Fate, Transport, and Transformation of Per- and Poly-Fluorinated Substances (PFAS) in Wastewater Treatment Plants

Prepared for: ***2023 Battelle Bioremediation Symposium***

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Background – PFAS in WWTPs

Science of the Total Environment 874 (2023) 162357

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Per- and polyfluoroalkyl substances fate and transport at a wastewater treatment plant with a collocated sewage sludge incinerator

Brannon A. Seay *, Kavitha Dasu, Ian C. MacGregor [1], Matthew P. Austin, Robert T. Krile, Aaron J. Frank, George A. Fenton, Derik R. Heiss, Rhett J. Williamson, Stephanie Buehler [1]

Water Research

Volume 233, 15 April 2023, 119724

Occurrence of quantifiable and semi-quantifiable poly- and perfluoroalkyl substances in united states wastewat treatment plants

Charles E. Schaefer [a], Jennifer L. Hooper [b], Laurel E. Strom [b], Ibrahim Abusallout [b], Eric R.V. Dickenson [c], Kyle A. Thompson [c d], Gayathri Ram Mohan [e], Dina Drennan [b], Ke Wu [f], Jennifer L. Guelfo [f]

Journal of Hazardous Materials

Volume 447, 5 April 2023, 130854

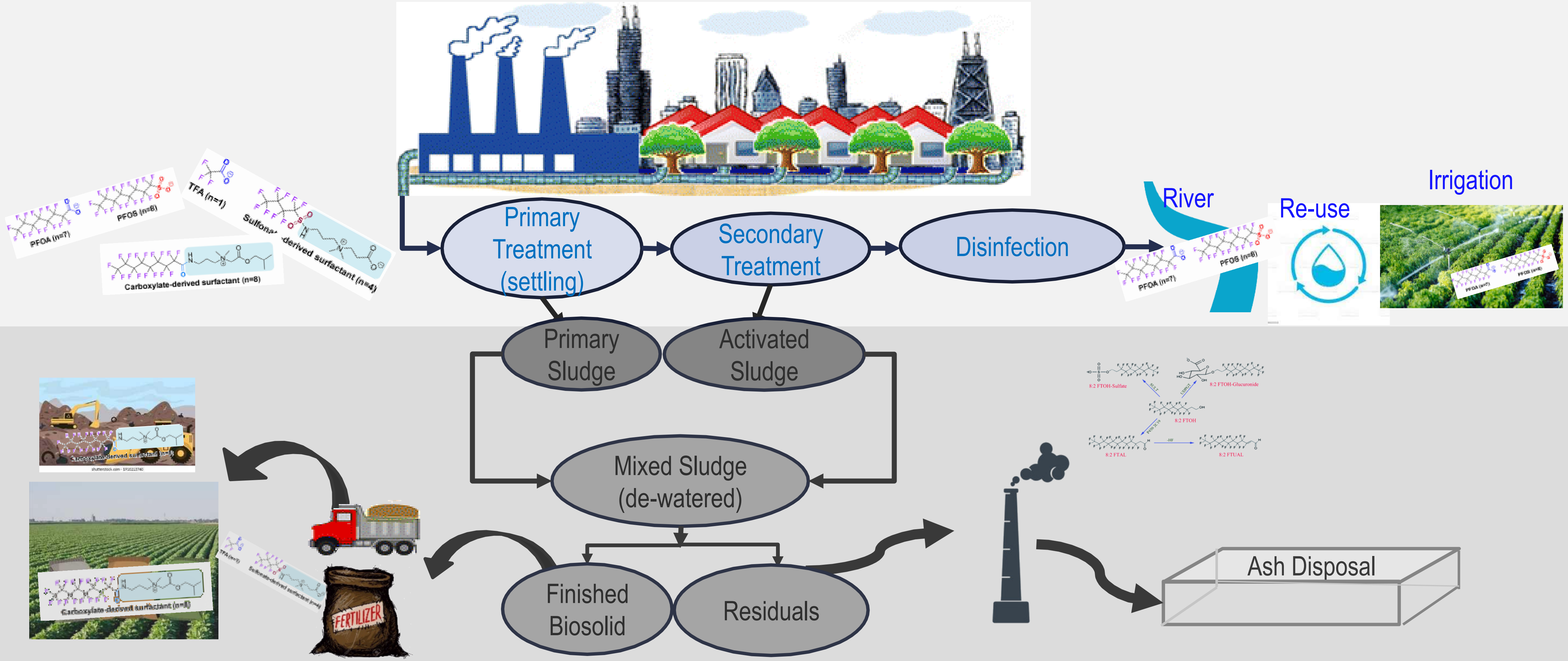
High-resolution temporal wastewater treatment plant investigation to understand influent mass flux of per- and polyfluoroalkyl substances (PFAS)

Drew Szabo [a b], Jaye Marchiandi [a], Subharthe Samandra [a], Julia M. Johnston [a], Raoul A. Mulder [c], Mark P. Green [c], Bradley O. Clarke [a]

Large scientific gaps on PFAS fate and transport in WWTPs.

- PFAS concentrations in effluent versus influent
- The effects of different processes on PFAS fate
- Disposal options for wastewater residuals

Introduction – PFAS Fate in WWTPs



Project Objectives

- Understand spatial and temporal variability of PFAS during wastewater treatment (WWT)
- Develop methods for evaluation of mass balances for PFAS and organic fluorine during WWT
- Assess relationships between PFAS partitioning and/or transformation and WWT operational parameters
- Explore PFAS sampling techniques and analytical approaches in WWTPs (lessons learned)

Methods

- EPA method 1633 (Targeted 40 PFAS)
  - Only detected values are reported for this presentation.
  - PFBA data not presented for this method (possible interferences)
  - 6:2 FTS data not presented (QAQC)
  - The method includes PFCAs, PFSAs, FTSs, FTCAs, FOSAs
- Total Oxidizable Precursor Assay (1633-40 Compound list/537.M)
- Total Organic Fluorine
  - Extractable organic fluorine (EOF) for solids
  - Adsorbable organic fluorine (AOF) for liquids (similar method to draft 1621 EPA method)

Overview of Participating Facilities

Facility	Flow (MGD)	Main Processes	Solids Handling	Disinfection	Leachate Septage	Effluent
Facility 1	38 ± 20	Wet oxidation	Incinerator	Cl	--	Discharge
Facility 2	78 ± 30	Biological Nutrient Removal	Incinerator	Cl	Leachate	Discharge
Facility 3	25 ± 1	Aeration & Biological Nutrient Removal	Land Application	Cl	Leachate	Discharge
Facility 4	5	Biological Nutrient Removal	Land Application	UV Cl	--	Discharge
Facility 5	4 ± 0.1	Biological Nutrient Removal	Land Application	Cl	Septage	Discharge
Facility 6	20-25	5 stages (Anaerobic/Anoxic/Aerobic/Anoxic/Reaeration)	Incinerator	Cl	Leachate	Discharge

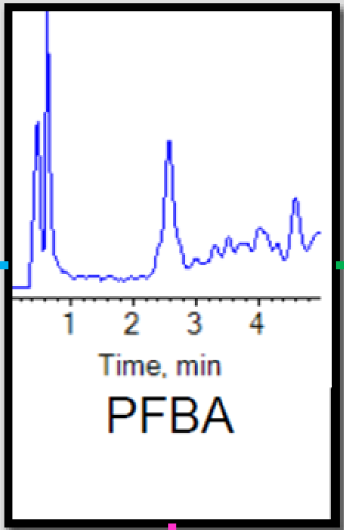
Analytical Challenges

Multiple analytical challenges

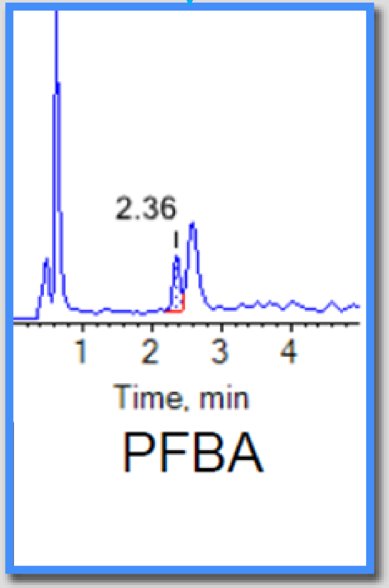
Interfering Peaks with PFBA →

Implementing 1633 method challenged commercial analytical laboratories:
1,300+ samples to date

