LAND APPLICATION OF BIOSOLIDS: TRENDS AND PERSPECTIVES

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Virtual Webinar

MIDWEST BIOSOLIDS ASSOCIATION

Land Application of Biosolids: Trends and Perspectives

Conduit of our wastes
Biosolids, Wastewater

- Introduction, Perceptions
- Occurrence of Organic Contaminants of Concern (COCs)
- COCs in biosolids processing examples
- COC Fate in a subset of biosolids-applied sites
- Feed Crop Uptake Snapshots: Greenhouse and Field
- Perspectives and a Path Forward

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EPA Office of Inspector General Report 2022

EPA Unable to Assess the Impact of Hundreds of Unregulated Pollutants in Land-Applied Biosolids

- The EPA identified 352 pollutants in biosolids that cannot be considered for regulation due to either lack of data or risk assessment tools.
- 61 pollutants designated as acutely hazardous, hazardous or priority pollutants plus pharmaceuticals, steroids, etc.

Response from USEPA Office of Water and Office of Enforcement and Compliance Assurance on Draft Report and OIG Evaluation

(Appendix D of OIG Report)

"We are concerned about how the science is presented in the OIG report. It is biased and raises alarm … and is taken out of context. ….

…..The presence of a pollutant in biosolids alone does not equate to scientific risk, but the EPA's Biosolids Program is working hard to prioritize its risk assessment work for known but not yet regulated pollutants."

