PFAS in Biosolids:
Navigating a Rapidly Evolving Landscape

What happens **NEXT** is happening **NOW**.

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April 15, 2026

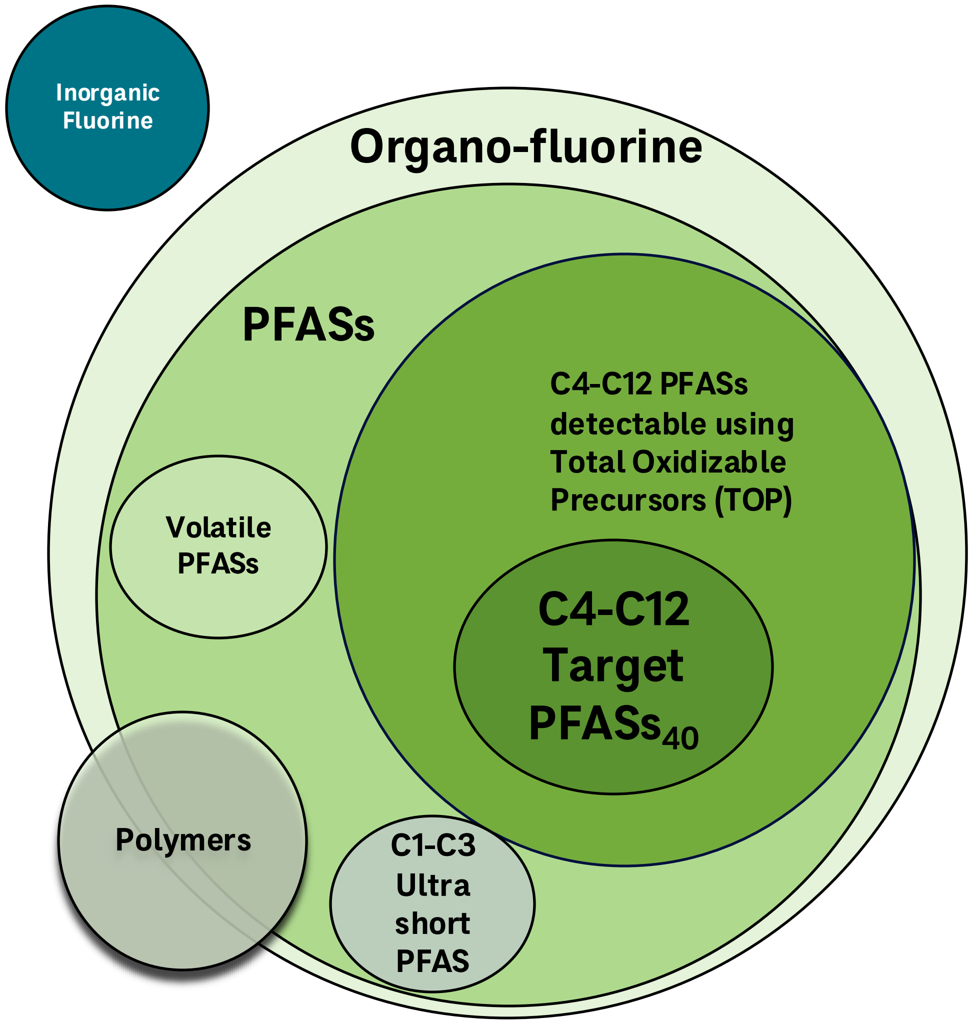
CDM Smith

Agenda

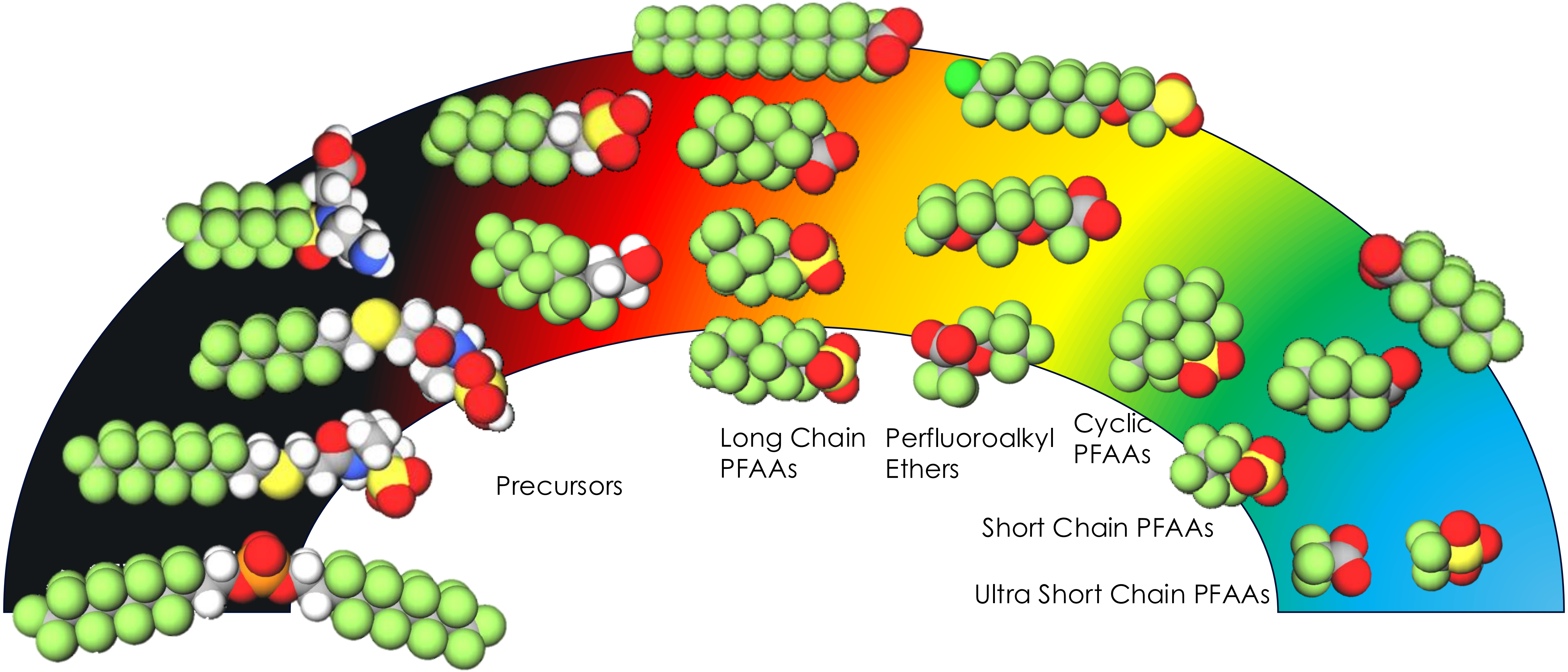
1. Introduction
2. EPA Risk Assessment
3. Current Biosolids Management Practices
4. Regulations in the US
5. Impacts of Regulations
6. Advanced treatment
7. Research
8. Conclusions

PFASs Terminology

- PFASs – whole class
  - Defined by Buck et al. 2011, previously PFCs
  - OECD Definition 7 million compounds
  - USEPA Definition 15,000 compounds
- PFOS – perfluorooctane sulfonate
- PFOA – perfluorooctanoic acid
- Which PFASs are:
  - Currently Regulated
  - Detectable
  - May be regulated in future
  - Pose an unacceptable risk?



Source: Smith, S. J., et al., 2024. The Need to Include a Fluorine Mass Balance in the Development of Effective Technologies for PFAS Destruction. Environmental Science & Technology. 58, 2587-2590.