Municipal Influent

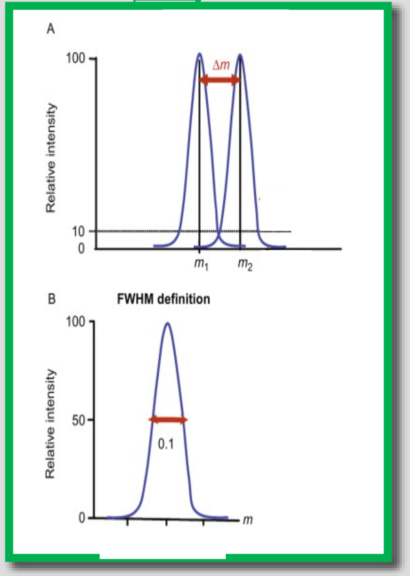


Matrix Spike

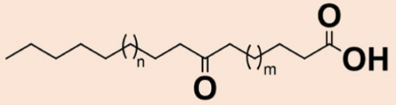


Improved Chromatography to separate the peaks

High Resolution Mass Spectrometry



Interfering Peak ?
Bangma et al., 2023 identified SOFAs as interfering peak with PFBA in biota samples
Bangma et al., 2023, Chemosphere, 137722

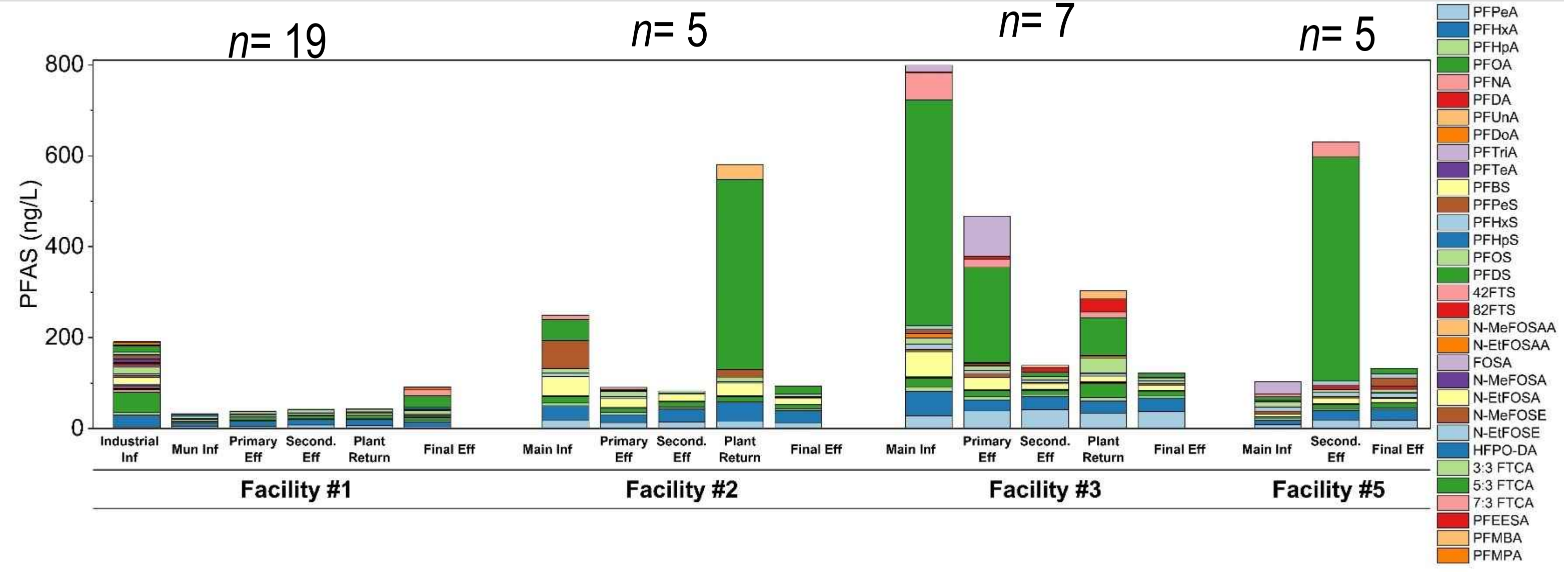


Saturated Oxo Fatty Acids (SOFAs)

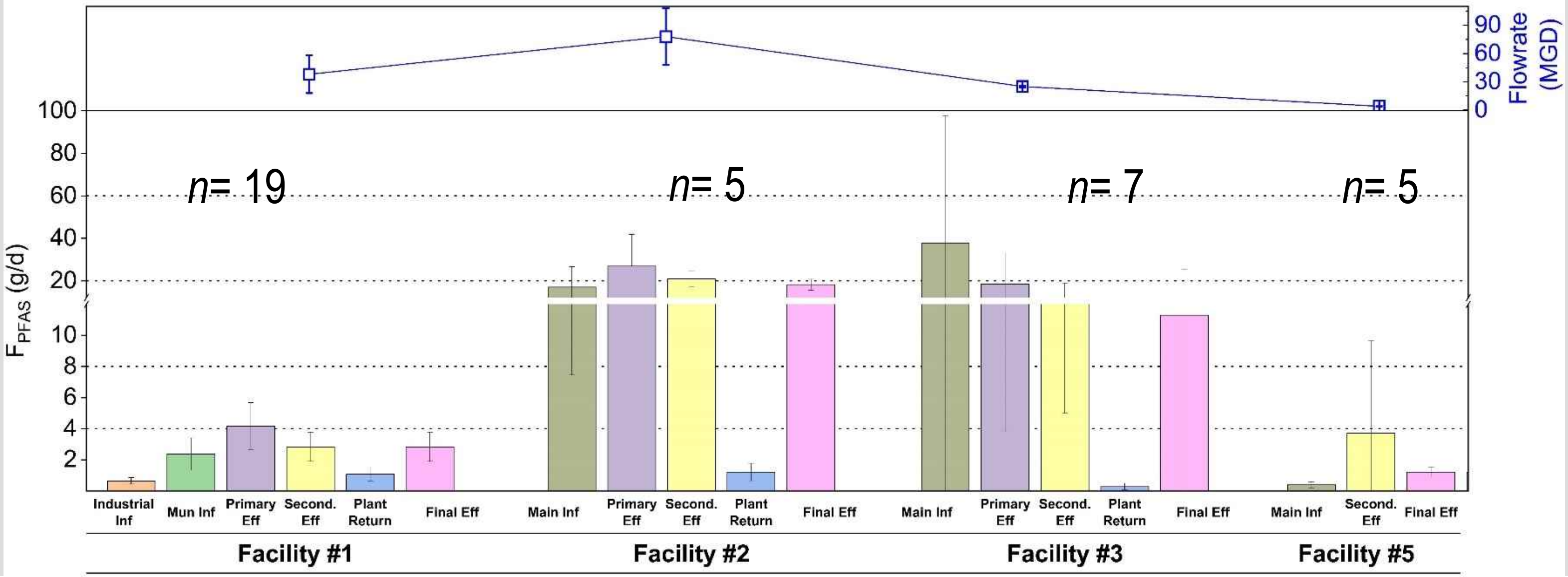
PFAS Composition
&
F_{PFAS} Mass Flux in Facilities