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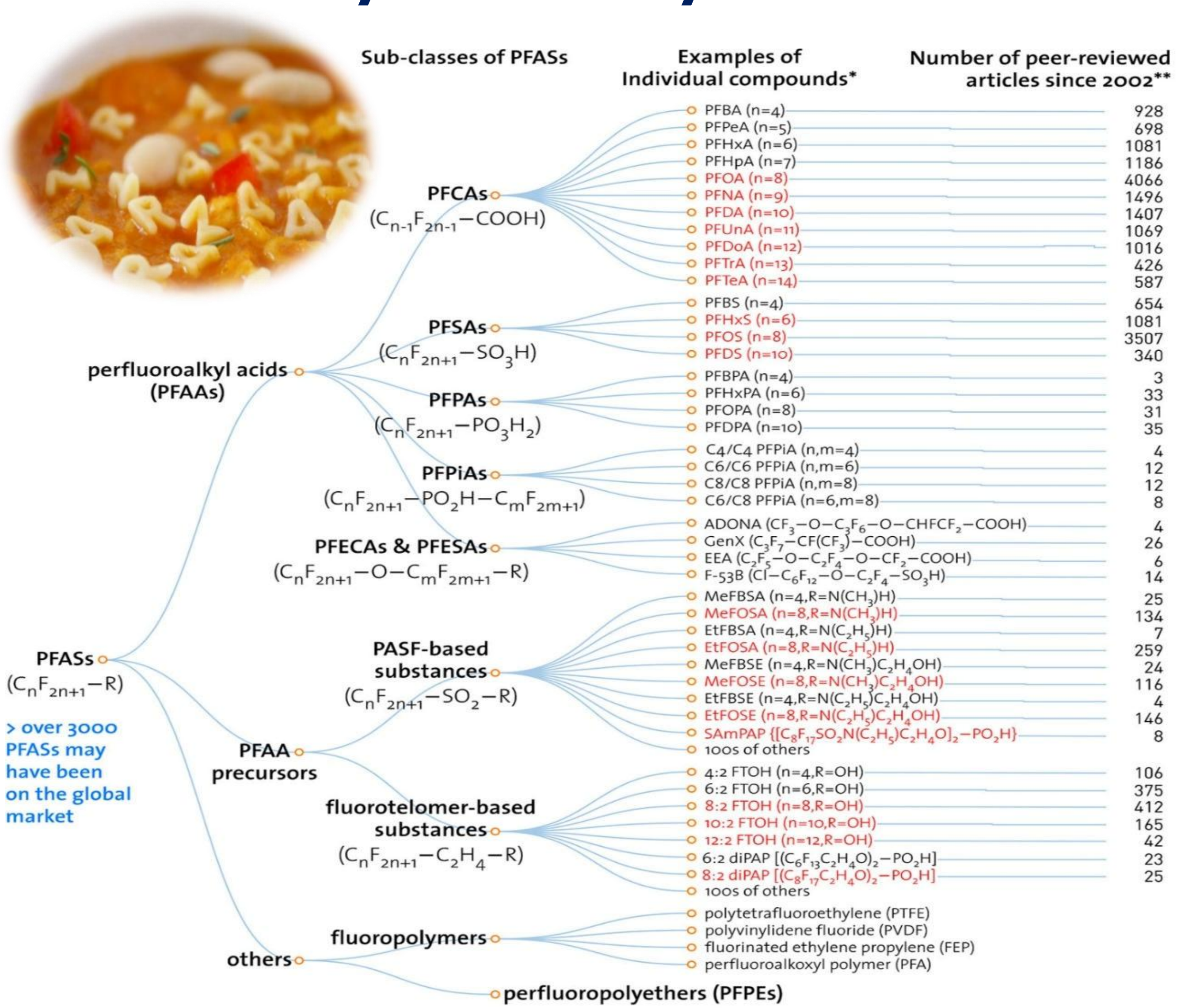
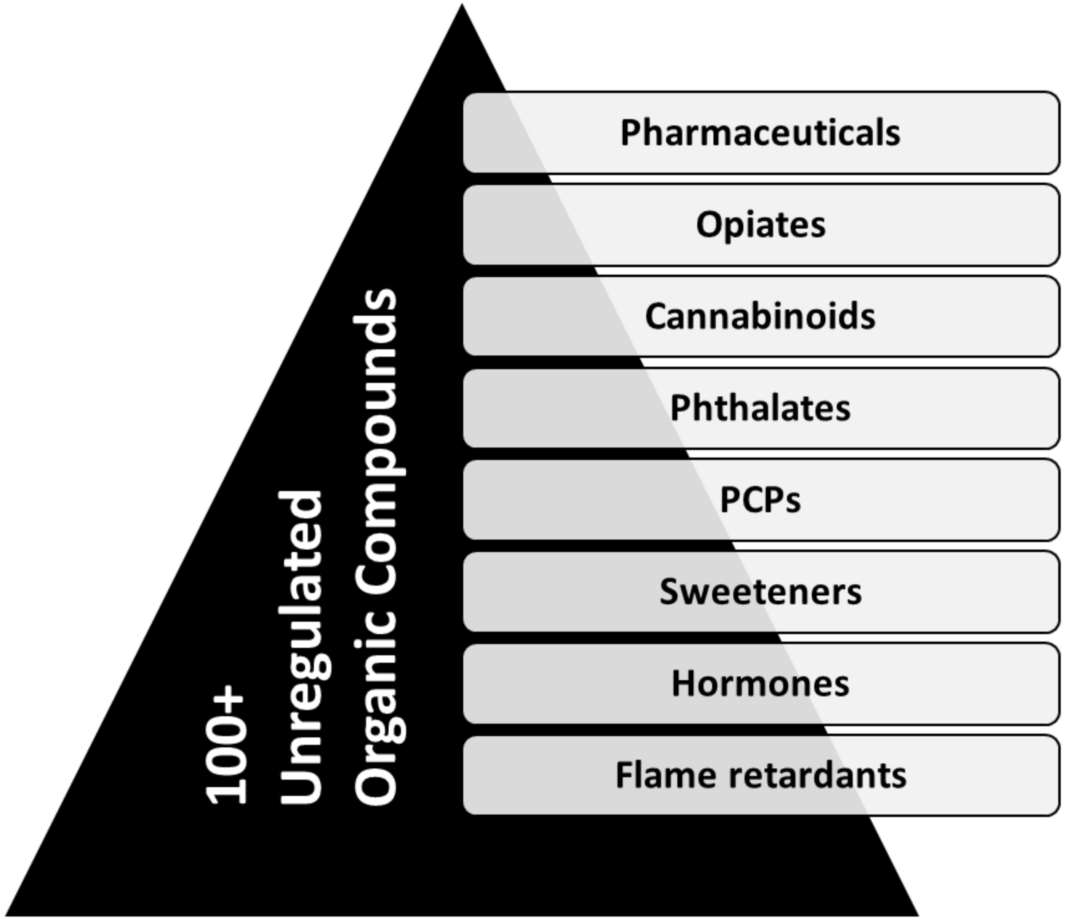
Per- & Polyfluoroalkyl Substances



* PFASs in **RED** are those that have been restricted under national/regional/global regulatory or voluntary frameworks, with or without specific exemptions (for details, see OECD (2015), Risk reduction approaches for PFASs. http://oe.cd/1AN).
** The numbers of articles (related to all aspects of research) were retrieved from SciFinder® on Nov. 1, 2016.