Broad Spectrum of PFAS

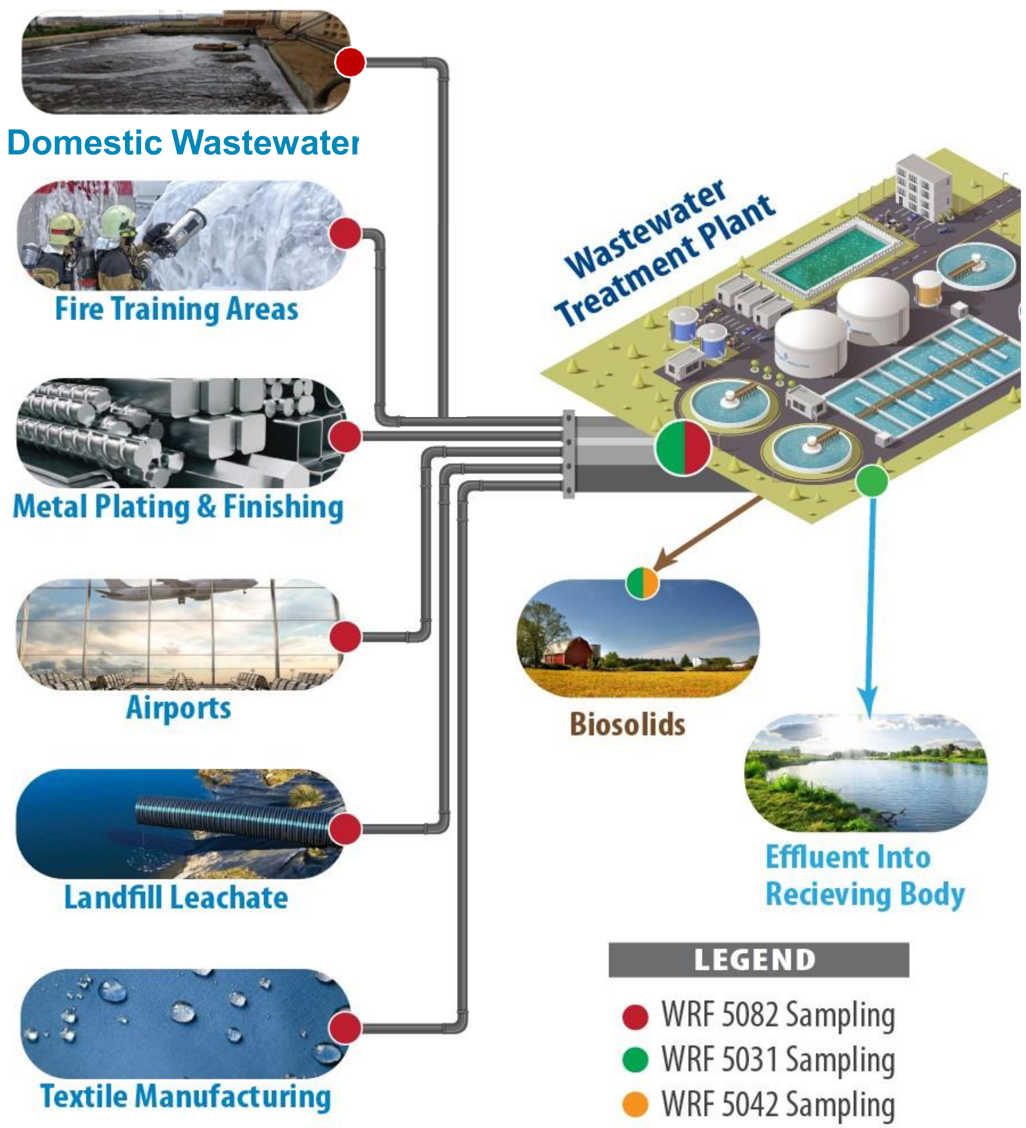
PFAS in regular things...

Media	Concentration	Citation
Dust in your home	523,000 parts per trillion	Wu, Y., K. Romanak, T. Bruton, A. Blum and M. Venier. 2020. Per- and polyfluoroalkyl substances in paired dust and carpets from childcare centers. Chemosphere 251:126771.
Lipstick	216,000 to 1,560,000 parts per trillion	Whitehead, H.D., M.Venier, Y. Wu et al. 2021. Fluorinated Compounds in North American Cosmetics. Environ. Sci. Tech. Letters 8:7:538-544.
Take-out food packaging	7,000,000 to 876,000,000 parts per trillion	Loria, K. 2022. Dangerous PFAS Chemicals Are in Your Food Packaging. Consumer Reports, March 2022.
Dog Poop	85,000 +/- 94,500 parts per trillion	Ma, J. H. Zhu, K. Kannan. 2020. Fecal Excretion of Perfluoroalkyl and Polyfluoroalkyl Substances in Pets from New York State, United States. Environ. Sci. Tech. Letters 7:3:135-142.
YOUR Poop	86.9 parts per trillion	Moodie, D., T. Coggan, K. Berry, A. Kolobaric et al. 2021. Legacy and emerging per- and polyfluoroalkyl substances (PFASs) in Australian biosolids. Chemosphere 270:129143.
Contact Lenses	106,000,000 to 20,700,000,000 part per trillion (!!)	https://www.mamavation.com/health/pfas-contact-lenses.html
Pacemakers and Other Medical Devices	Widely variable	Glüge J , Scheringer M , Cousins IT , DeWitt JC , Goldenman G , Herzke D, Lohmann R , Ng CA , Trier X , Wang Z . An overview of the uses of per- and polyfluoroalkyl substances (PFAS). Environ Sci Process Impacts. 2020 Dec 1;22(12):2345-2373

Adapted from: Brown, S. Connections: Facts Versus Fear Mongering, BioCycle, Sept 3, 2024

PFASs Sources to Wastewater

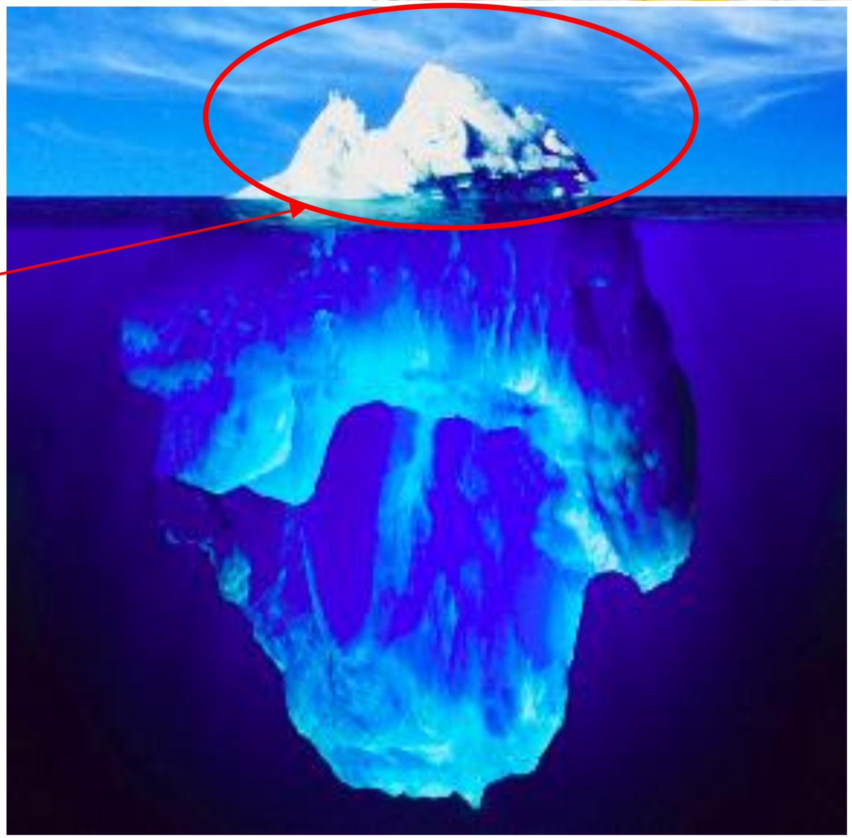
- Short-/long-chained PFAS and PFAA precursors are widely detected in wastewater.
- Conventional treatment processes do not remove PFAS:
  - PFAA precursors accumulate in biosolids.
  - PFAS concentrations in WW effluent > WW influent.
- Domestic wastewater is a major source of PFAS mass loading.



