

PFAS Cycling Between Landfills and WWTPs

NY Federation of Solid Waste & Recycling Conference
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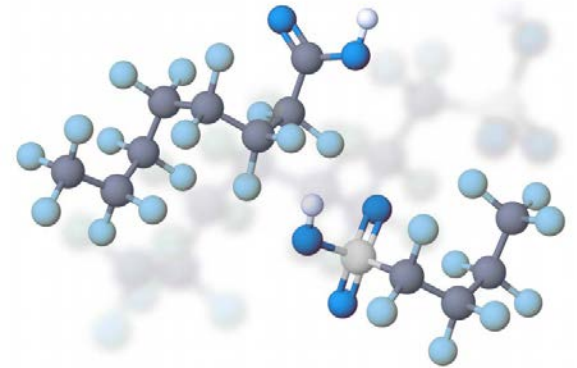
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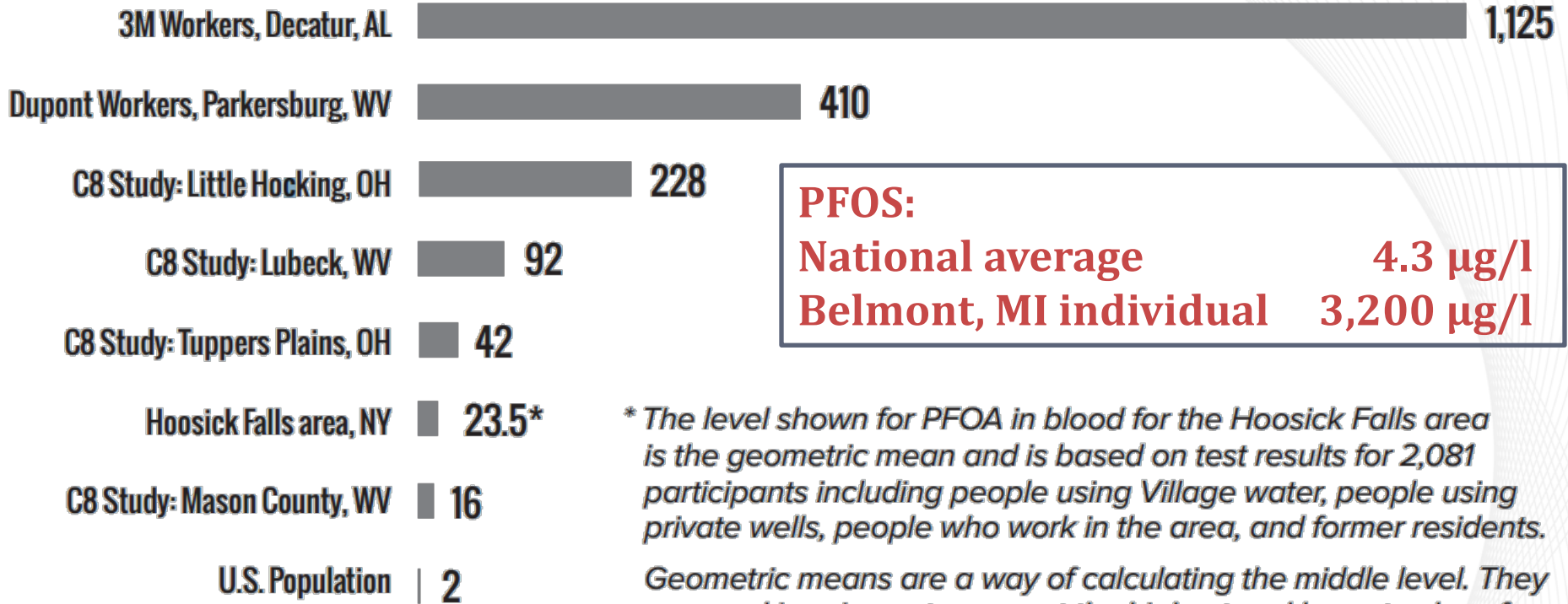
Presentation Overview



- PFAS Introduction
- PFAS in Landfill Leachate
- Sources of PFAS in Municipal Solid Waste
- Cycling of PFAS Between Landfills and Wastewater Treatment Plants

Importance of Drinking Water Exposure PFOA Levels in Blood Serum ($\mu\text{g}/\text{L} = \text{ppb}$)

(<https://www.health.ny.gov/environmental/investigations/hoosick/docs/qandabloodtestingshort.pdf>)



PFOS:

National average 4.3 $\mu\text{g}/\text{l}$

Belmont, MI individual 3,200 $\mu\text{g}/\text{l}$

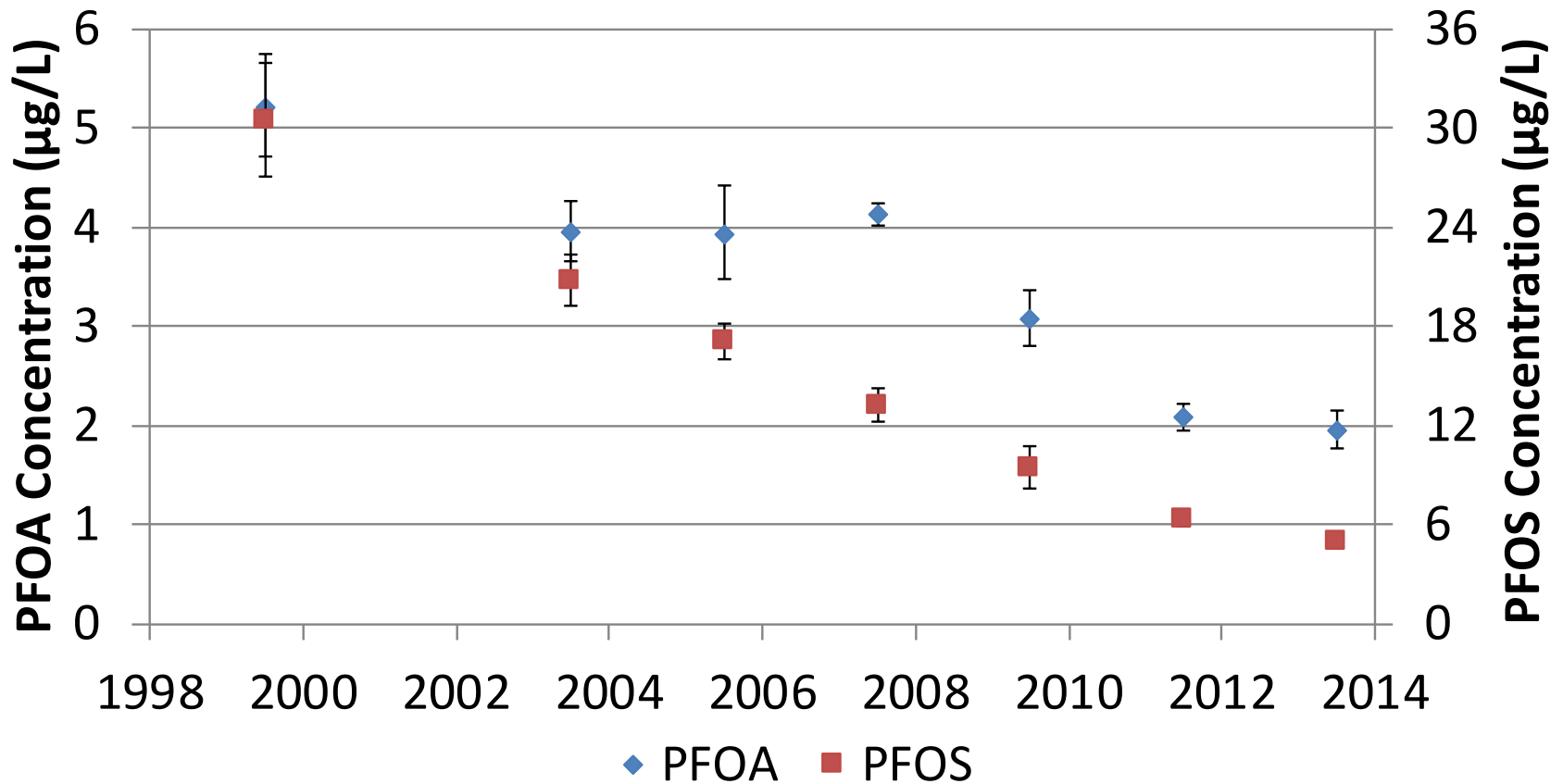
** The level shown for PFOA in blood for the Hoosick Falls area is the geometric mean and is based on test results for 2,081 participants including people using Village water, people using private wells, people who work in the area, and former residents.*

Geometric means are a way of calculating the middle level. They are used in science to prevent the highest and lowest values from distorting the average when rest of the data are close together.

PFOA and PFOS Trends in Blood Serum

Geo Mean PFAS Levels in Blood (National Data)

Error bars = 95% confidence interval



PFAS in Consumer Products

(adapted from ITRC Fact Sheets <https://pfas-1.itrcweb.org/fact-sheets/>)

- Paper and packaging
- Clothing and carpets
- Outdoor textiles and sporting equipment
- Ski and snowboard waxes
- Non-stick cookware
- Cleaning agents and fabric softeners
- Polishes and waxes, and latex paints
- Pesticides and herbicides
- Hydraulic fluids
- Windshield wipers
- Paints, varnishes, dyes, and inks
- Adhesives
- Medical products



Sources of PFAS at Landfills (?)

- Consumer products
- Sewage sludge
- Industrial wastes
- Auto shredder residue
- Debris from fire cleanup
- Discarded AFFF
- Other sources



PFAS in Landfill Leachate

- Lang et al (2017) published PFAS measurements in landfill leachate (*Environ. Sci. Technol.* **51**:2197–2205)
 - 70 PFAS / 95 samples / 18 landfills
 - Estimate 563 – 638 kg of PFAS in leachate per year in the U.S.