Source: Wang et al., 2017, ES&T, 51:2508-2518

Pharmaceuticals & personal care product chemicals (PPCPs) and still others



Reflects Innovations and Societal Use

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MANAGING CHEMICALS OF CONCERN (COCS) IN WASTEWATER AND BIOSOLIDS MANAGEMENT

Multiple PFAS sources – industry, landfills, domestic

Conduit of our wastes

Wastewater Influent → Sorption to Sludge → Effluent discharged to streams or used for irrigation

Sorption to Sludge → Biosolids → Land-applied as a soil amendment

Treatment process with type and treatment stage

COCs entering our WWRFs exit via effluent or sludge partially altered to other compounds or unaltered – most are NOT regulated

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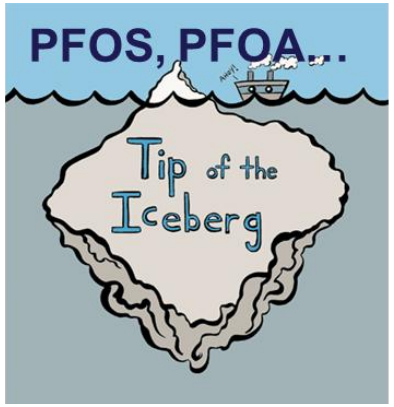
Most recent regulatory activity have been focused on PFAS



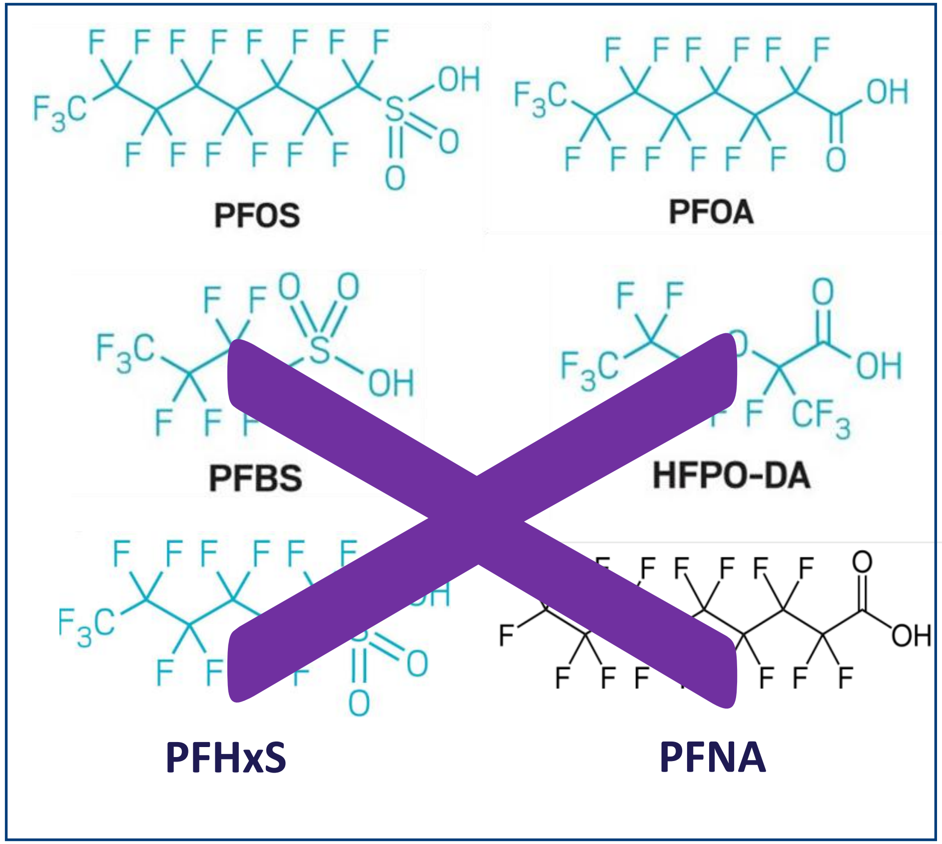
APRIL 10, 2024 U.S. EPA SETS PFAS MAXIMUM CONCENTATION LEVELS (MCLS) IN PPT (NG/L)