Laboratory Analysis

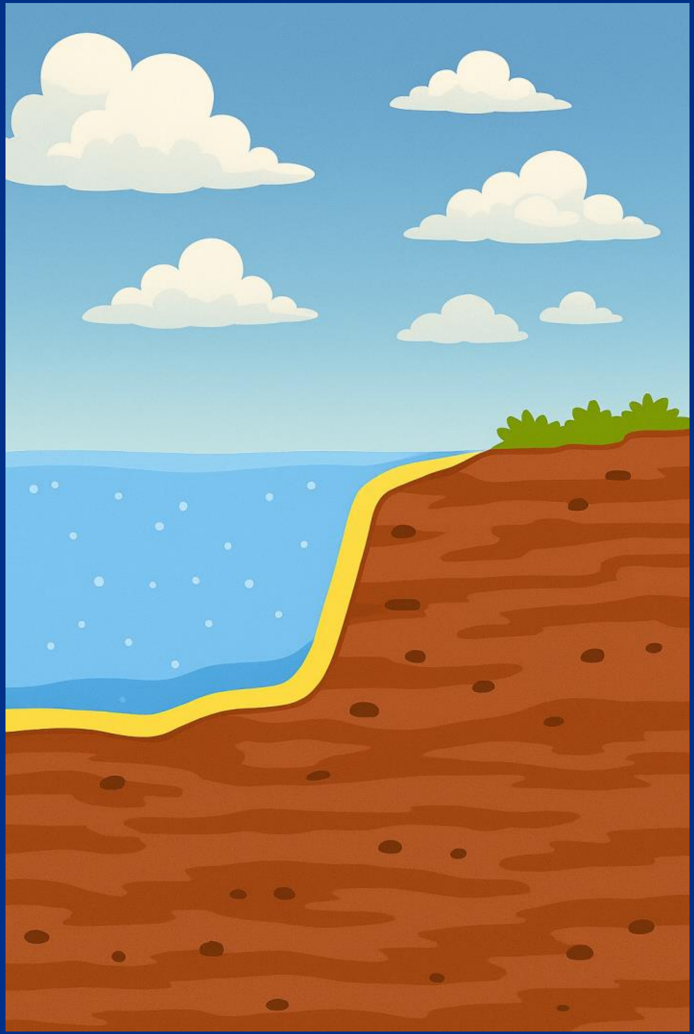
Targeted Analysis

- USEPA Modified Method 537.1
  - 18 PFAS (12 PFAAs + 6 Other PFAS Including GenX)
- USEPA Method 533
  - 25 PFAS (16 PFAAs + 9 Other PFAS Including GenX)
  - Focuses on Short Chain
- Method 1633A for 40 PFAS
- DWI 47 PFAS



EPA Risk Assessment

Opportunities for PFAS intervention



Air

- Some point sources
- Challenging to regularly to sample, test, and regulate

Water

- WTPs and WWTPs point sources are regularly sampled and already regulated

Soil

- Amendments can be regulated

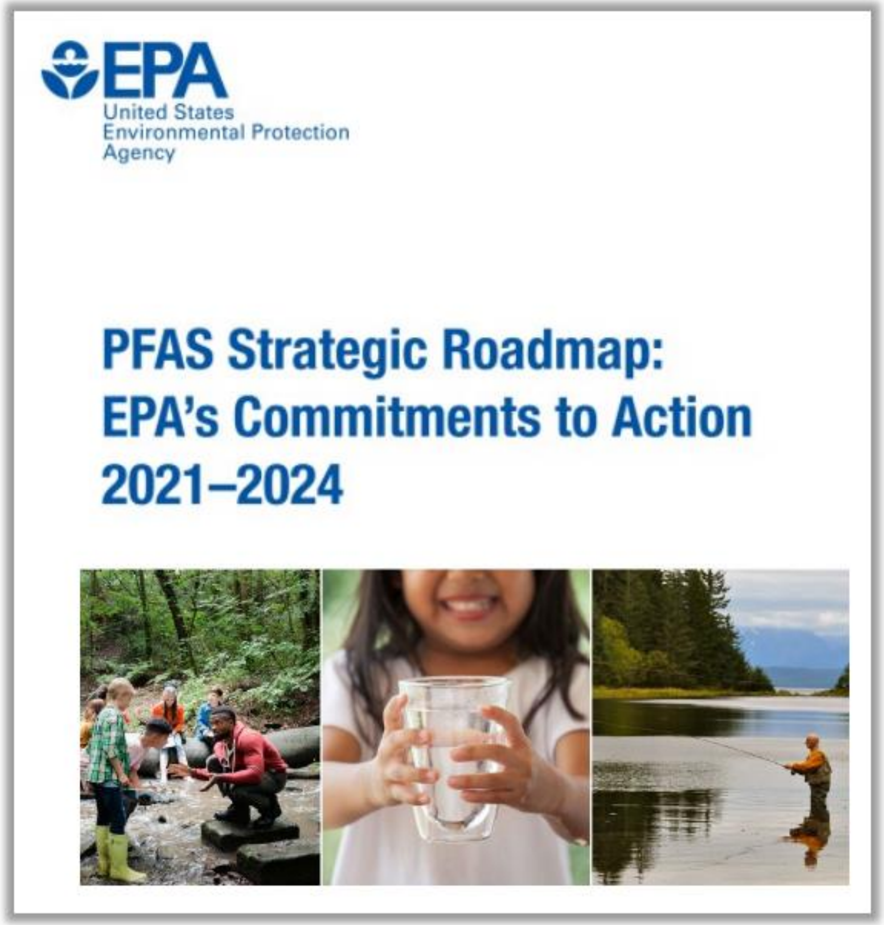
EPA PFAS roadmap for biosolids

Winter 2024: Completion of the risk assessment for PFOA and PFOS

2025-2026: Anticipated that EPA would issue a Final Rule

2026-2031: Assuming a 5-year compliance schedule

The risk assessment will serve as the basis for determining whether regulation of PFOA and PFOS in biosolids is appropriate



EPA Draft Risk Assessment for PFOA and PFOS

- Modeled using the Central Tendency Risk Assessment: assuming median (50th percentile) exposure conditions
- Biosolids Application Scenarios:
  - Farm – pasture
  - Farm – food crop
  - Land reclamation
  - Sludge monofills
- 1 ppb PFOA or PFOS at various application rates
- **Not a regulation**

Modeled Scenarios Application Rates

Scenario	Concentration of PFOA and PFOS	Application Rate	Number of Applications	Human Exposure Duration
Farm – pasture-raised livestock	1 part per billion (ppb)	10 dry metric tons (DMT) per hectare (ha)	Once annually for 40 years	10 years – cancer 1 year – noncancer
Farm – food crops (fruits and vegetables)	1 ppb	10 DMT/ha **4 dt/acre**	Once annually for 40 years	10 years – cancer 1 year – noncancer
Land reclamation sites	1 ppb	50 DMT/ha **20 dt/acre**	One application only	10 years – cancer 1 year – noncancer
Sewage sludge surface disposal sites (sewage monofills)	1 ppb	Flow rate 4x10^-6 m3/sec	Disposal site operating for 50 years	10 years – cancer 1 year – noncancer