Ballpark Estimate of PFAS in Sewage Sludge

Assume

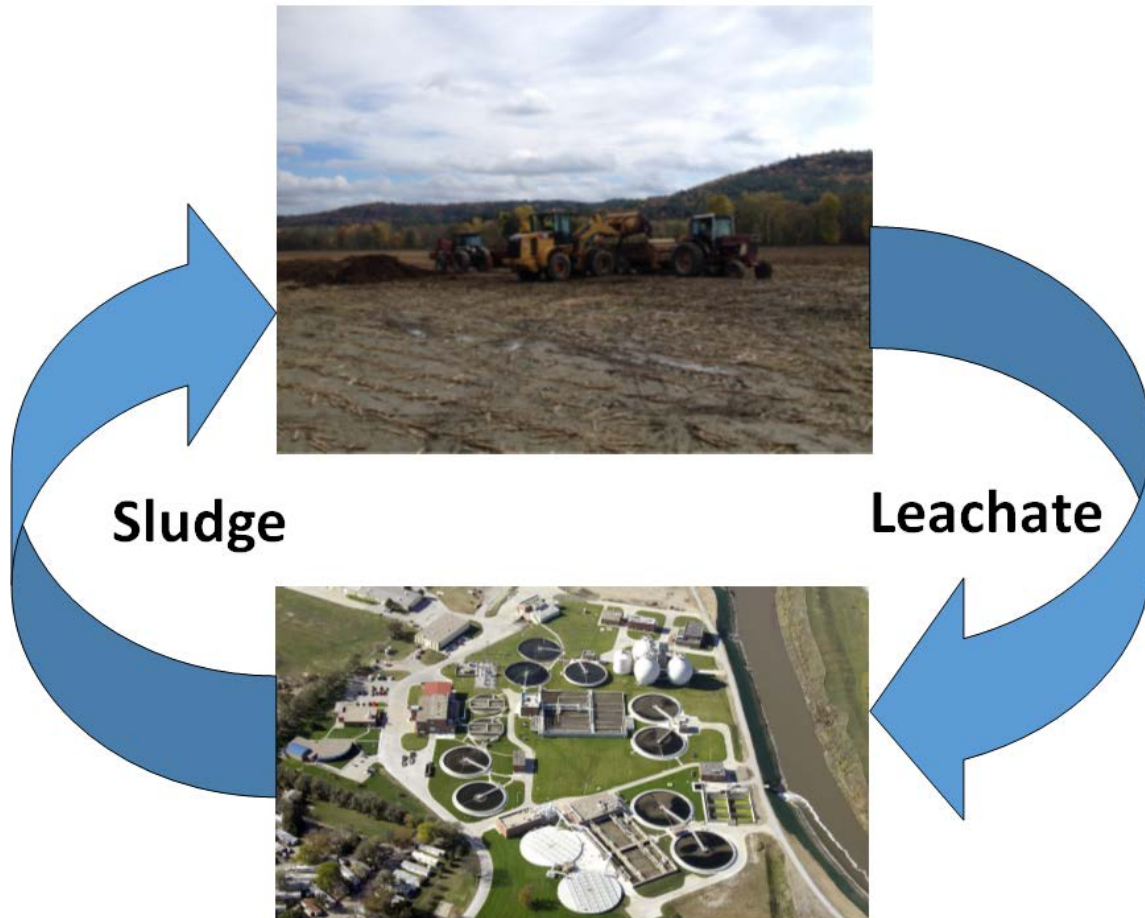
- 7.7 million tons of sewage sludge (estimate for 1998 in U.S)
- PFAS content 100 ppb ($\mu\text{g}/\text{kg}$) in sludge



Find

- 700 kg/year of PFAS in sewage sludge
- Order of magnitude comparable to leachate

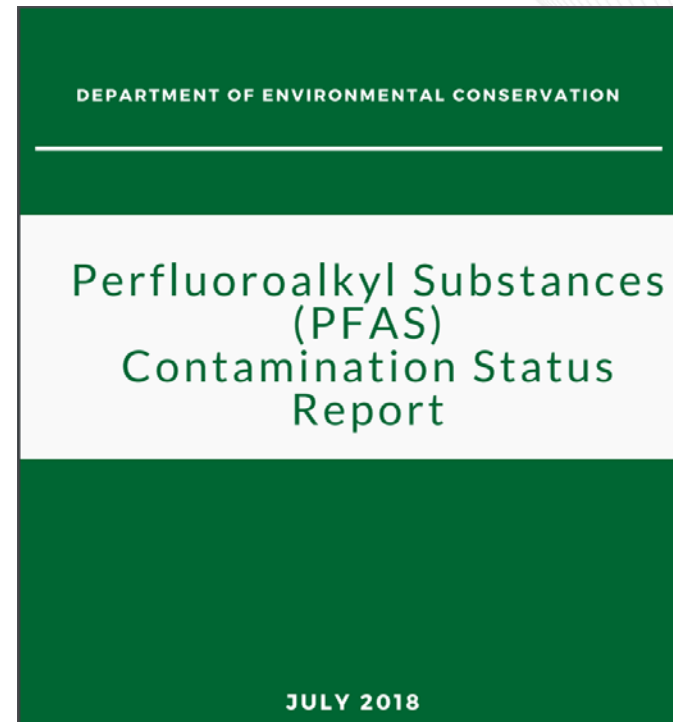
PFAS Relationship Between Landfills and Wastewater Treatment Plants (WWTPs)



Do PFAS cycle between landfills and WWTPs?

Leachate and Sludge Data

- VT DEC (1) investigated PFAS in landfill leachate and WWTP sludge (and WWTP influent/effluent)
 - 29 PFAS
 - 5 landfills
 - 1 active
 - 4 closed
 - 6 WWTPs