PFAS	MCLG	MCL (enforceable levels)
PFOA (C8)	Zero	4.0 ppt
PFOS (C8)	Zero	4.0 ppt
PFNA (C9)	10 ppt	10 ppt
PFHxS (C6)	10 ppt	10 ppt
PFBS (C4)	1000 ppt	1000 ppt
HFPO-DA (GenX Chemicals)	10 ppt	10 ppt
Mixtures of 2 or more PFNA, PFHxS, PFBS, and HFPO-DA	1.0 (unitless) Hazard Index Σ MCL/measured concentration	

MCLG = maximum contaminant level goals

2025

Per-



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REGULATED OR NOT WE HAVE TO ADDRESS PUBLIC/COMMUNITY PERCEPTION/CONCERNS

PFAS *'news'* has revied/escalated concerns about COCs in biosolids.

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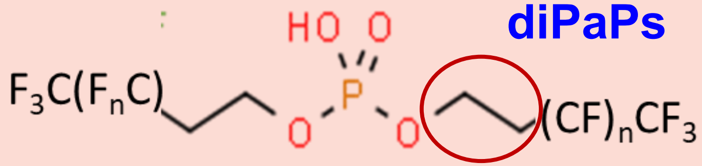
PFAS TRANSFORMATION IN SOLIDS PROCESSING IN WASTEWATER TREATMENT PLANTS AND AFTER LAND APPLICATION: A CASE OF MULTIPLICATION

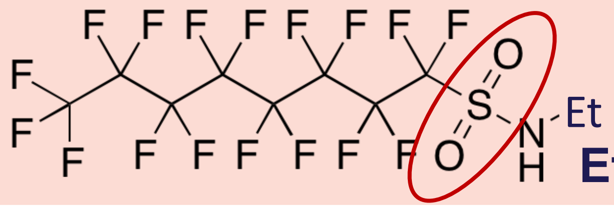
C8 Fluorotelomer-based Example



diPaPs

Precursors to PFAAs

C8 Electrochemically-derived Example

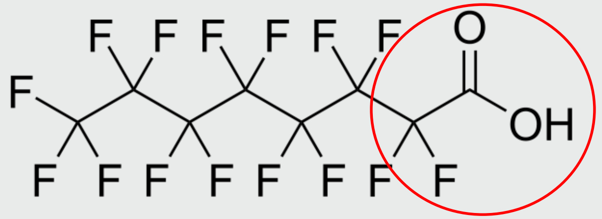


EtFOSA (C8)

Intermediates

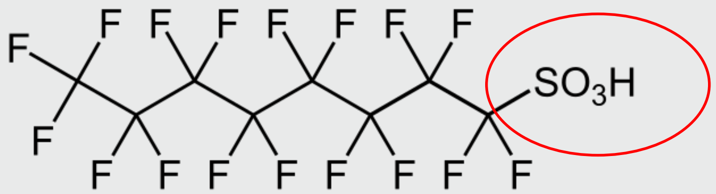
Multiple steps, pathways, and rates

Intermediates



Perfluoroalkyl carboxylic acids (PFCAs) with PFOA dominant

Intermediates and Terminal Metabolites (the PFAAs)
More mobile than precursors



C8, PFOS
Perfluoroalkyl sulfonic acid (PFSA)

PFCAs + PFSAs = Perfluoroalkyl acids (PFAAs)