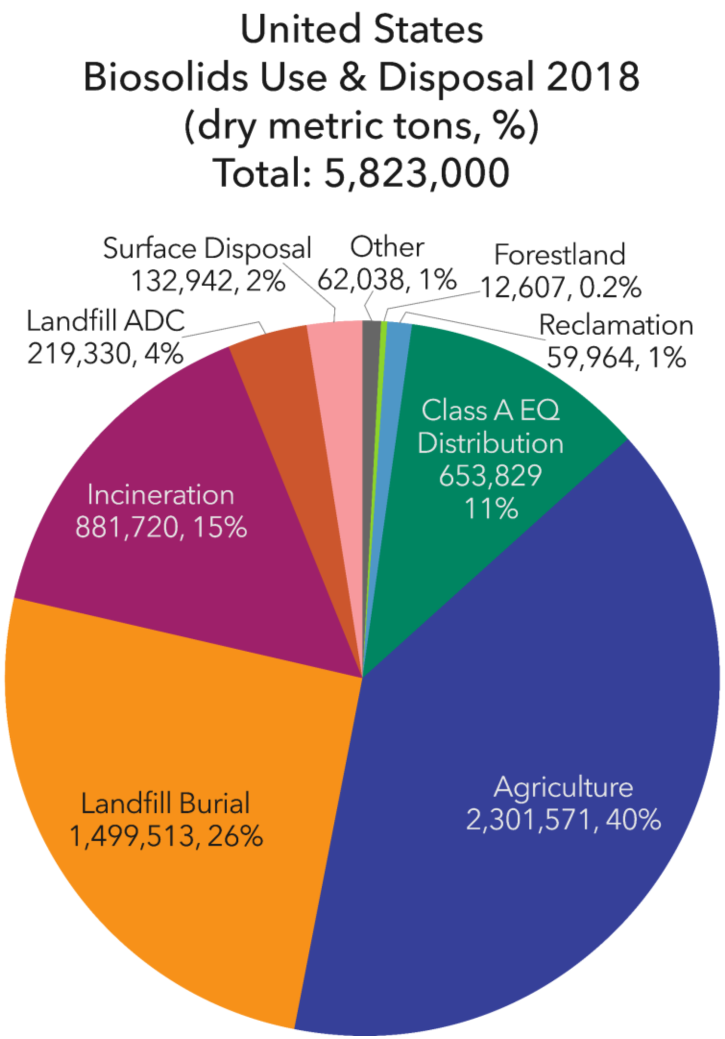
Key Take Aways

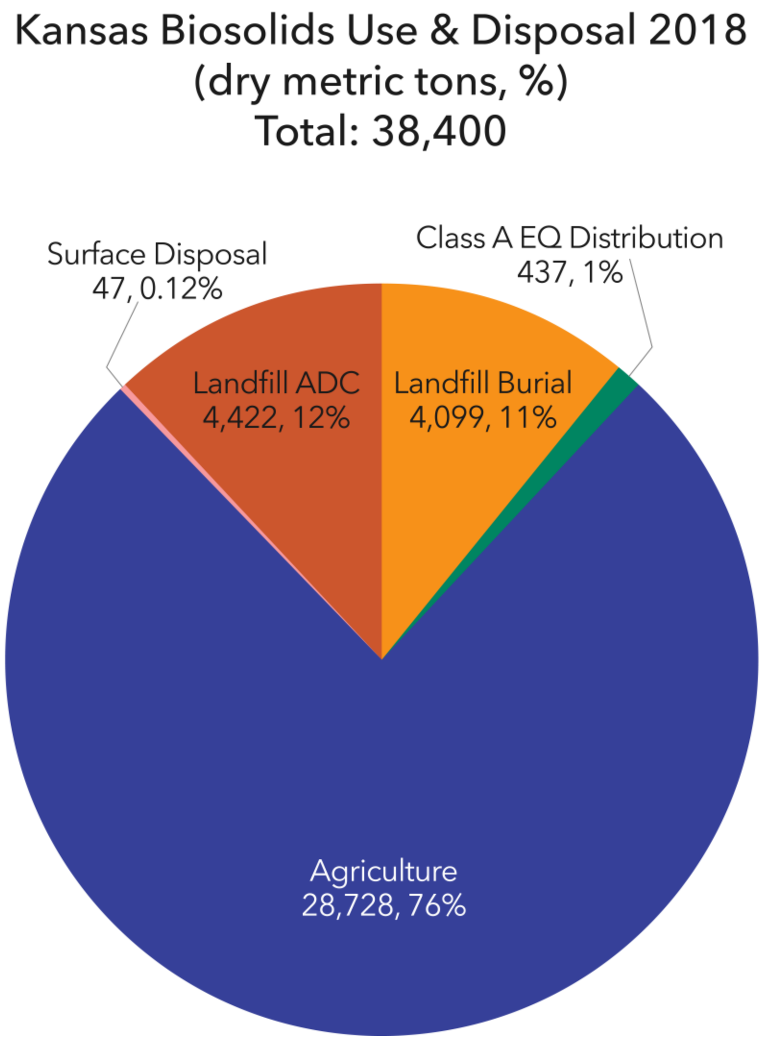
- The draft risk assessment is not a rule and does not compel any action. The comment period ended on **August 14th, 2025**.
- This risk assessment does not focus on the general public.
- Bottom line: **More data and research is needed**

- QR for the full risk assessment

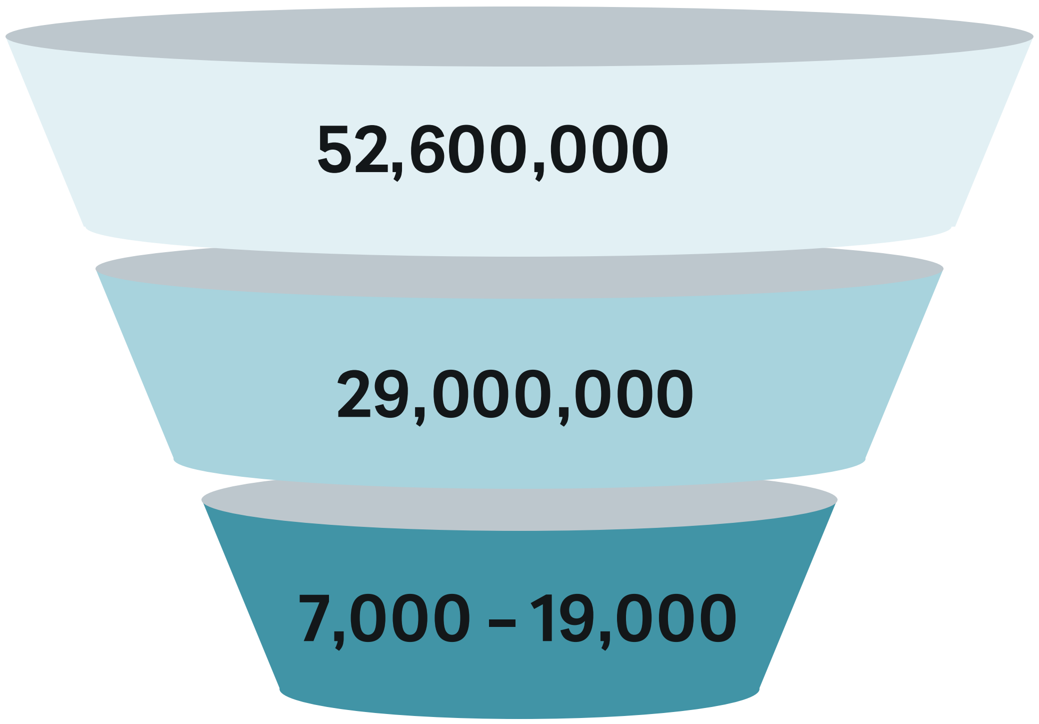
Current Biosolids Management Practices

National Biosolids Data Project (2018)





Biosolids Management – Kansas



Land area of Kansas in Acres, **100%**

Area of Crop Land in Acres, **85%**

Area of Crop Land with biosolids land application
0.1% – 0.7% of the total land area
0.2% - 0.6% of the crop land
Assuming 4 – 1.5 dt/acre application

Boisolids Management – Iowa

Year	Biosolids Applied (tons)	Total Area Applied (acres)	Average Amount per acre (tons/acre)*
2018	44,385	18,861	2.35
2019	53,813	22,708	2.37
2020	49,250	16,771	2.94
2021	40,003	16,214	2.47
2022	40,413	16,055	2.52
2023	41,294	17,138	2.41
2024	37,803	15,974	2.37

*Michigan restricts application to **1.4 dry tons per acre** for affected biosolids and the EPA risk assessment used **4 dry tons per acre.**

Regulations in the US

Federal Regulations – EPA Timeline

EPA

EPA biennial pollutant reviews under Clean Water Act (2005 – 2021)

1980s	National Sewage Sludge Survey conducted.
1993	Part 503 regulations published by EPA.
1996	First review of Part 503 focused on land application safety.
2002	Second review of Part 503 focused on public health. EPA responded with 14 step action plan.
2009	Targeted National Sewage Sludge Survey identified 145 pollutants including PFAS, metals, pharmaceuticals.
2017	Renewed EPA focus on PFAS in biosolids. Updated biosolids risk models and outreach.
2020 & 2021	National biosolids stakeholder meetings held to summarize EPA actions.
Jan 2023	ELG Plan 15 finalized for PFAS in industrial discharges and leachate.
Jan 2025	Draft Risk Assessment for PFOA & PFOS. Concluded that 1 ppb of PFOS and PFOA in biosolids may pose an unacceptable health risk to farm families.
2026 to 2027	Final risk assessment for PFAS in biosolids expected.
2028 to 2030	Proposed EPA PFAS biosolids rule anticipated.
2031 to 2033+	Anticipated compliance if PFAS rule is finalized.

??