PFAS Data Nomenclature/Presentation

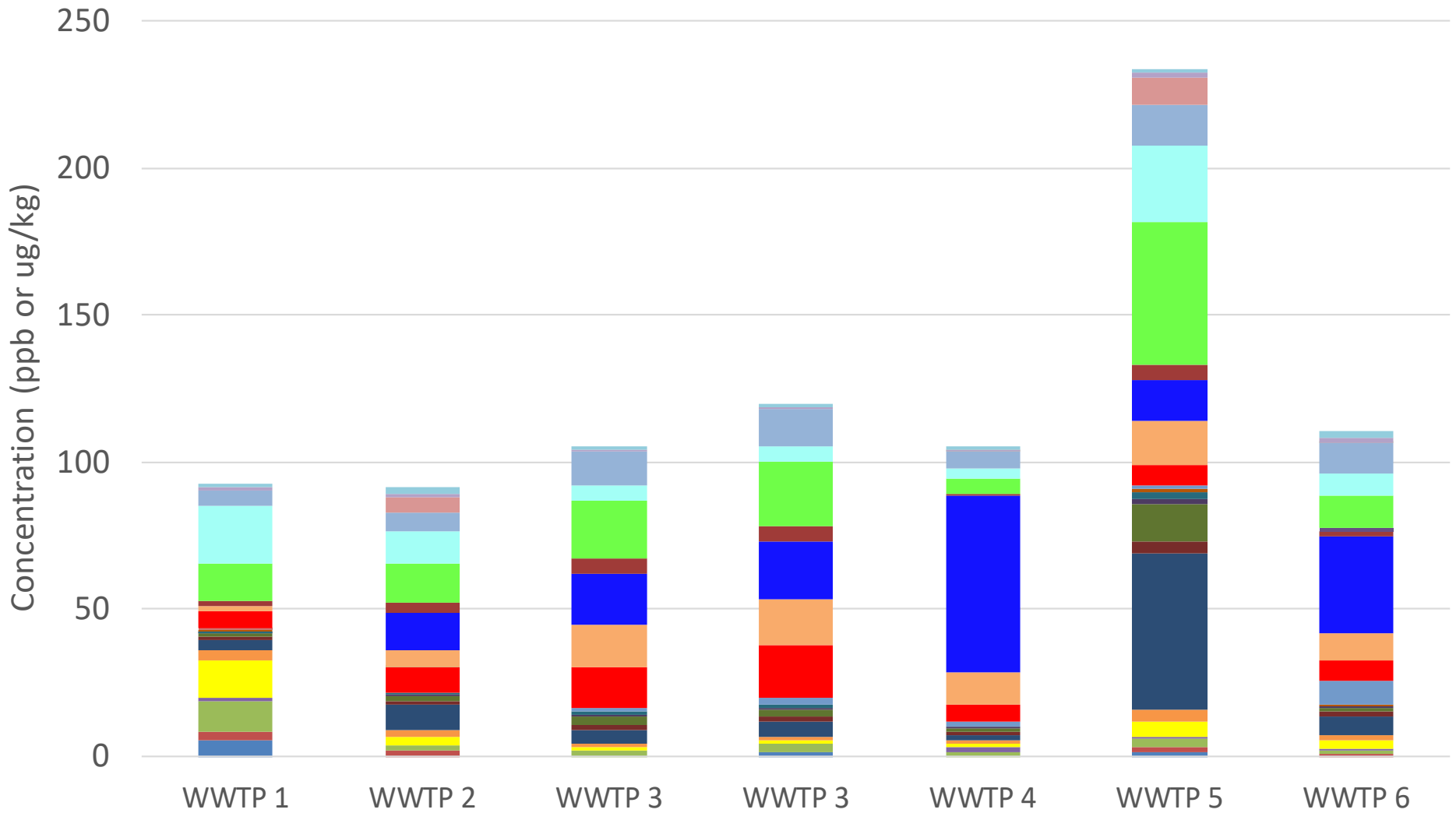
- Substitute PFAS and Precursors
 - 6:2 FTS – 6:2 Fluorotelomer sulfonate
 - PFOSA – Perfluorooctanesulfonamide
 - N-EtFOSA – N-Ethylperfluorooctanesulfonamide
- Sulfonic Acids
 - PFBS – Perfluorobutanesulfonic acid (4 C)
 - PFDoS – Perfluorododecanesulfonic acid (12 C)
- Carboxylic Acids
 - PFBA – Perfluorobutanoic acid (4 C)
 - PFTeDA – Perfluorotetradecanoic acid (14 C)