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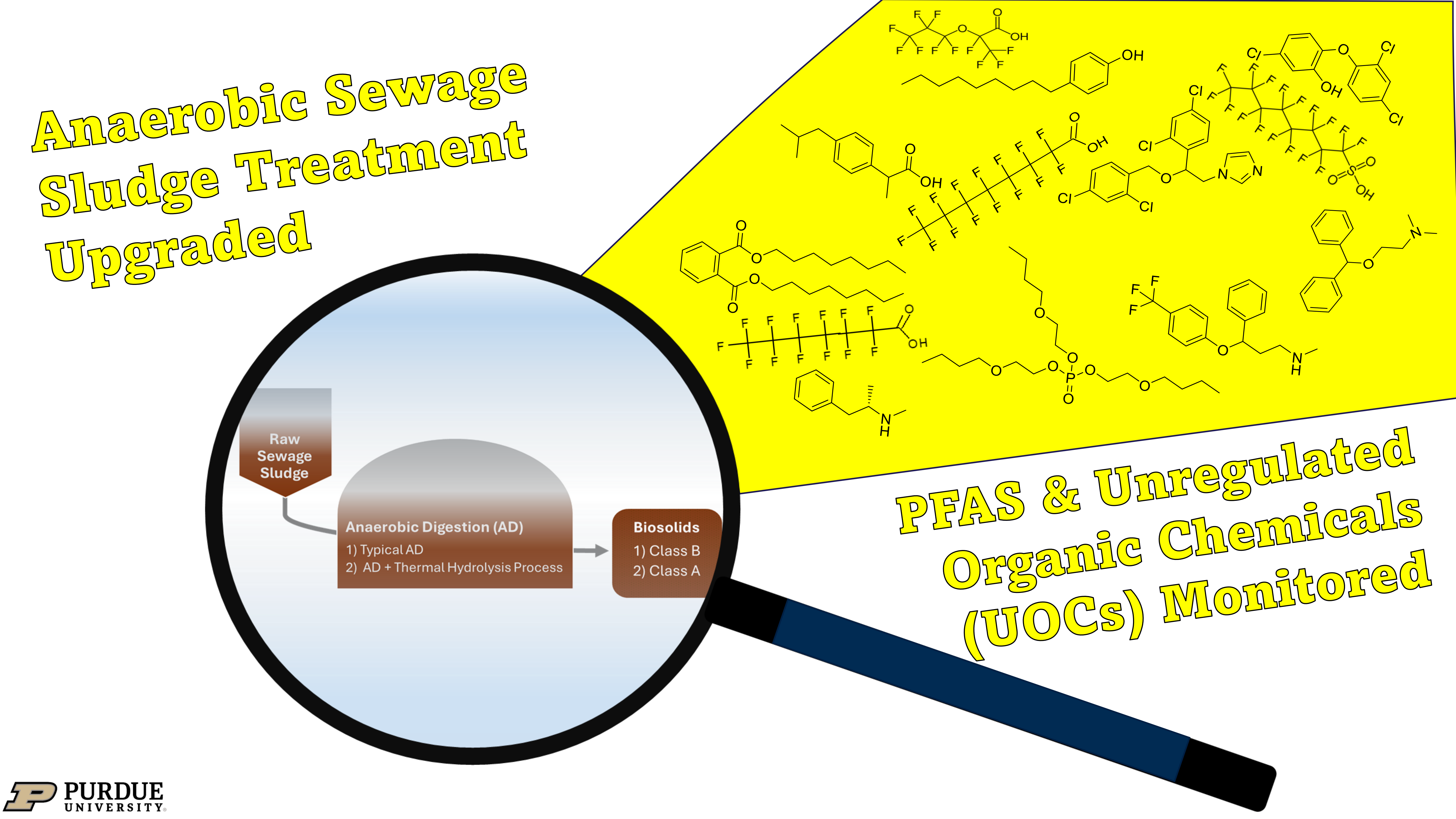
Anaerobic Sewage Sludge Treatment Upgraded
Raw Sewage Sludge
Anaerobic Digestion (AD)
1) Typical AD
2) AD + Thermal Hydrolysis Process
Biosolids
1) Class B
2) Class A
PFAS & Unregulated Organic Chemicals (UOCs) Monitored
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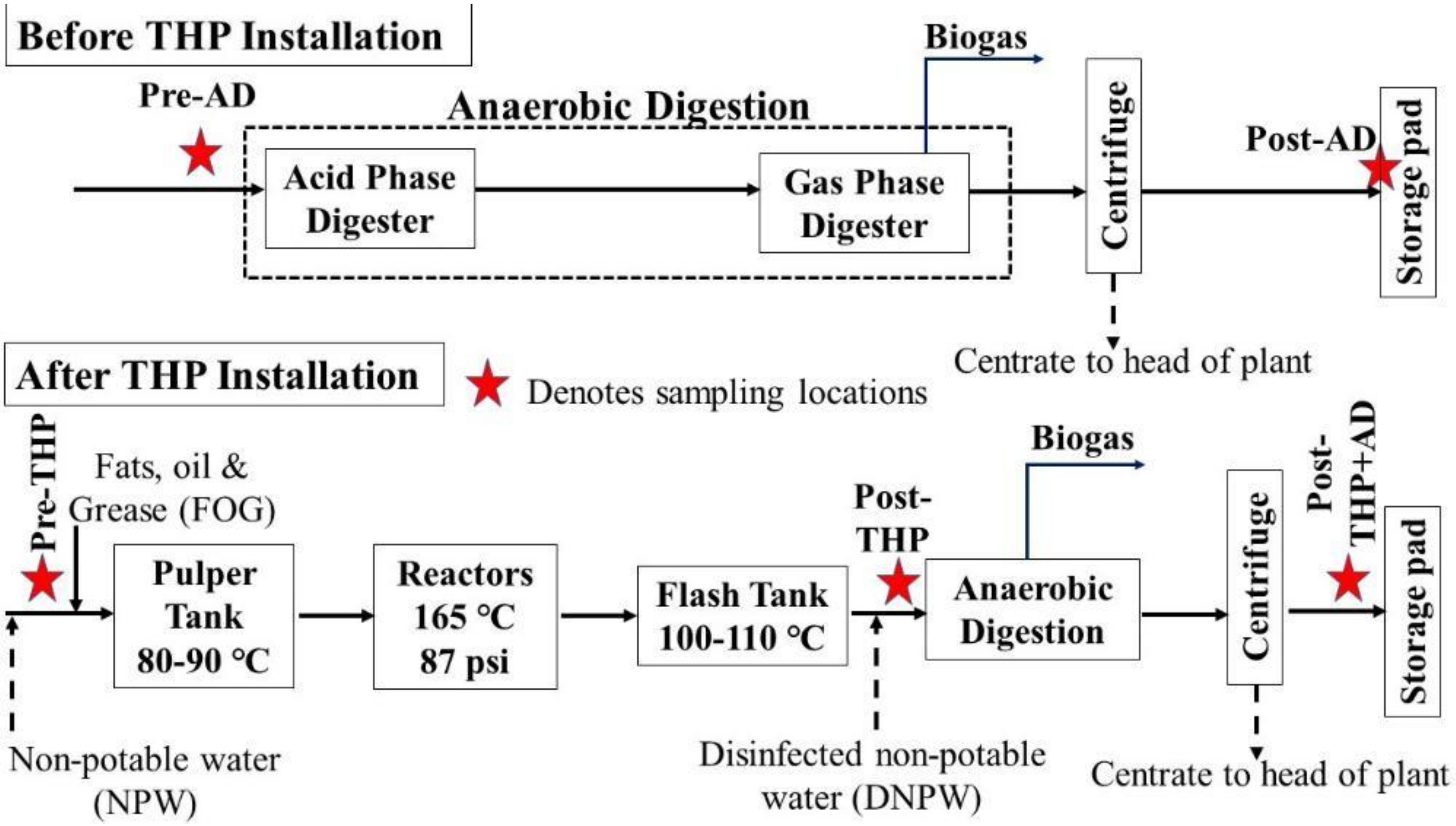
PFAS Transformation in Solids Processing to Biosolids for Application