Results

PFAS Composition

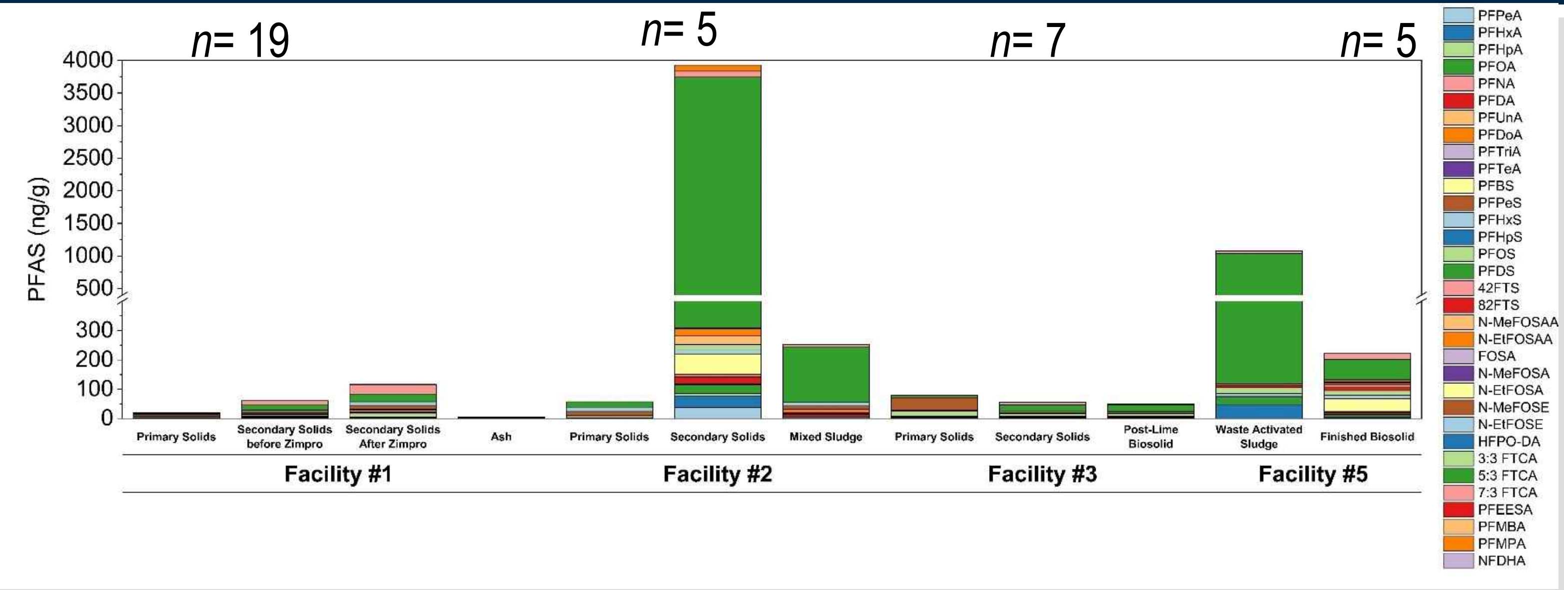


F_{PFAS} Mass Flux in Facilities

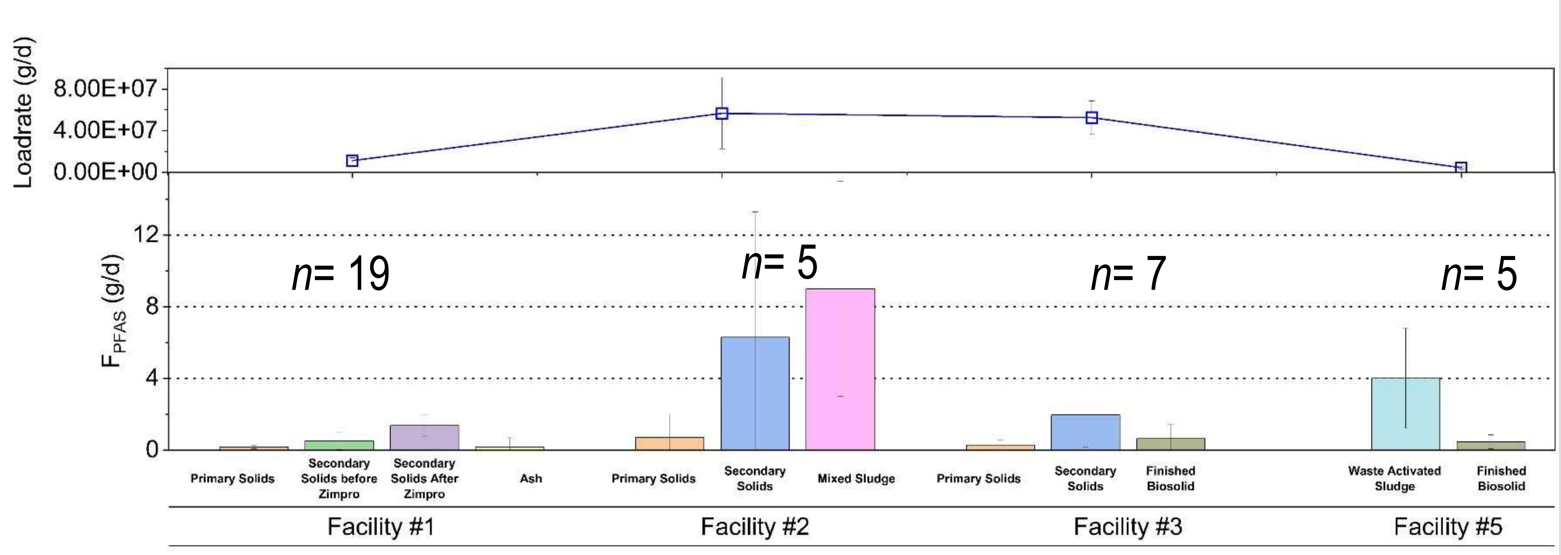


Results

PFAS Composition



F_{PFAS} Mass Balances



Results

	Secondary Sludge Before Process	Secondary Sludge After Process
Facility #1	2.25 ± 0.14	2.41 ± 0.23

	Mixed Sludge
Facility #2	2.68 ± 0.22

Log k_d (L/kg)

C_s/C_w values for PFOS

PFOS partitioning in different sludges

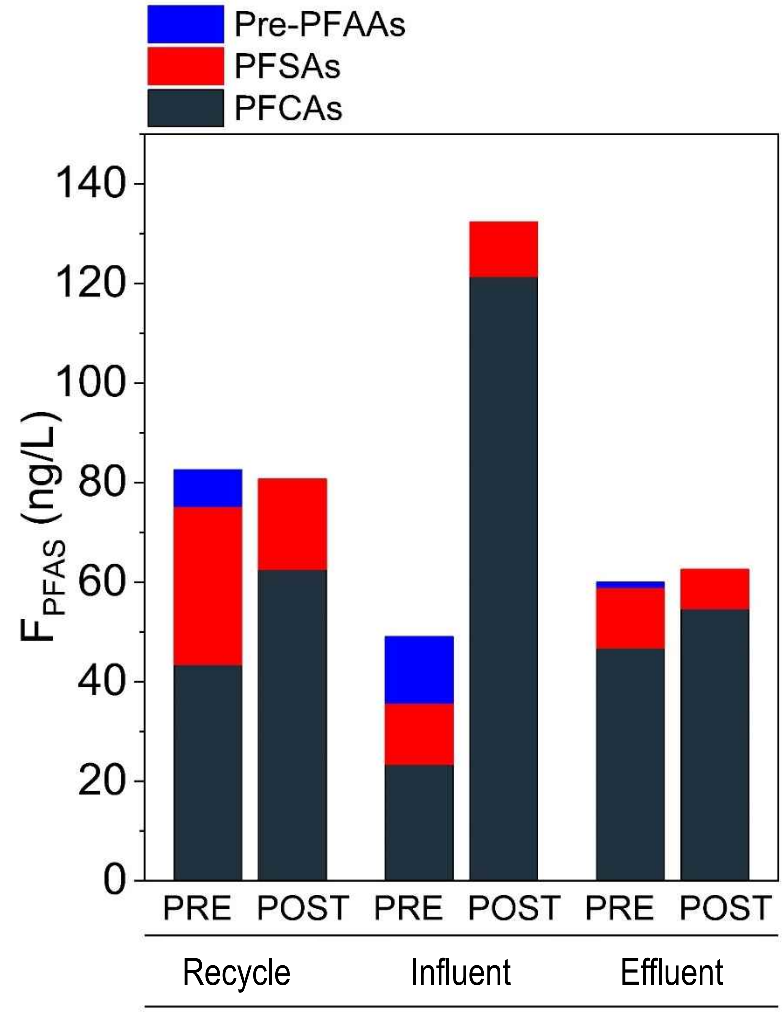
	Primary Sludge	Secondary Sludge
Facility #3	2.64	2.72 ± 0.05