■ 8:2 FTS	■ 6:2 FTS
■ 4:2 FTS	■ N-EtFOSE
■ N-MeFOSE	■ N-EtFOSAA
■ N-MeFOSAA	■ N-EtFOSA
■ N-MeFOSA	■ PFOSA

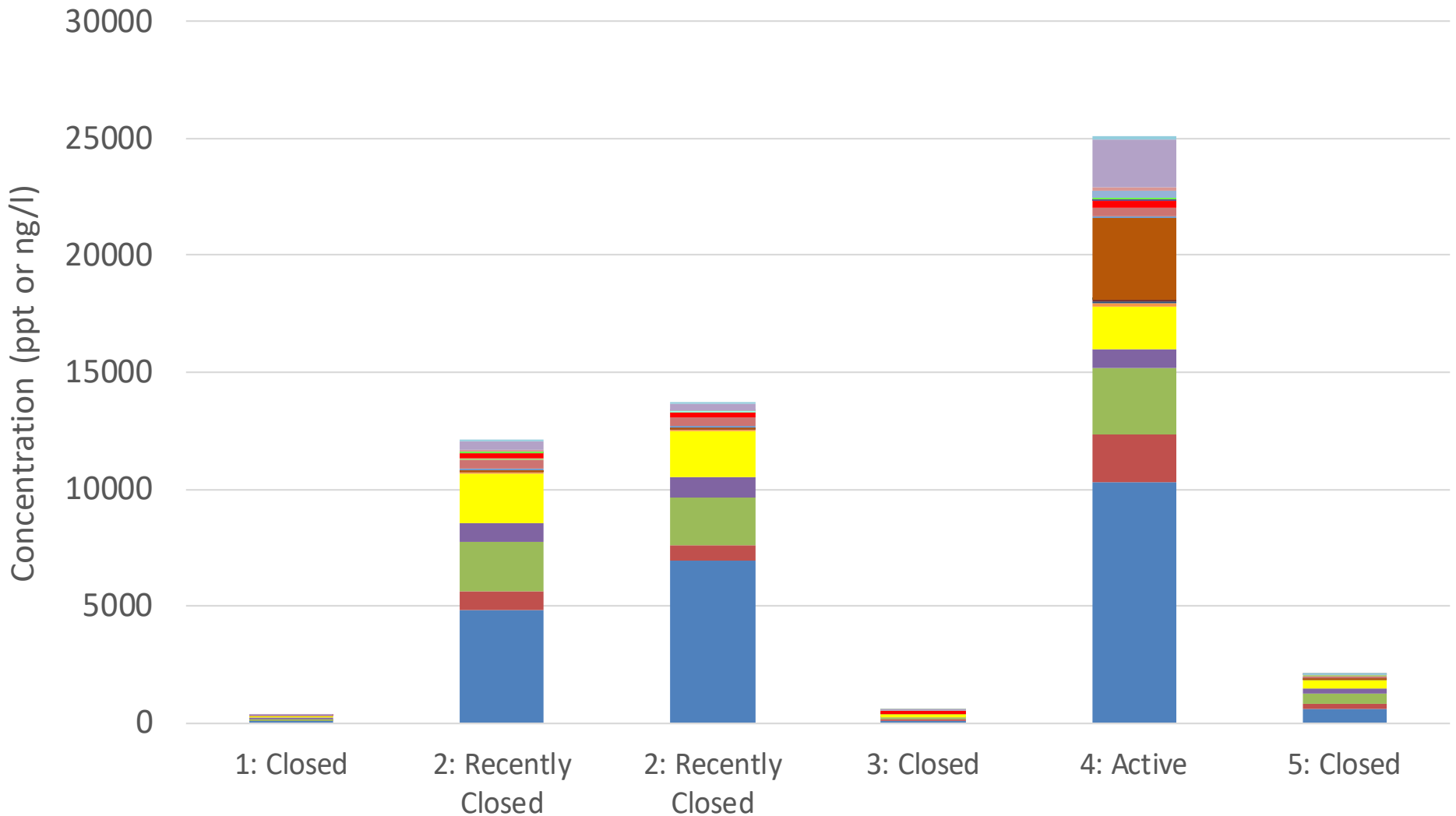
■ PFDoS	■ PFDS
■ PFNS	■ PFOS
■ PFHpS	■ PFHxS
■ PFPeS	■ PFBS

