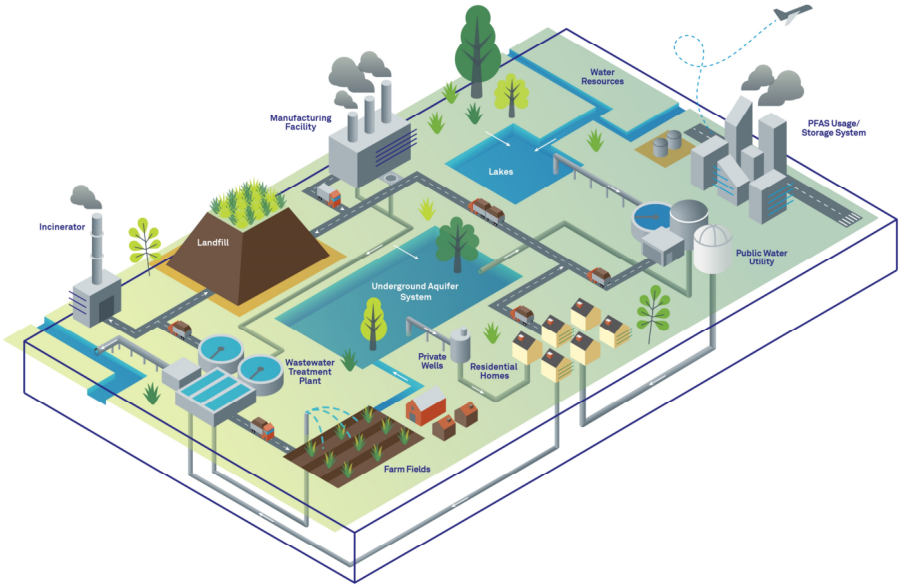
Leachate PFAS Treatment Costs

Technology	% PFAS Removal	Residuals Management	Capacity (gpd)	CAPEX ($)	Annual OPEX ($/yr)	OPEX Only ($/gal)
Standalone 3 Stage RO+Evap	>99	Evap+Off-site (deep well)	50,000	13,700,000	4,015,000	0.22
	>99	Evap+Solidification	50,000	14,200,000	2,190,000	0.12
	>99	On-site Solidification	85,000	12,000,000	4,033,250	0.13
	>99	Deep well	100,000	14,800,000	5,100,000	0.28
Standalone 3 Stage RO	>99	Foam Fractionation+Solidification	50,000	10,200,000	2,030,000	0.11
MBR+GAC+IX	50	Regen/Disposal	50,000	7,800,000	1,200,000	0.07
MBR+Conventional RO	>99	Off-site Solidification	100,000	19,700,000	9,700,000	0.53
Evaporation (ZLD) No LFG	100	On-site Solidification	50,000	10,300,000	7,070,000	0.39
Evaporation (ZLD) W/ LFG	100	On-site Solidification	50,000	6,600,000	3,900,000	0.21
Foam Fractionation	98	Evap+Off-site (deep well)	50,000	4,100,000	537,000	0.043

- OPEX costs do not include POTW disposal costs
- Typical POTW disposal fees are low (e.g.,<$0.01-0.02/gallon)
- PFAS residuals management may be 20-30% or more of OPEX

Landfill/POTW Interaction and Social Responsibility: Challenge and Opportunity

- Mutual dependency
- Leachate is a small contributor of PFAS in most cases
- Both are “end of the line” managers of consumer wastes
- Both are tasked as protectors of human health and the environment
- One study concluded landfills may sequester >98% of PFOS that is disposed
- Should be viewed as a couplet rather than individually regarding PFAS
- POTWs should consider employing mass-based limits that are allocated based on technology and cost considerations and to reflect landfill’s role as society’s primary PFAS waste repository and to limit impacts to residents



Thank you.
Questions?

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