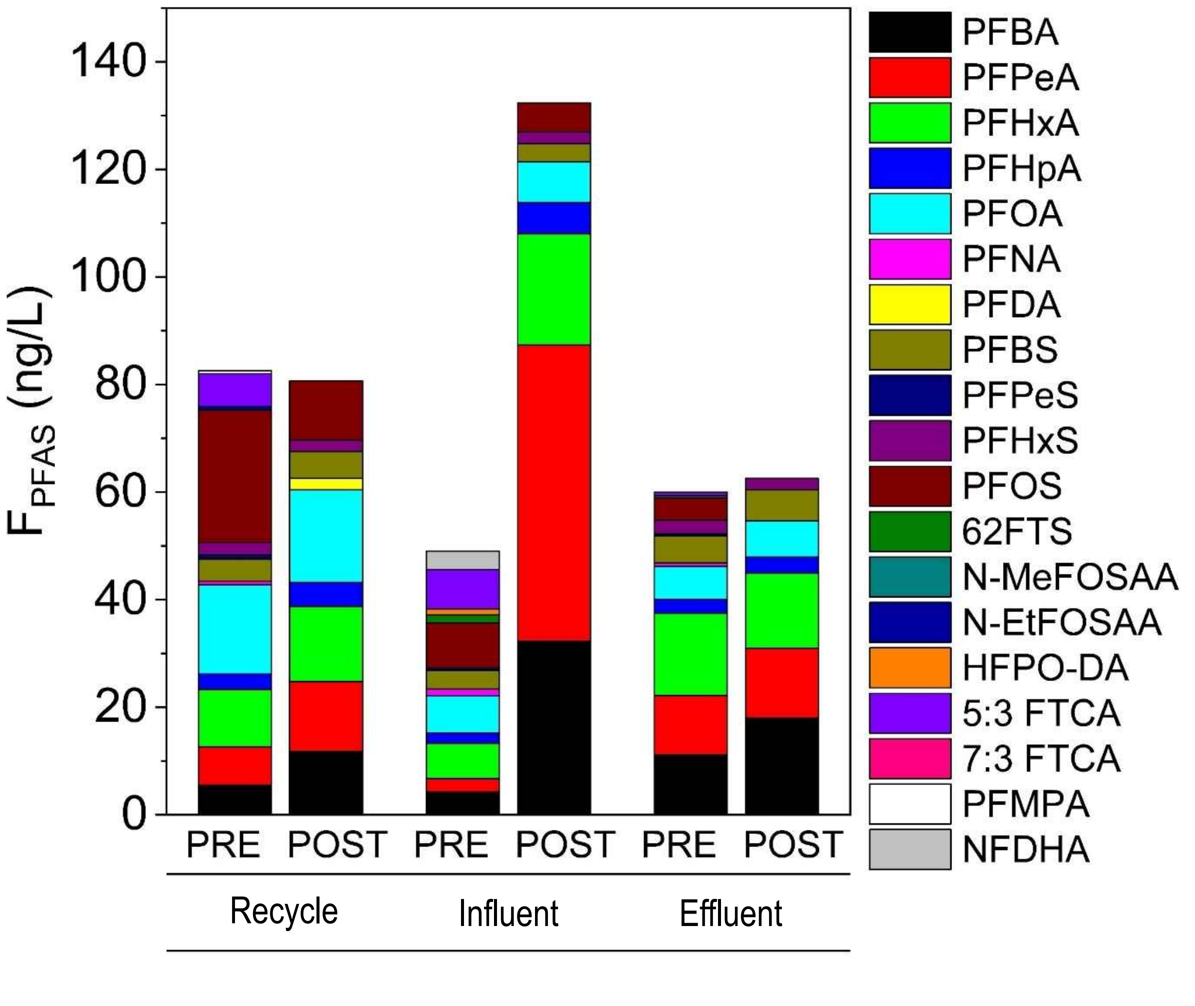
	Feed	Waste Activated Sludge
Facility #5	2.83 ± 0.22	2.73

Log k_d values are consistent with Ebrahimi et al., 2021, Chemosphere, 129530

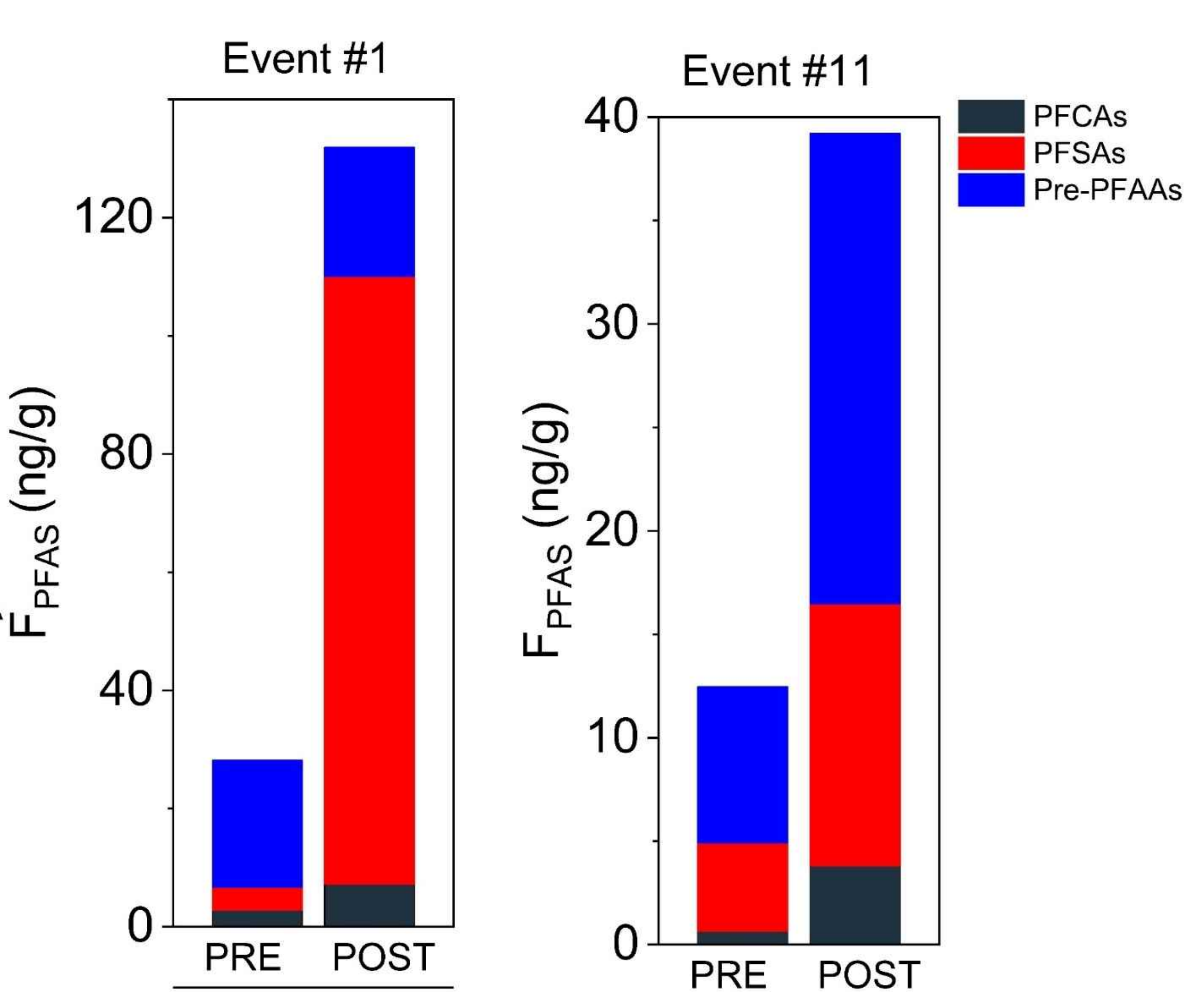
Total Oxidizable Precursors (TOP) Assay and Total Organic Fluorine (TOF)