■ FTeDA	■ PFTeDA
■ PFDoA	■ PFUnA
■ PFDA	■ PFNA
■ PFOA	■ PFHpA
■ PFHxA	■ PFPeA
■ PFBA	

PFAS in VT Sewage Sludges

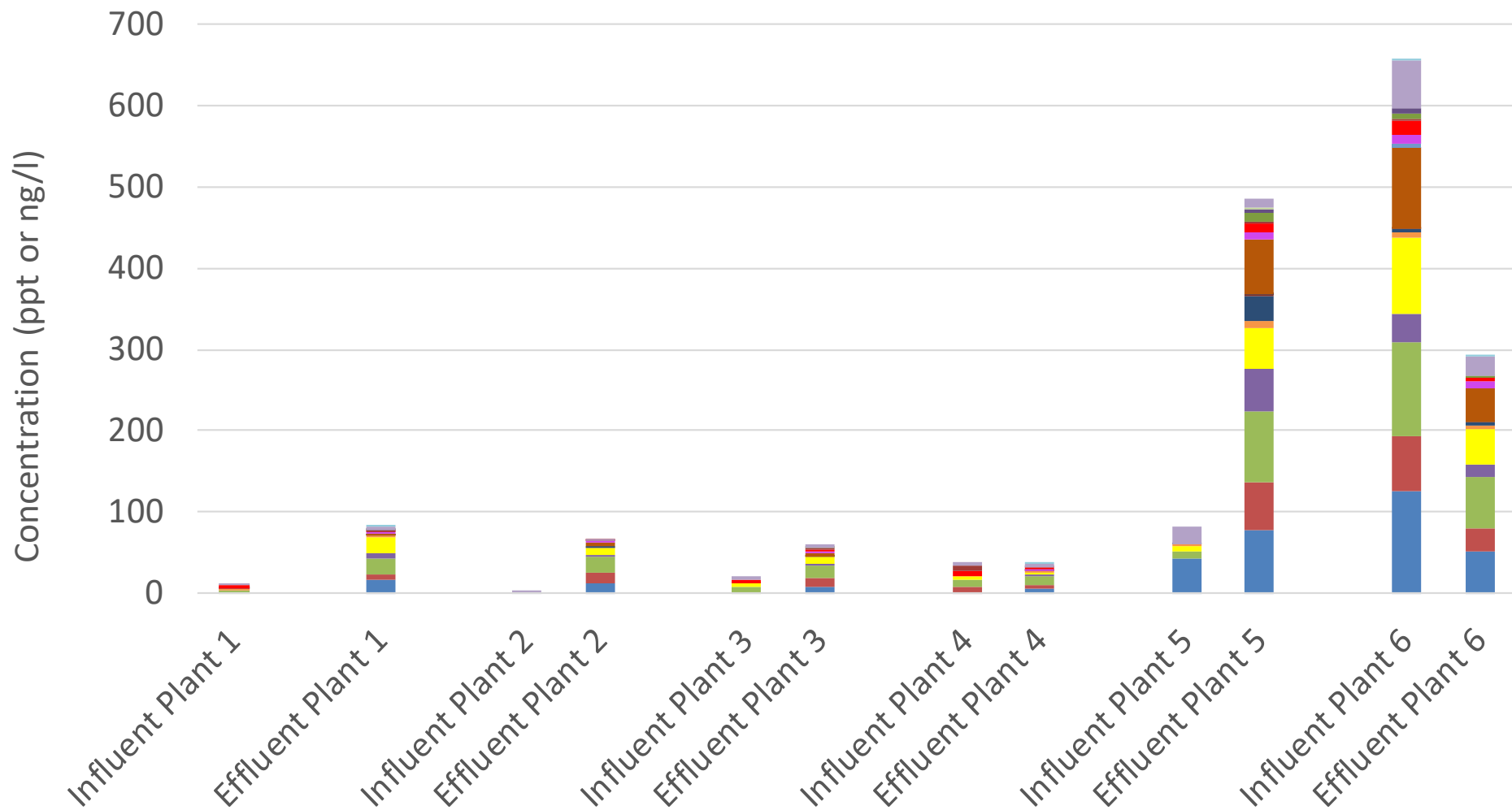


PFAS in VT Landfill Leachate



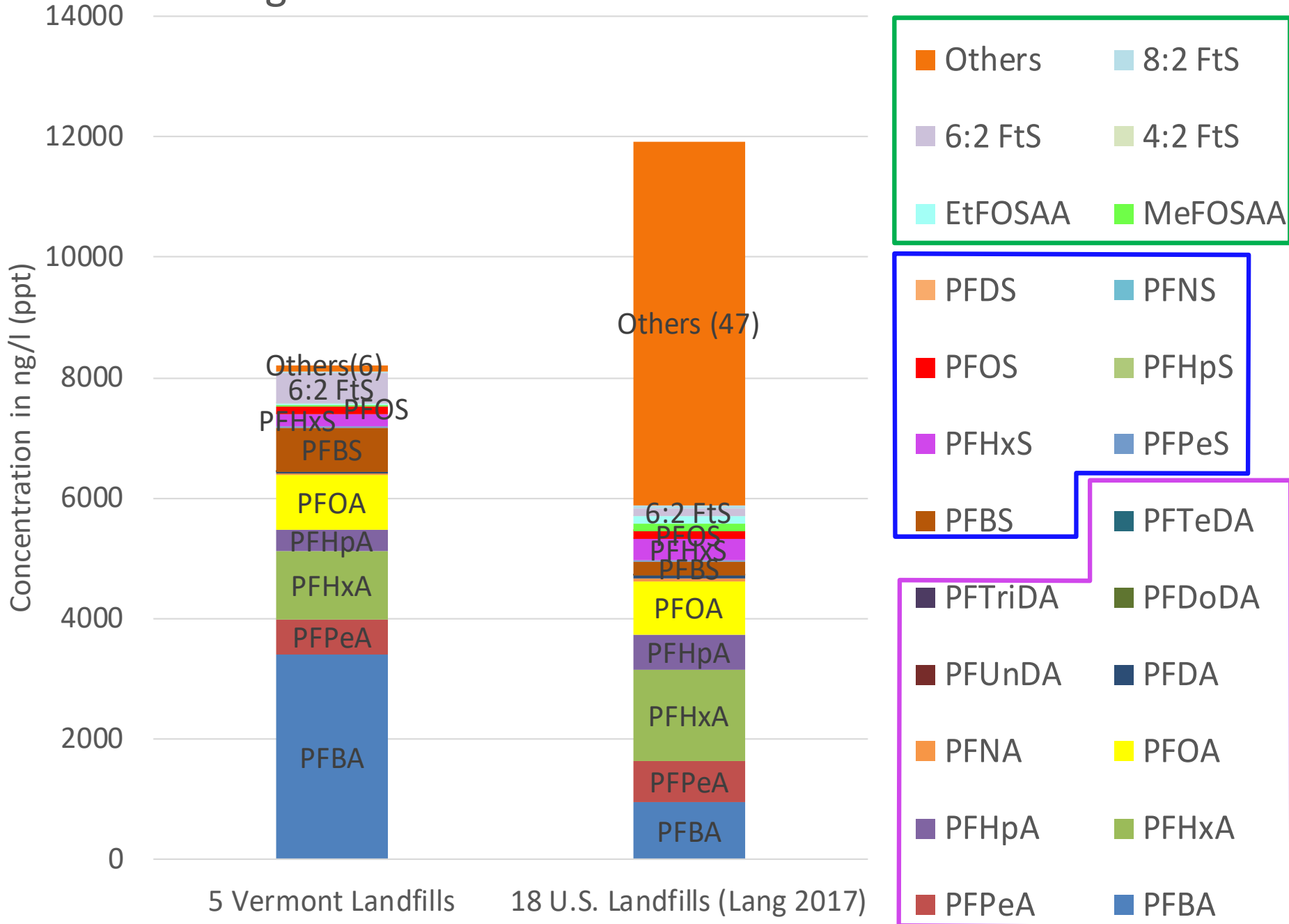
- PFBA
- PFPeA
- PFHxA
- PFHxA
- PFOA
- PFNA
- PFDA
- PFUnA
- PFDoA
- PFTrDA
- FTeDA
- PFBS
- PFPeS
- PFHxS
- PFHpS
- PFOS
- PFNS
- PFDS
- PFDoS
- PFOSA
- N-MeFOSA
- N-EtFOSA
- N-MeFOSAA
- N-EtFOSAA
- N-MeFOSE
- N-EtFOSE
- 4:2 FTS
- 6:2 FTS
- 8:2 FTS