2016 Lifetime Health Advisory: Combined 70 ppt PFOA & PFOS in Drinking Water

Regulatory Activities

Minnesota
- Tiered approach, PFOA *or* PFOS
  - >125 ppb: land application not allowed
  - 51-124 ppb: source ID and limited land application
  - 21-50 ppb: track cumulative application rates
  - <20 ppb: no restrictions

Wisconsin
- PFOA + PFOS
  - >150 ppb: land application not allowed
  - >50 ppb: source control required and limited land application
  - >20 ppb: implement source investigation and reduction efforts
  - <20 ppb: no restrictions

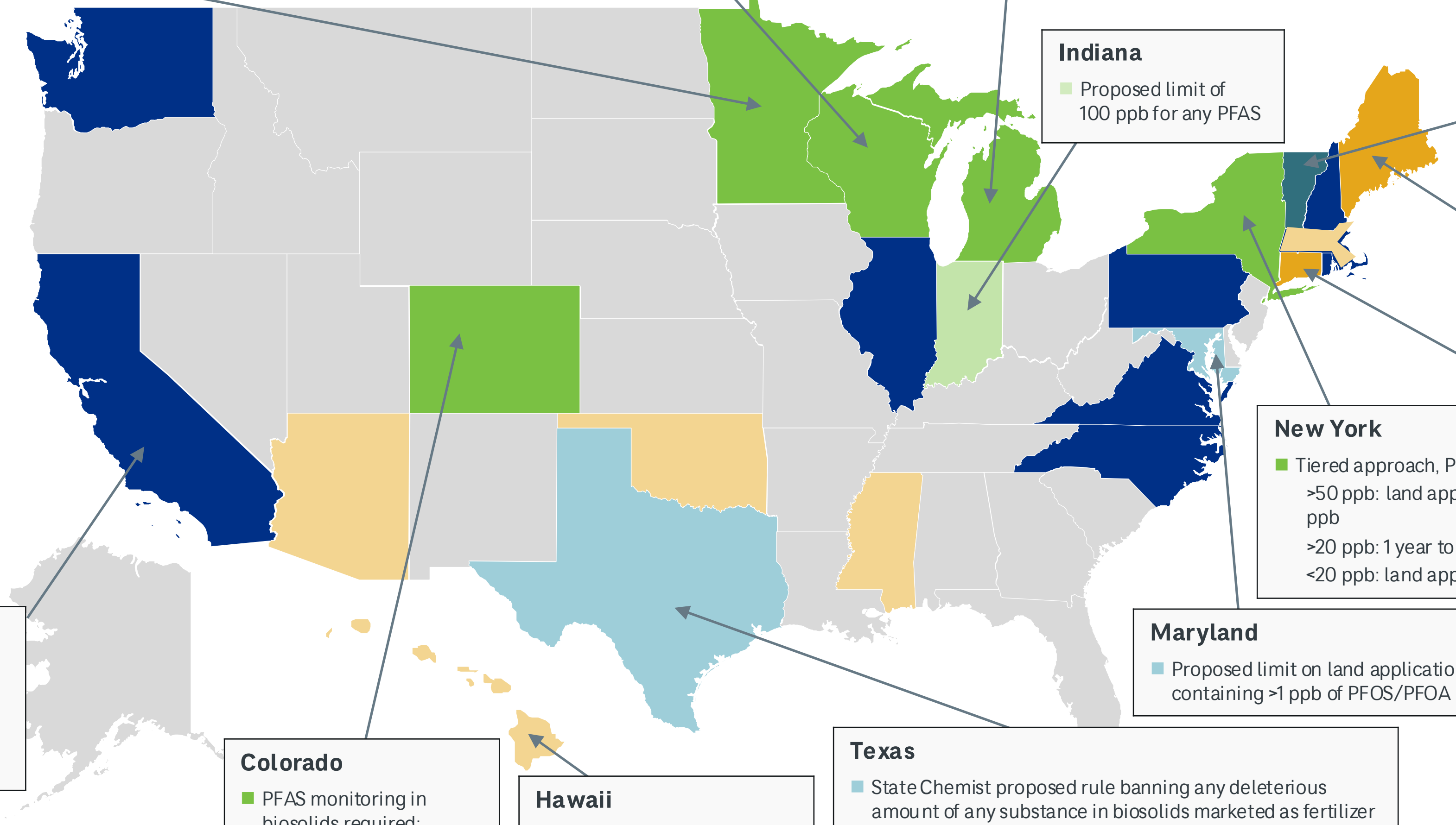
Michigan
- Tiered approach, PFOA *or* PFOS
  - >100 ppb: land application not allowed
  - >20 ppb: source control required and limited land application
  - <20 ppb: no restrictions
  - PFOA+PFOS <20 ppb: "Exceptional Quality" eligible

Vermont
- Land application requires soil *and* biosolids be below: 3.4 ppb – PFOS; 1.6 ppb – PFOA; 0.84 ppb – PFHpA; 0.44 ppb PFNA; 0.38 ppb – PFHxS

Indiana
- Proposed limit of 100 ppb for any PFAS

Maine
- Ban on land application/biosolids due to PFAS concern

Connecticut
- Ban on biosolids that contain PFAS



Required Monitoring

Source Control Screening Level(s)

Proposed Source Control Screening Level(s)

Stringent Limits

Proposed Stringent Limits

Biosolids Land Application Ban

Proposed Biosolids Land Application Ban or *Proposed* Ban that did not pass

New York
- Tiered approach, PFOA or PFOS
  - >50 ppb: land application not allowed until <20 ppb
  - >20 ppb: 1 year to reduce to <20 ppb
  - <20 ppb: land application allowed

California
- Senate Bill 682
- Assembly Bills 652, 1200, 1817
- DDW MCLs
- Statewide PFAS Plan

Maryland
- Proposed limit on land application containing >1 ppb of PFOS/PFOA

Colorado
- PFAS monitoring in biosolids required; PFOA >50 ppb requires source investigation

Hawaii
- Prohibit permits for sludge with detectable PFAS

Texas
- State Chemist proposed rule banning any deleterious amount of any substance in biosolids marketed as fertilizer
- Proposed limits for land application: PFOA – 0.9 ppb; PFOS – 5.1 ppb; and limits on 14 other compounds

ppb = µg PFAS/kg biosolid

Changes ongoing.

State Regulations – Timeline

Maine

1980s	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Promoted land application of biosolids.			Strict PFAS screening limits for biosolids (**2.5 ppb PFOA, 5.2 ppb PFOS**). Effectively halted Class B land application.		LD-1600 Land Application Contaminant Monitoring Fund created. PFAS testing begins at land application sites.	LD-1911 passed banning land application, sale, or distribution of biosolids. Funding for farmers and testing allocated.	Ban effective: first state to ban land application of biosolids.			**Ban remains in place**