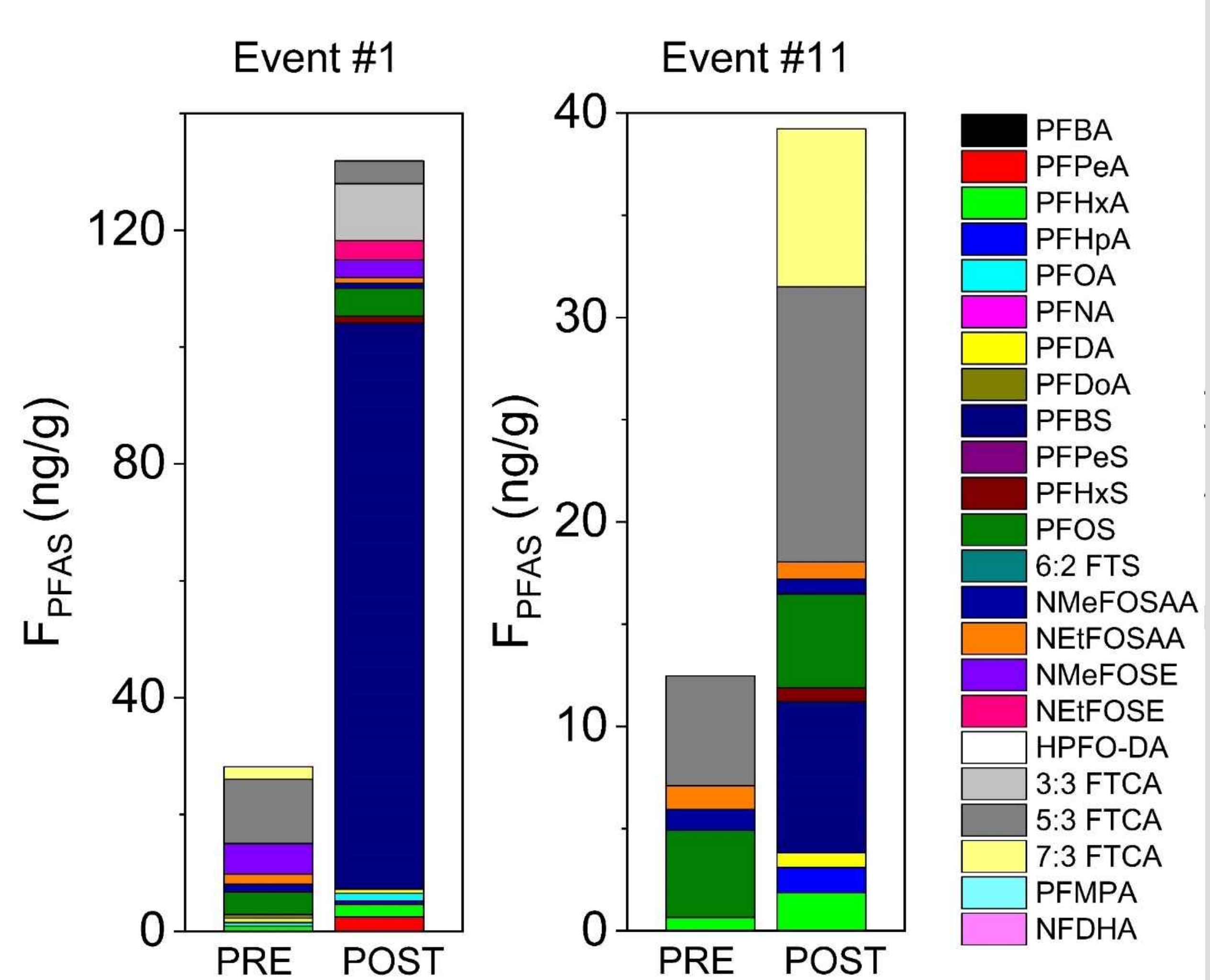
Results- TOP Assay Liquid Streams– Facility #3