PFAS in VT WWTP Influent and Effluent

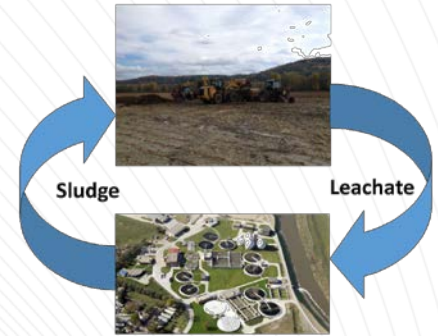


- | | | | | | | | |
|----------|----------|---------|---------|----------|--|-----------|-----------|
| PFBA | PFPeA | PFHxA | PFHpA | PFOA | PFNA | PFDA | PFUnA |
| PFDoA | PFTrDA | FTeDA | PFBS | PFPeS | PFHxS | PFHpS | PFOS |
| PFNS | PFDS | PFDoS | PFOSA | N-MeFOSE | N-EtFOSE | N-MeFOSAA | N-EtFOSAA |
| N-MeFOSE | N-EtFOSE | 4:2 FTS | 6:2 FTS | 8:2 FTS | PFAS in Red Rectangles Not in Analyte List | | |

Average PFAS Concentrations in Landfill Leachate

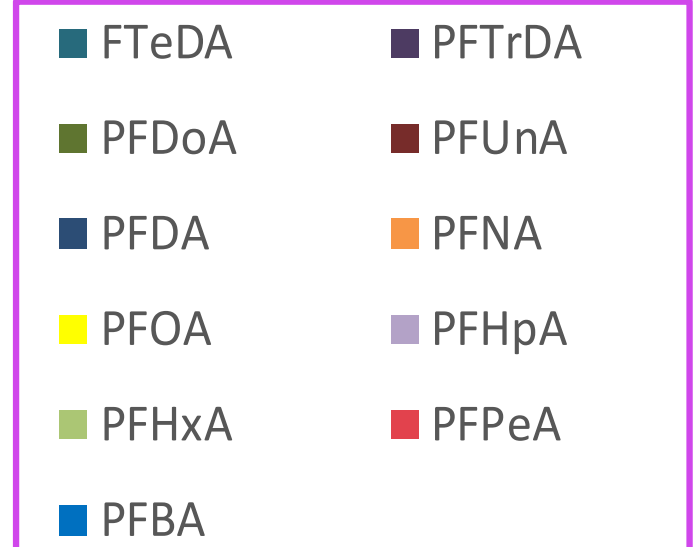
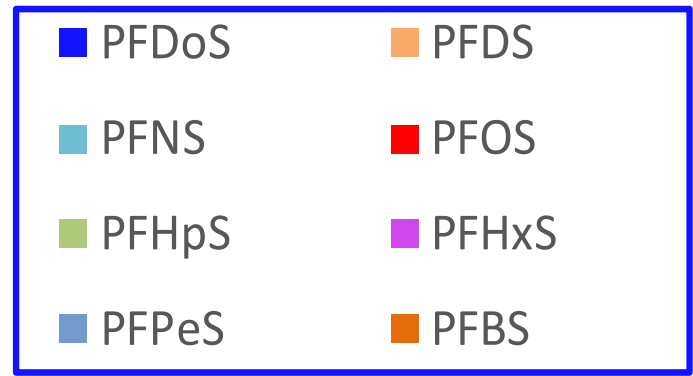
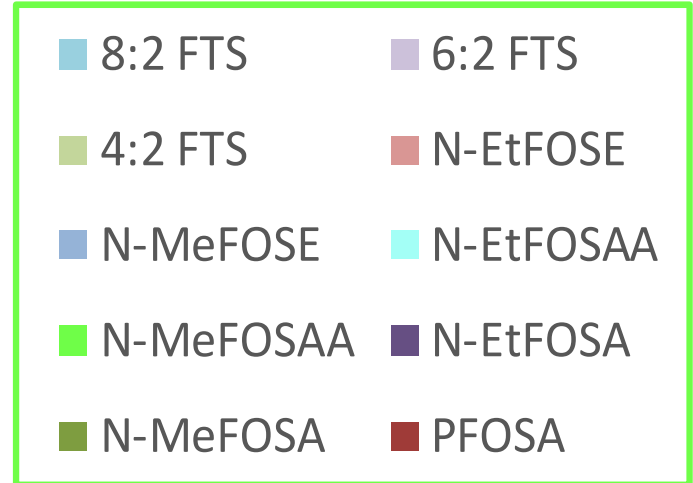
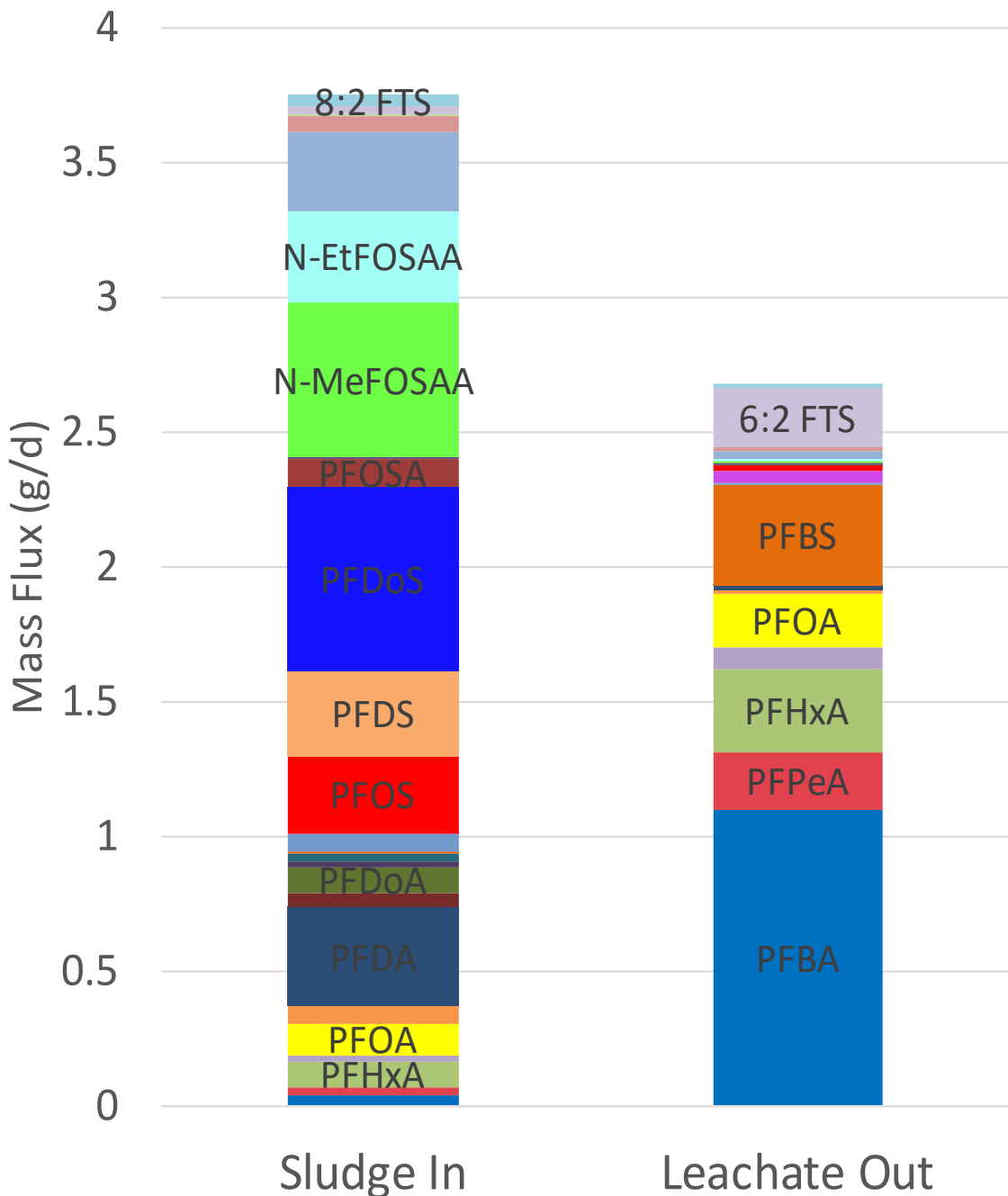