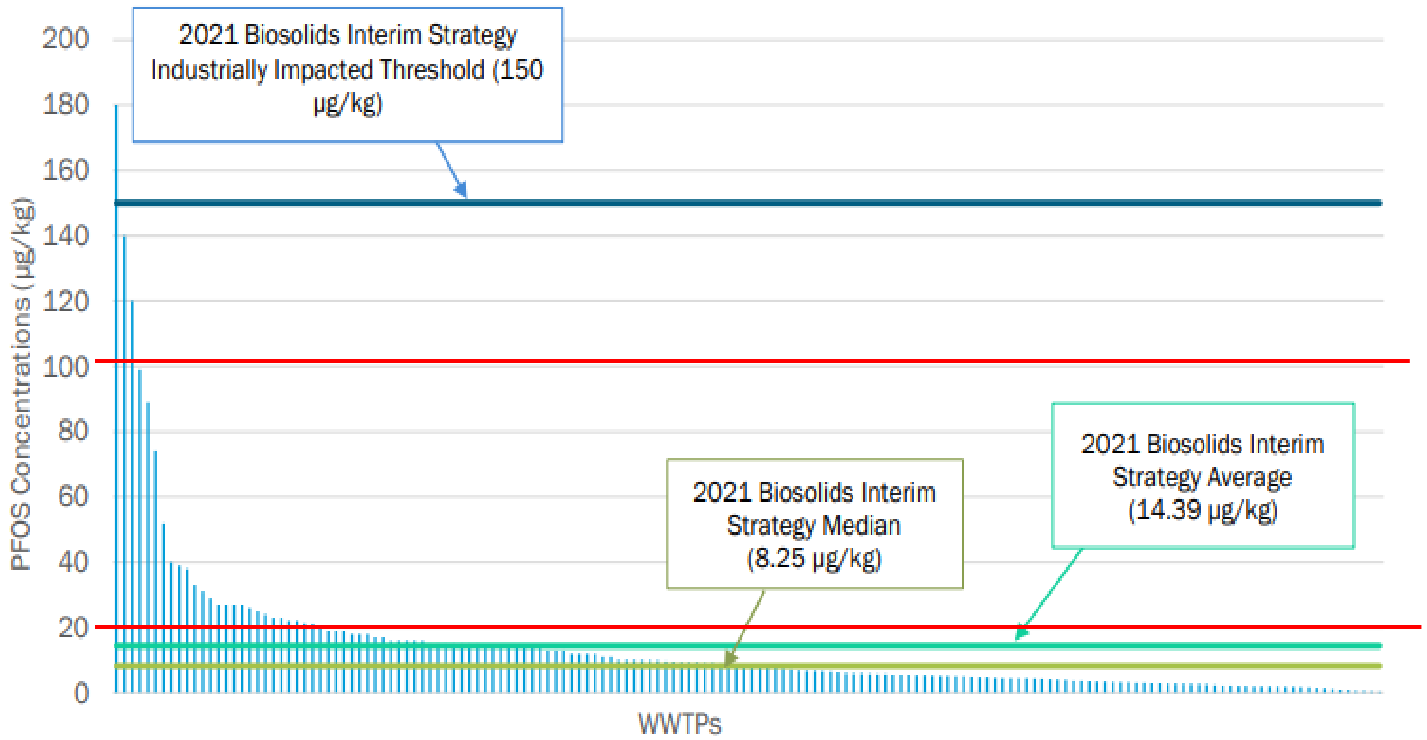
Michigan

1980s	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Promoted land application of biosolids.	Michigan PFAS Action Response Team (MPART) established.	IPP PFAS Initiative created and sampling of land application sites begins.		Strict PFAS drinking water MCLs established (**8 ppt PFOA, 16 ppt PFOS, etc.**)	Interim strategy for land application established. **Biosolids > 150 ppb PFOS** cannot be land applied.	National attention when PFOS contaminated beef traced to biosolids. Regulations continued on testing rather than bans.		Interim strategy updated with 3 tier approach for **PFOS & PFOA> 100 ppb**: can't be land applied **20-99 ppb**: limited land application **< 20 ppb**: no restrictions		**Interim strategy remains enforced**

Michigan EGLE – Biosolids Land Application Interim Strategy

Updated January 2024

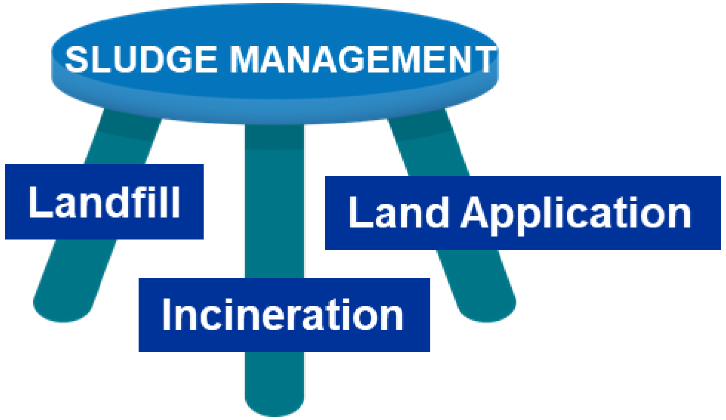
- PFOS and PFOA > 100 µg/Kg (ppb)
  - Land application not allowed.
  - Investigate source reduction
- PFOS and PFOA 20 – 100 µg/Kg (ppb)
  - Land application allowed at max 1.5 dt/acre
  - Investigate source reduction
- PFOS and PFOA < 20 µg/Kg (ppb)
  - Land application allowed



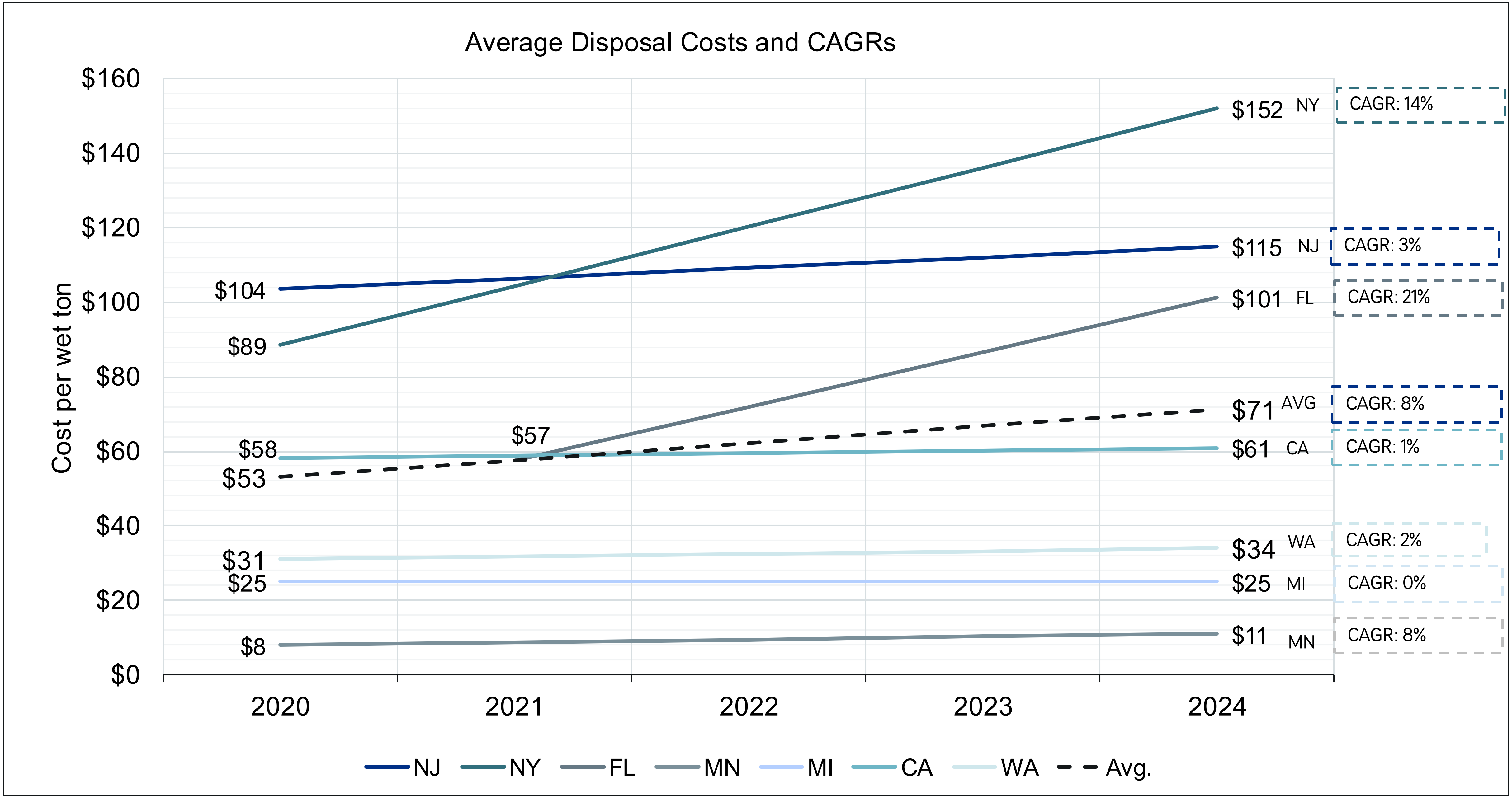
Source: Michigan EGLE: Updated interim strategy, January 2024