Class B

Class A



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Thermal Hydrolysis Process (THP)

Biogas Production

↑ Sustainable Energy

↑ TS %

↓ Transportation

Class A Biosolids

↑ Fertilizer

↑ Digester Loading Capacity

↓ Incineration

↓ Landfill

- ✓ Biogas production is used towards system operation
- ✓ Higher Total Solids reduces hauling costs (lower water weight) and the associated greenhouse gasses
- ✓ Class A biosolids are land applied as fertilizer
- ✓ The increased biosolid treatment capacity and reduces what may be going to incineration or landfilling

↓ Carbon

Sustainability

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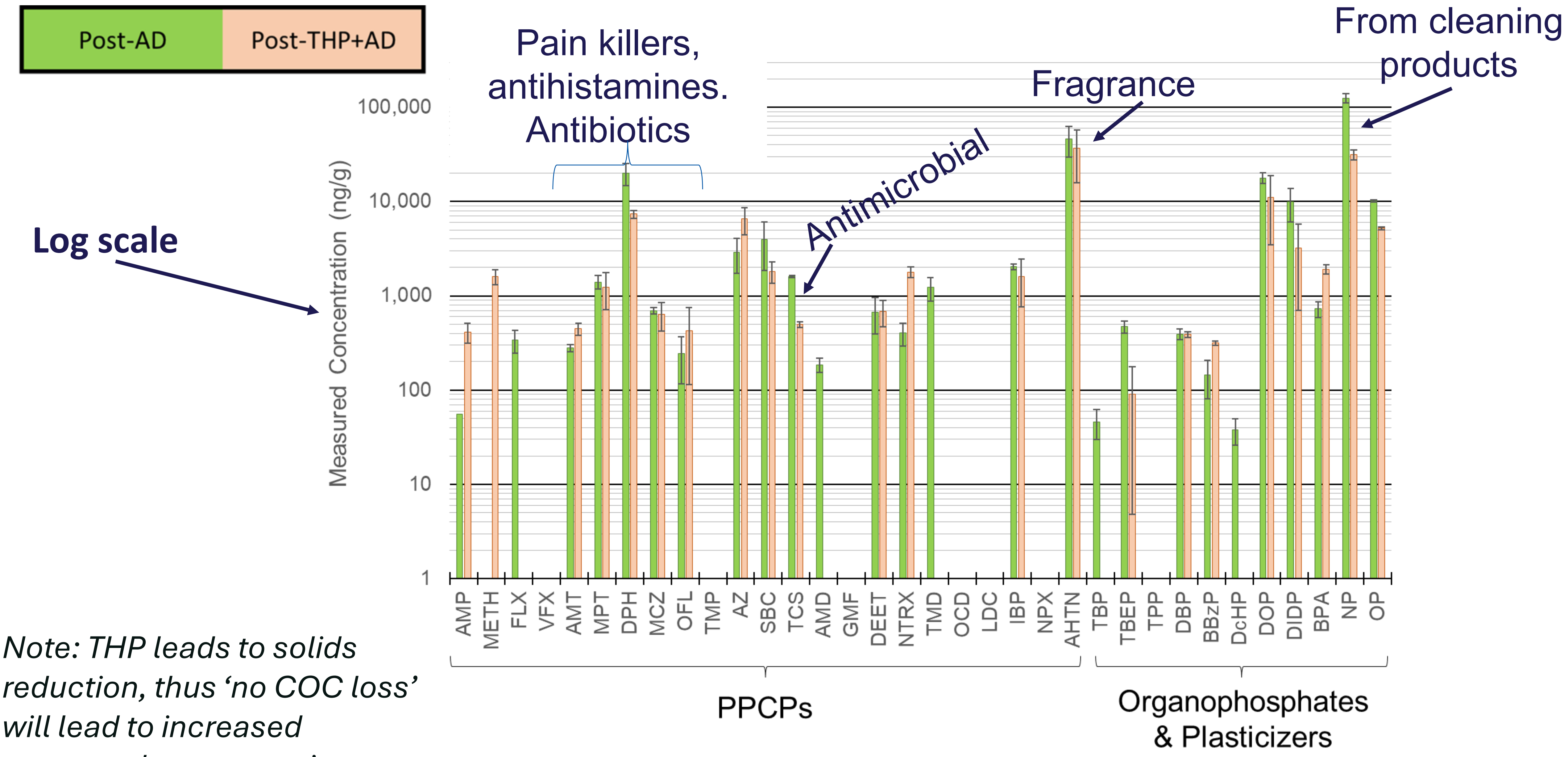
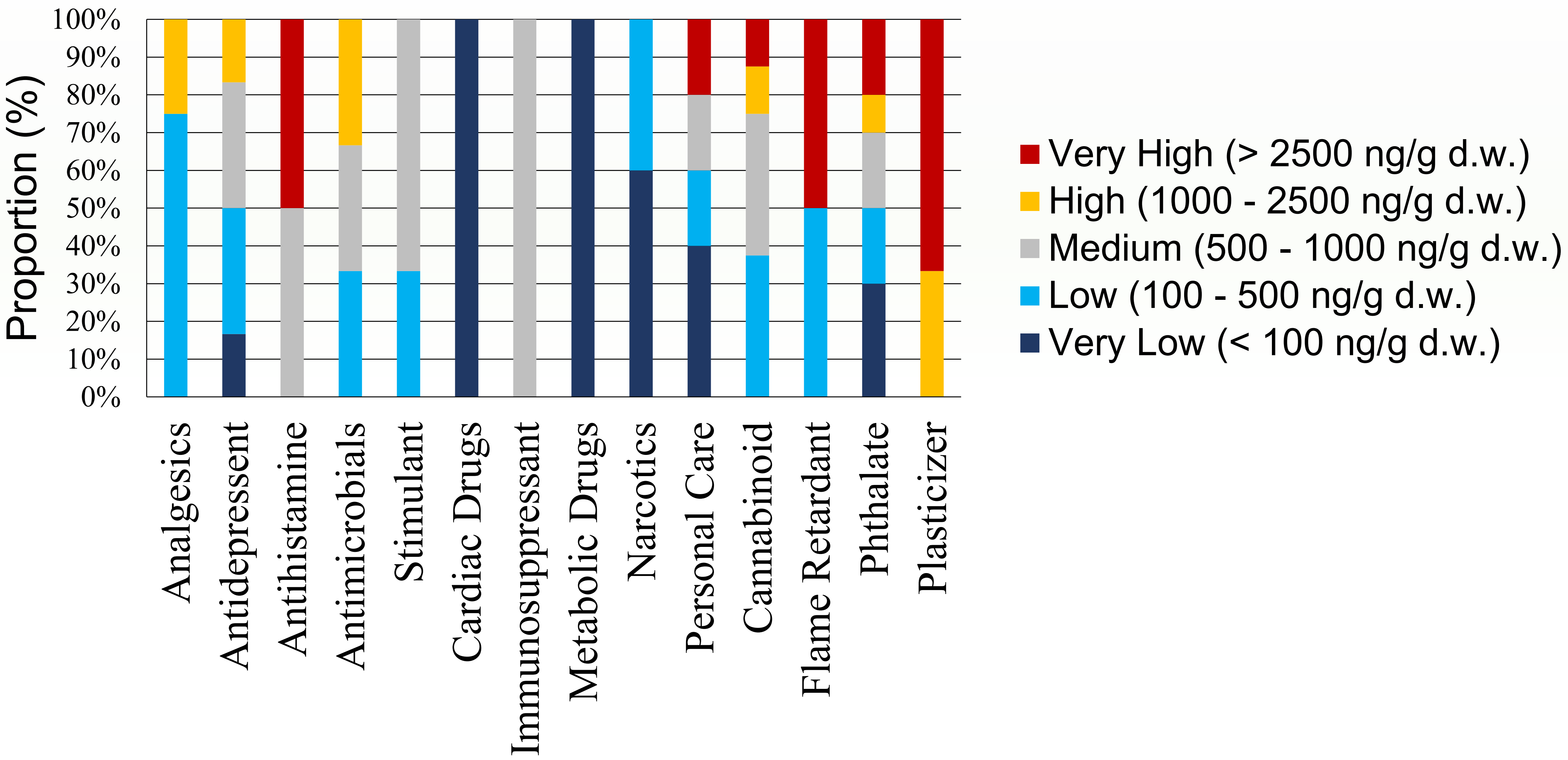
Post-AD and Post THP+AD