PFAS Cycle/Comparison



- Case study very rough examination of an active landfill
 - Leachate generation ~ 30,000 gal/d
 - Sludge acceptance ~ 270,000 lb/day (wet)
 - Sludge water content 75%
 - Average PFAS concentration in sludge
 - Landfill-specific PFAS concentration in leachate

PFAS Cycle / Mass Flux Comparison



Observations

- Estimates of PFAS fluxes into (sludge) and out of (leachate) the landfill are similar in magnitude, but the PFAS distributions differ markedly
 - Long-chain PFAS, especially sulfonic acids, may sequester in the landfill
 - Short-chain compounds are prevalent in leachate, and appear to come from sources other than sludge
- PFAS cycling may not be significant at the compound level, and the overall PFAS balance appears to be much more complex
- Comparing PFAS data can be challenging due to varying analyte lists



Additional Questions



- What fraction of WWTP loading comes from landfill leachate?
- What are the specific sources of PFAS found in leachate?
- What fractions of the PFAS in leachate are due to landfill gas condensate?
- Can leachate be treated in a cost-effective manner?
- Are air emissions of PFAS important?

For More Information ...

- The Interstate Technology & Regulatory Council (ITRC) PFAS Team

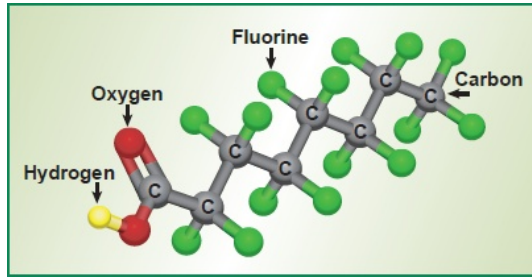
<http://itrcweb.org/Team/Public?teamID=78>

- Fact sheets available at:

<https://pfas-1.itrcweb.org/fact-sheets/>

- Naming Conventions and Properties
 - History and Use
 - Regulations, Guidance & Advisories
 - Environmental Fate & Transport
 - Site Characterization
 - Remediation
 - AFFF (coming soon)
- Detailed technical guidance later this year





Thank you for your attention!

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PFAS List

PFBA -Perfluorobutanoic acid
PFPeA -Perfluoropentanoic acid
PFHxA -Perfluorohexanoic acid
PFHpA -Perfluoroheptanoic acid
PFOA -Perfluorooctanoic acid
PFNA -Perfluorononanoic acid
PFDA -Perfluorodecanoic acid
PFUnA -Perfluoroundecanoic acid
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N-EtFOSA -N-Ethylperfluorooctanesulfonamide
N-MeFOSAA -N-Methylperfluorooctanesulfonamidoacetic acid
N-EtFOSAA -N-Ethylperfluorooctanesulfonamidoacetic acid
N-MeFOSE -N-Methylperfluorooctanesulfonamidoethanol
N-EtFOSE -N-Ethylperfluorooctanesulfonamidoethanol
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6:2 FTS -6:2 Fluorotelomer sulfonate
8:2 FTS -8:2 Fluorotelomer sulfonate