Impacts of Regulations

Impacts of Regulations on Biosolids Land Application

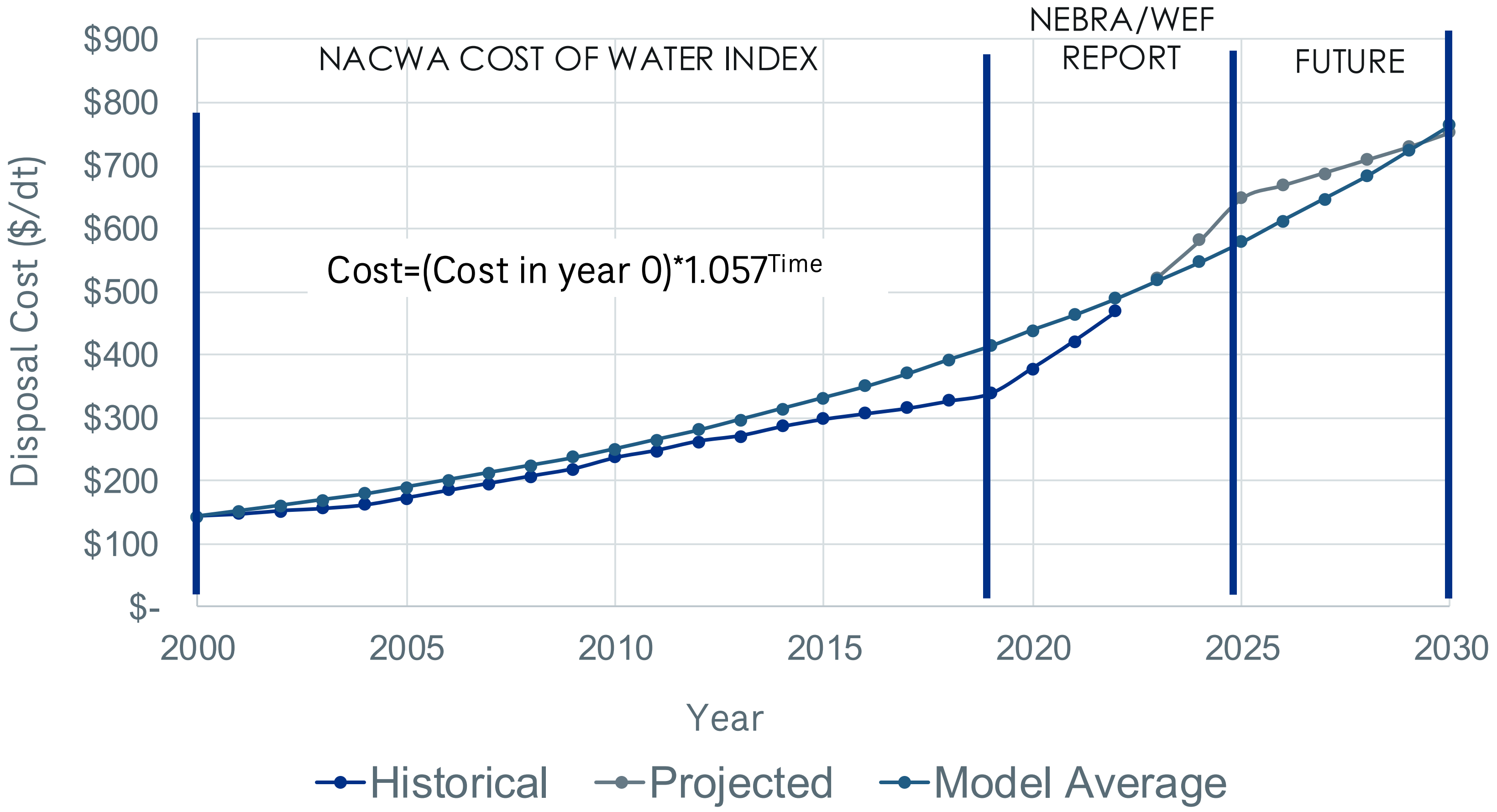


- Legacy Disposal becomes more competitive
  - Export biosolids to other regions
  - Pay a premium for local disposal
- Opens the market up to new disposal methods (gasification/pyrolysis)



Average Disposal Costs and CAGRs
Cost per wet ton
$160
$140
$120
$100
$80
$60
$40
$20
$0
2020
2021
2022
2023
2024
$104
$89
$58
$57
$53
$31
$25
$8
$152 NY
CAGR: 14%
$115 NJ
CAGR: 3%
$101 FL
CAGR: 21%
$71 AVG
CAGR: 8%
$61 CA
CAGR: 1%
$34 WA
CAGR: 2%
$25 MI
CAGR: 0%
$11 MN
CAGR: 8%
NJ
NY
FL
MN
MI
CA
WA
Avg.

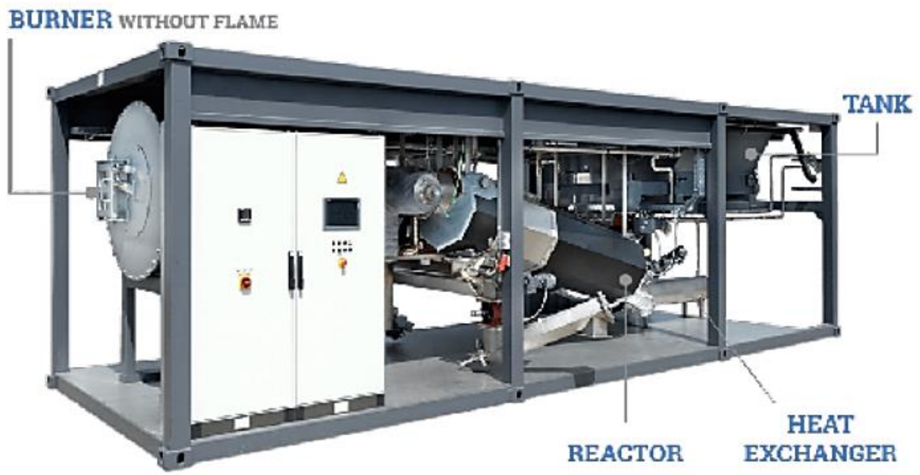
Historical Sludge Management Cost Escalation

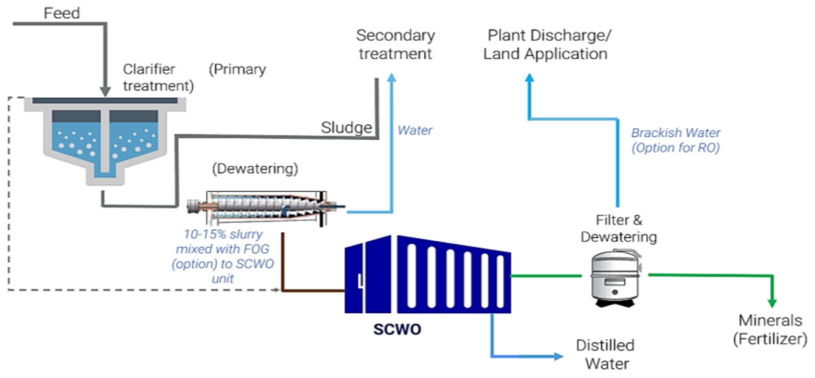


Advanced Treatment

Thermal Processes

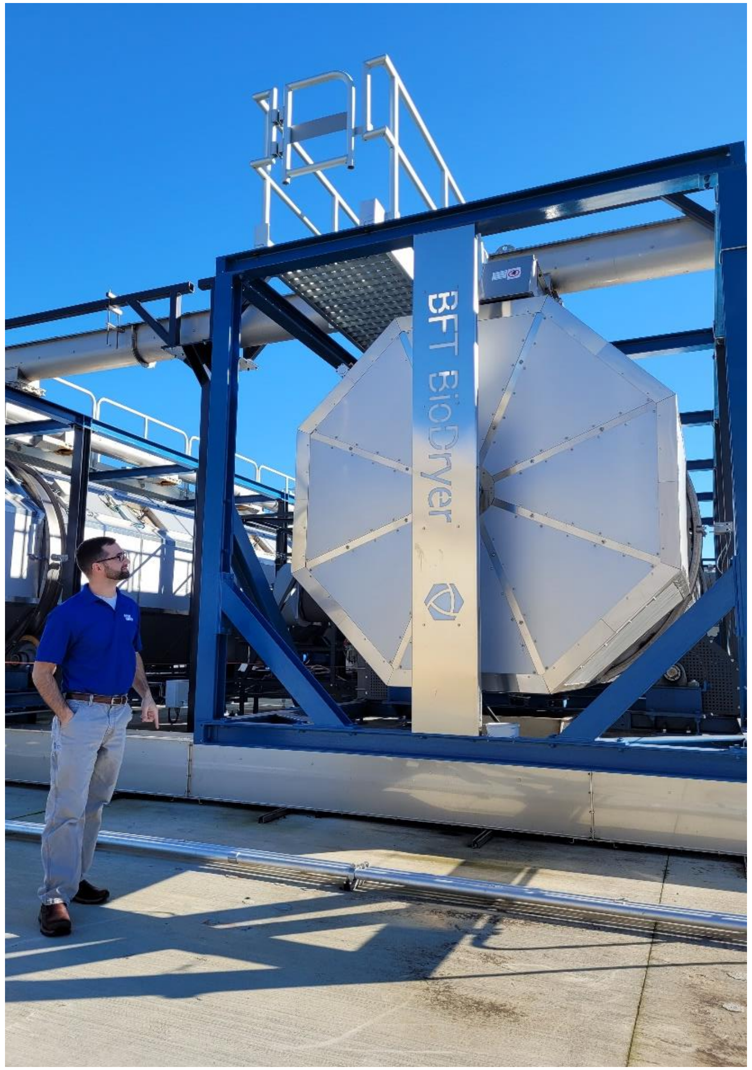
- Drying
- Incineration
- Gasification
- Pyrolysis
- Liquid sludge thermal oxidation
  - Supercritical water oxidation
  - Hydrothermal catalytic gasification
  - Deep shaft wet air oxidation
- Hydrothermal Liquefaction
- Plasma