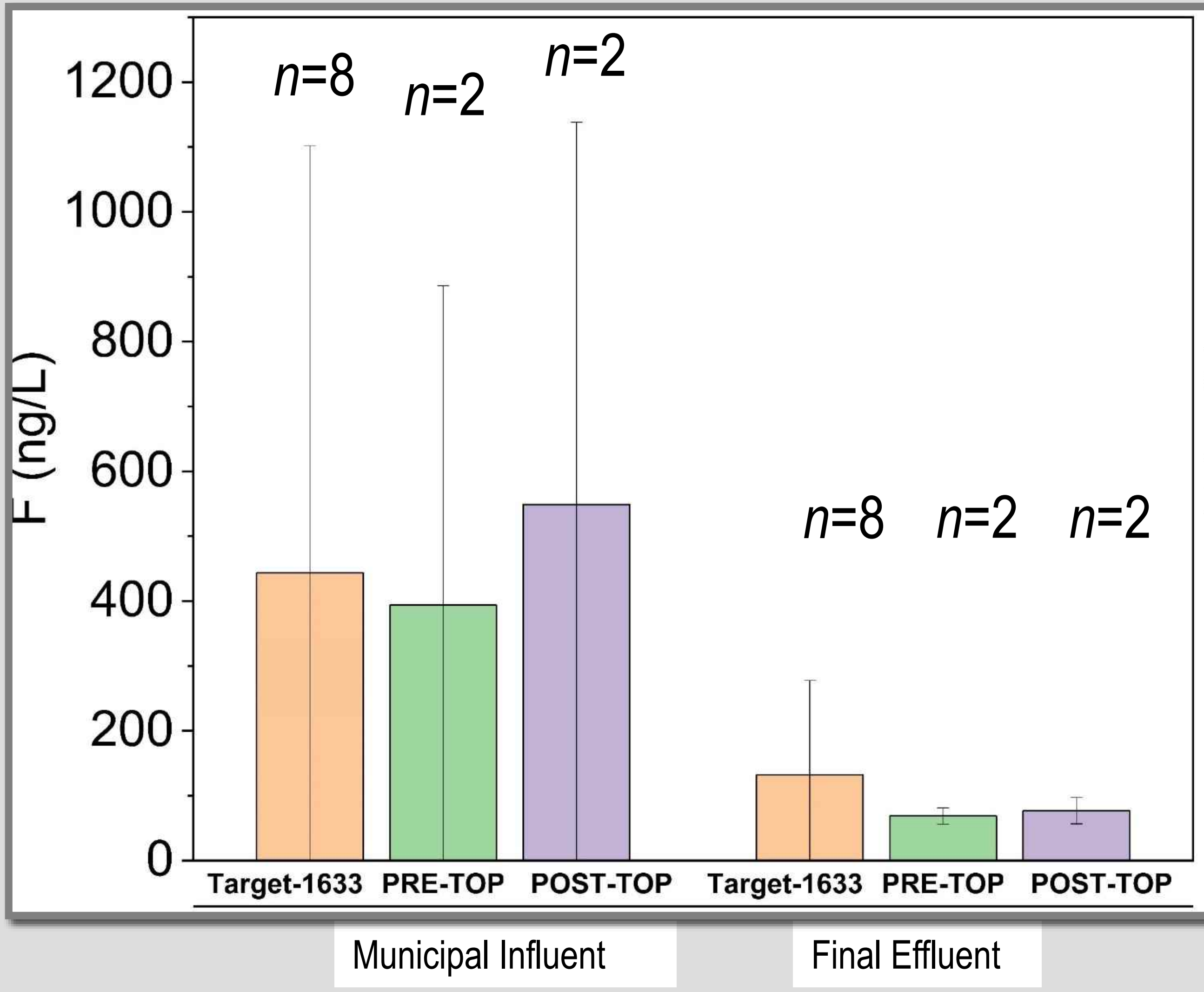


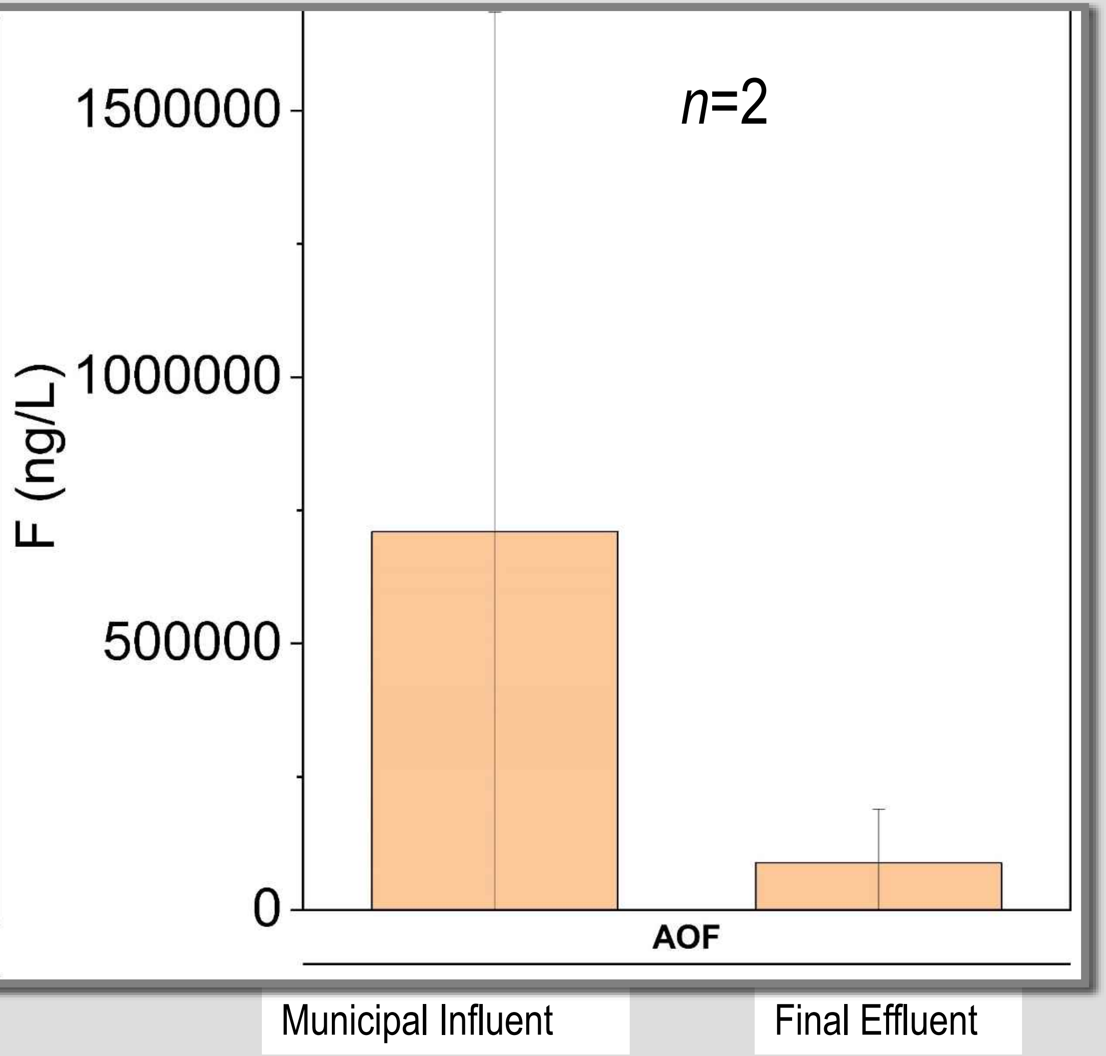
Results- TOP Assay Biosolid - Facility #3



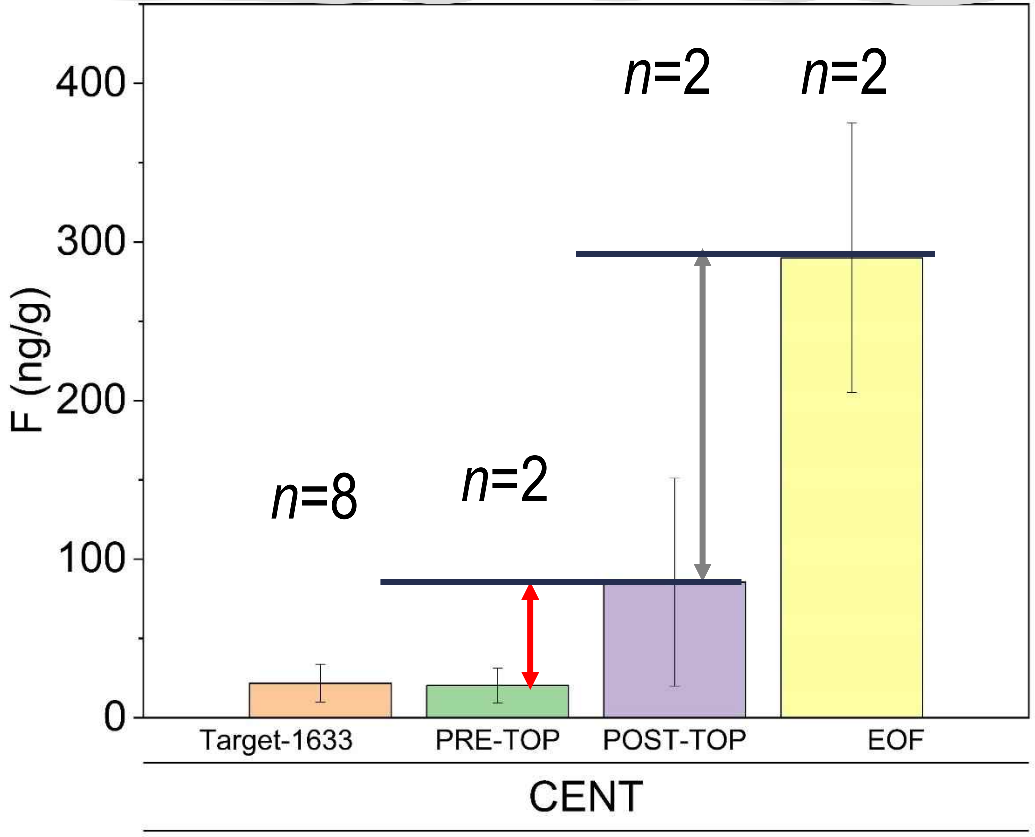


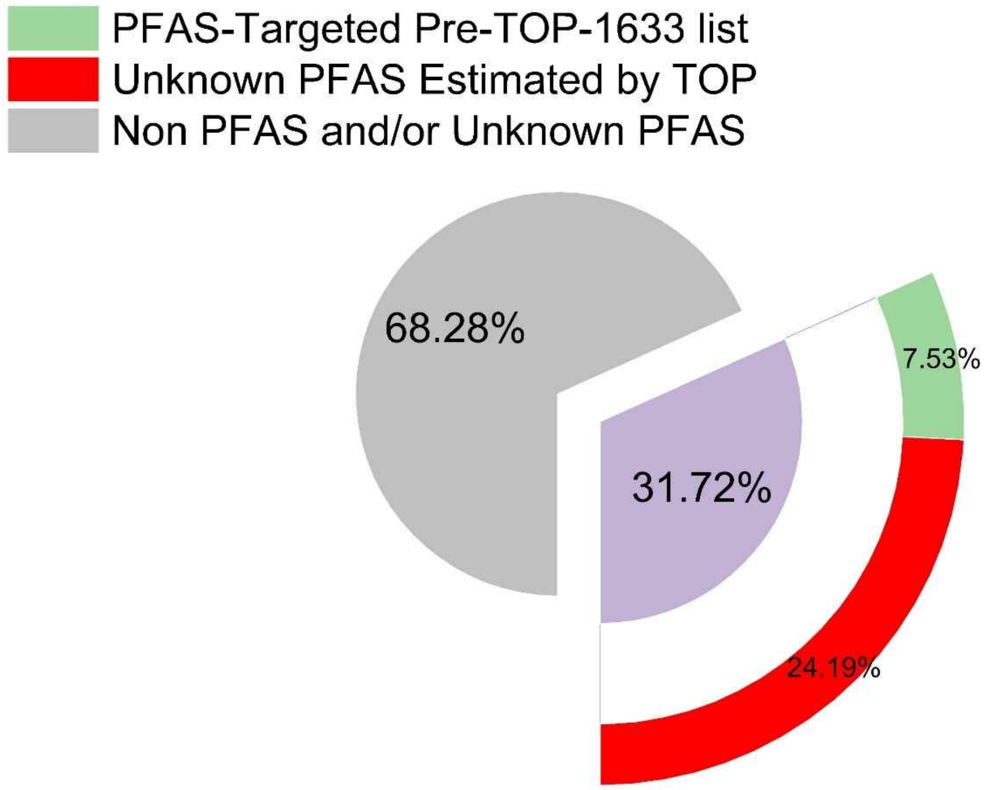
Results-Total Organic F Aqueous – Facility 3