Drying

- Class A beneficial reuse
- ~75% mass reduction
- Diverse outlets
  - Compost amendment (dilution)
  - Land app (out of state)
  - Landfill cover
  - Landfill
  - Cement kiln fuel



Pyrolysis/Gasification

- Operates at 660 -1,300°F (704°C)
- Recent research[1] on fate of PFAS
  - Measured PFAS and precursors in biosolids, biochar, and py-liquid
  - PFBA concentrations in py-liquid: 2x higher than in biosolids
  - FOSE compounds 2x higher in py-liquid than biosolids
- Additional research ongoing

[1] McNamara, Samuel, Sathyamoorthy, Moss, Valtierra, Cortes Lopez, Nigro, Somerville, Liu

Pyrolysis graphic at top provided by BioForceTech

Incineration

- Technology has been utilized at varying scales for decades
  - No new multiple hearth furnaces (MHFs) in years
  - Fluidized bed incinerators (FBIs) still being permitted and built in the US
- February ’24 WRF Paper: Fate of PFAS through two full-scale Sewage Sludge Incinerators (SSIs)
  - No PFAS in Ash
  - Short chain Alkyl Compounds in Stack
- Advanced Incineration - Veolia/Kruger ERS
  - Compact design
  - Higher operating temperature
  - PFAS Destruction

Research

Completed Research

WRF 5031 Occurrence and Fate and Transport of PFAS in US Water Reclamation Facilities

WRF 5042 Assessing PFAS Levels and Release from Finished Biosolids

THE Water Research FOUNDATION

CDM Smith

TEXAS TECH UNIVERSITY

PURDUE UNIVERSITY

NC STATE UNIVERSITY

Southern Nevada Water Authority

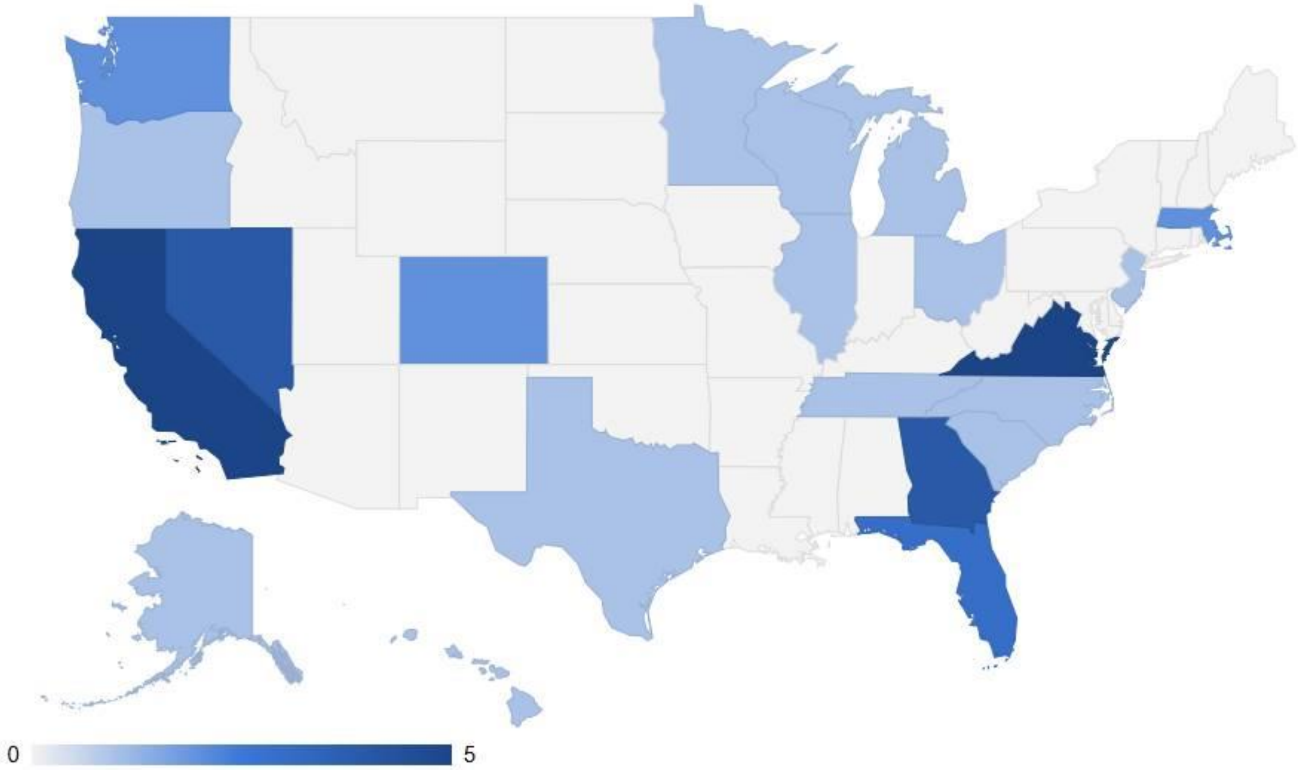
Gwinnett

WRF 5042: Assessing PFAS Release from Finished Biosolids (2019-2022)

Results	Implications
PFAS were present in biosolids samples from seven facilities with concentrations generally within an order of magnitude	Regulations would impact all wastewater facilities to varying degrees since WRFs could be seen as critical intervention points to remove PFAS
PFAS leaching from biosolids was sustained through 6 months mainly because of precursor transformation and organic content	A lot of variables impact when and where you measure PFAS (e.g., sorption, dilution, precursors). Design monitoring programs with experts to ensure the results are meaningful.
Long chain PFAS leached less from biosolids and leaching decreased with greater organic carbon content	More short chain PFAS analytical methods are needed.

WRF 5031
Fate and Transport of PFAS in WRF

- 38 WRRFs analyzed in 24 states
  - Varying flow rates
  - 73% served combined sewer systems
  - Varying treatment processes
- Quantify occurrence of PFAS in solid and liquid streams
- Identify geographical or seasonal variables that impact PFAS occurrence
- Assess PFAS behavior through treatment



Results

PFAS detected in the influent, effluent and biosolids of every sample collected

- Influent ~100 ng/L
- Effluent ~ 80 ng/L
- Biosolids ~ 160,000 ng/kg

About 70% leaves plant thru effluent, 30% in biosolids

Aqueous streams typically perfluoroalkyl acids (PFAAs)

Biosolids primarily polyfluoroalkyl substances (PFOS)

Precursor transformation evident through treatment processes

Additional Research that is ongoing

- National Collaborative PFAS Project (on going)
  - A network of real-world sites
  - Rapid attenuation of PFAS was shown to occur within the 0-3 feet soil depth, with additional attenuation from 3-6 feet.
  - Risk of groundwater PFAS contamination via land application was reported to have higher risk at location of industrial contamination, coarse textured soils, low clay and organic matter soil content, and/or shallow depth to groundwater.
  - Phase 2 focuses on crop uptake from land application sites
  - Preliminary results indicate that the best method for plant tissue extraction is the EPA 1633 fish tissue protocol

Additional Research

- WRF 5212: Enhanced Aeration and Scum Recovery for Physical Removal of PFAS from Wastewater Objective: To use bench- and field-scale testing to assess if PFAS removal from wastewater can be facilitated during biological aeration via scum capture (In progress; PI Charles Shafer; related study being performed for Nantucket, MA)
- WRF 5214: Direct In Situ Measurement of PFAS Transformation and Leaching from Land-Applied Biosolids (In Progress; PI Charles Shafer; will be presented at RBTT)
- WRF currently has 26 of 134 ongoing projects have "PFAS" in the project title
- Research specifically about how drying biosolids impacts the PFAS concentrations is ongoing

Conclusion

Final Thoughts

- **Source Reduction** remains the most economical mitigation strategy
  - Aggressively target high concentration sources
- Continue to **promote sustainable benefits** of land application
- **Communication and education is key!**
- More than standard analysis is needed to evaluate PFAS leaching from biosolids and transformation reactions
- Additional research is necessary to further quantify the risk of biosolids application to human health and the environment

Thank you!

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