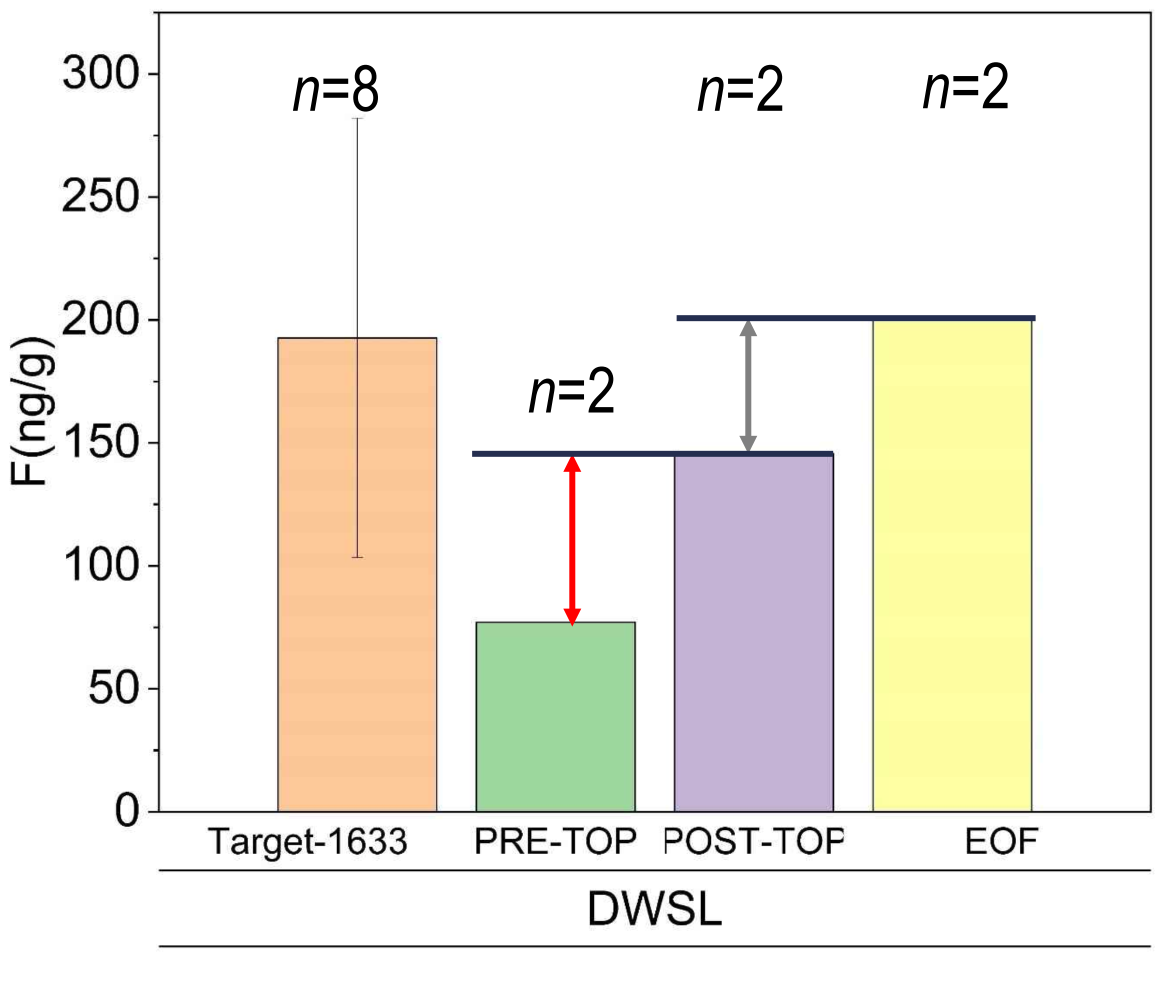


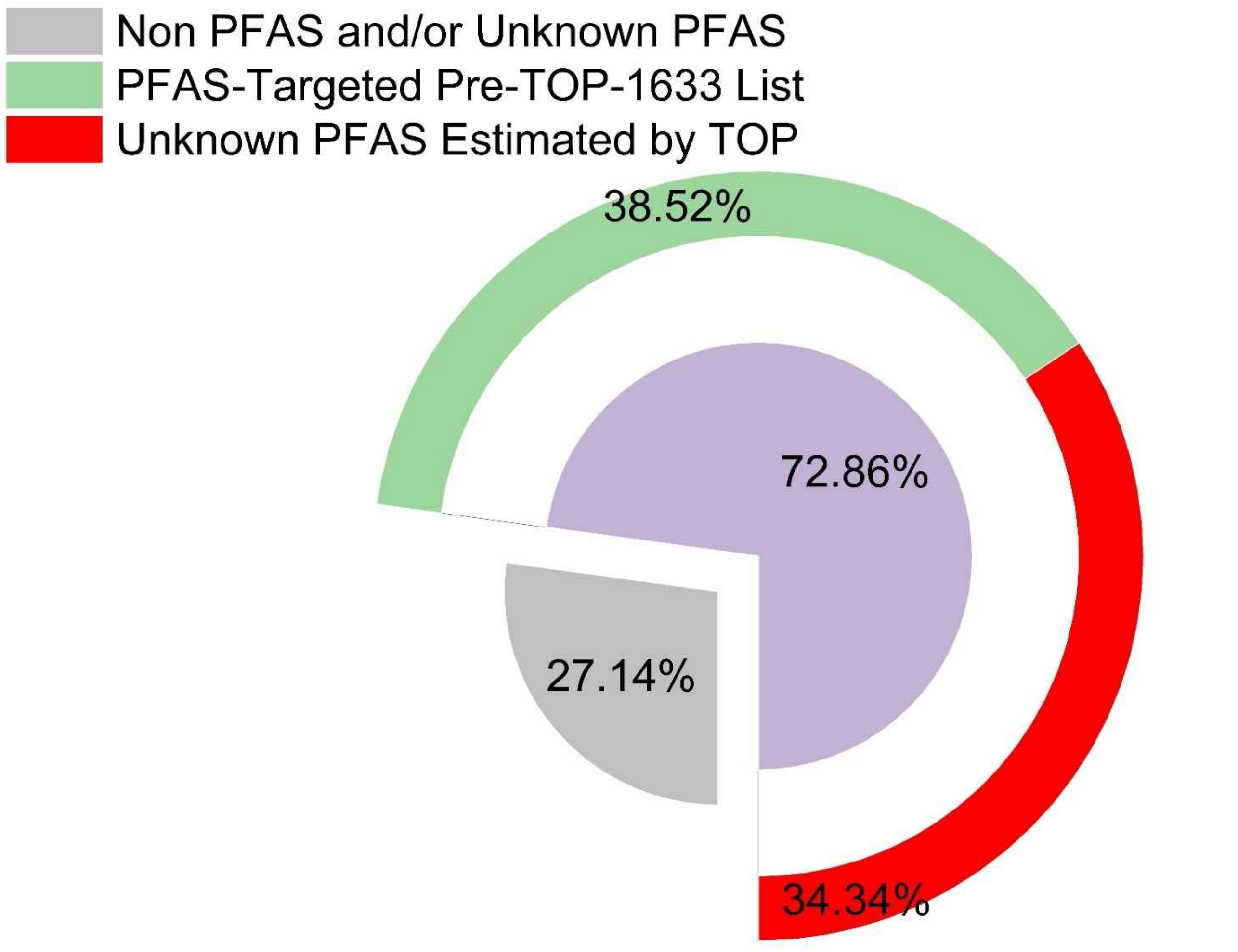
Results-Total F in Biosolid Facility 3



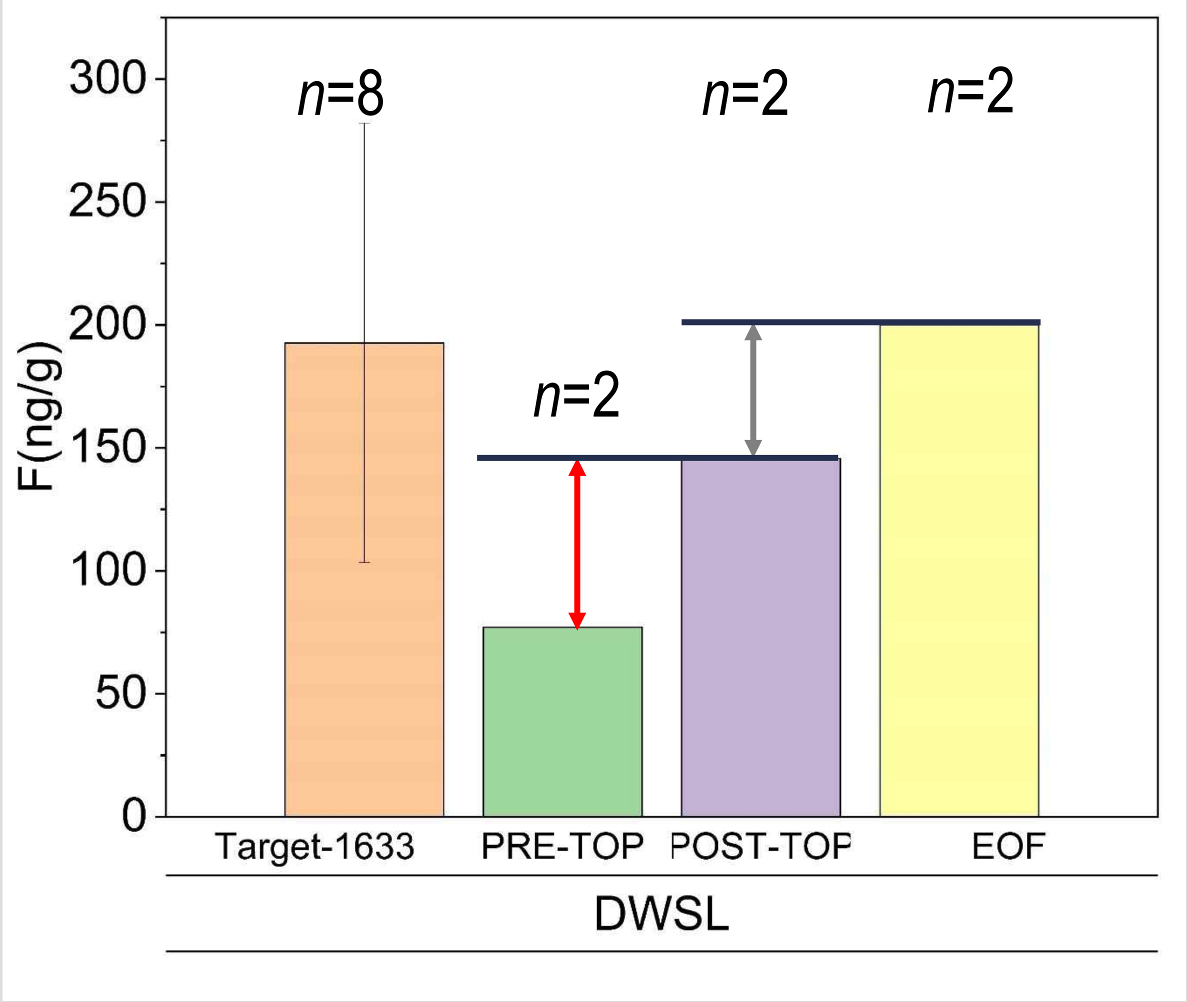


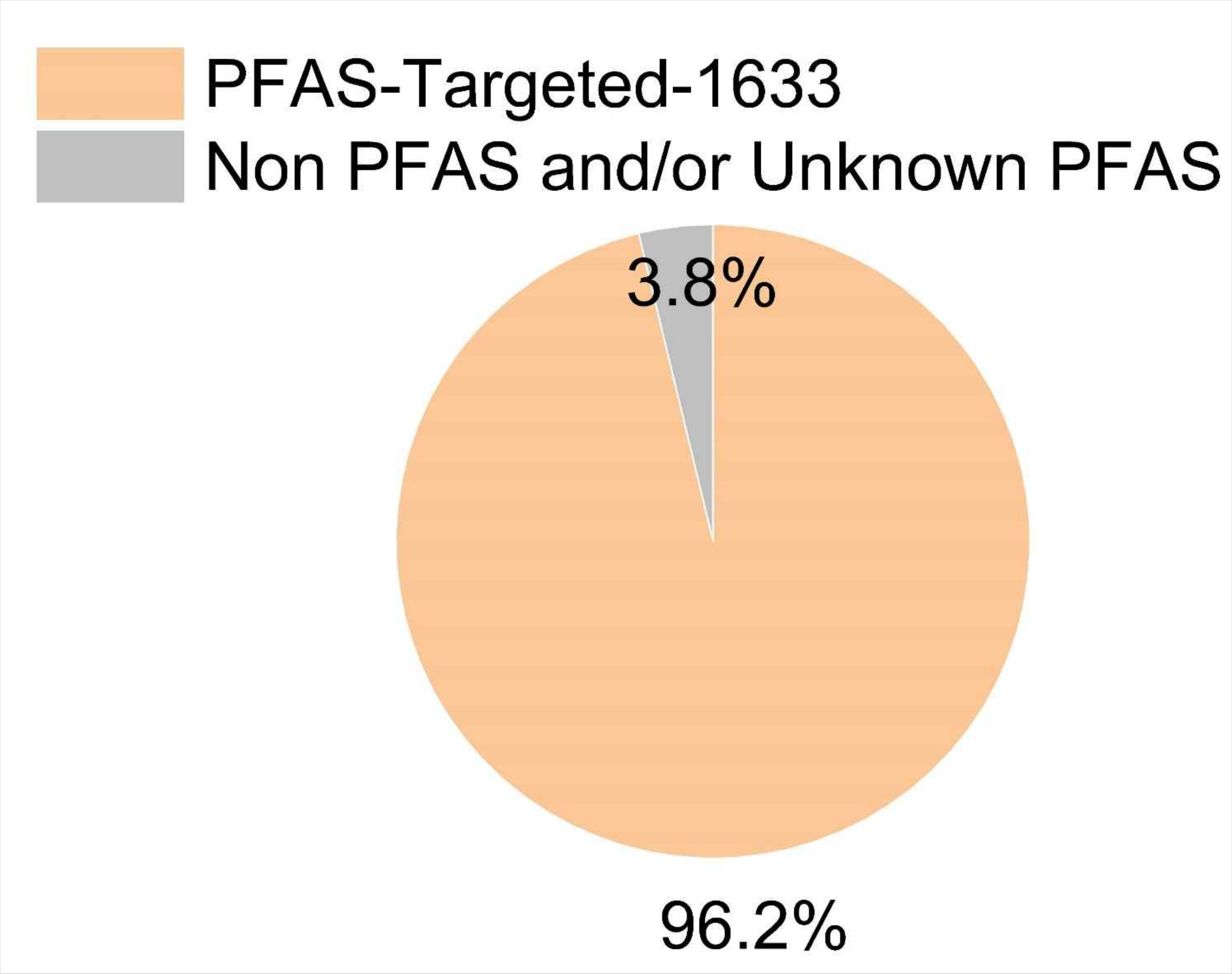
Results-Total F in Biosolid Facility 2





Results-Total F in Biosolid Facility 2





Preliminary Conclusions

- **Project still ongoing and assessing the origin of PFAS variability in WWTPs**
  - Specific sources may impact variability and offer a pretreatment option, e.g. landfill leachate
  - Indications for PFAS variations due to flow, simple HRT/SRT models may be required

- **General conclusion**
  - PFAS variability decreases from influent to effluent
  - PFAS Log K_d values imply an equilibrium for PFAS partitioning between solids and liquid streams
  - PFAS in incinerator ash is generally below detection limits

- **Data implies precursors transformation and potentially other organofluorine in WWTPs**

- **Significant analytical challenges even for large commercial analytical labs**

Thank You!

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