Note: THP leads to solids reduction, thus 'no COC loss' will lead to increased measured concentrations

Costello et al., awaiting final QAQC checks for manuscript submission

Class A Biosolids: THP Product Example



Costello et al., awaiting final QAQC checks for manuscript submission

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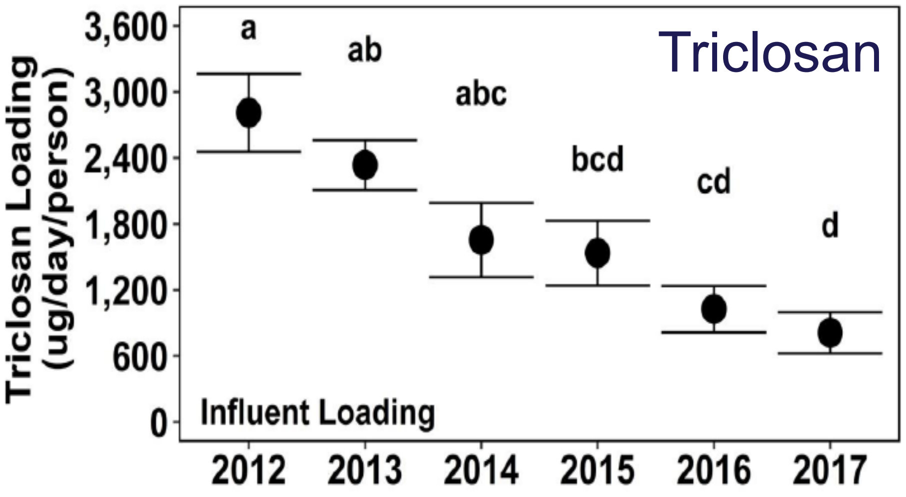
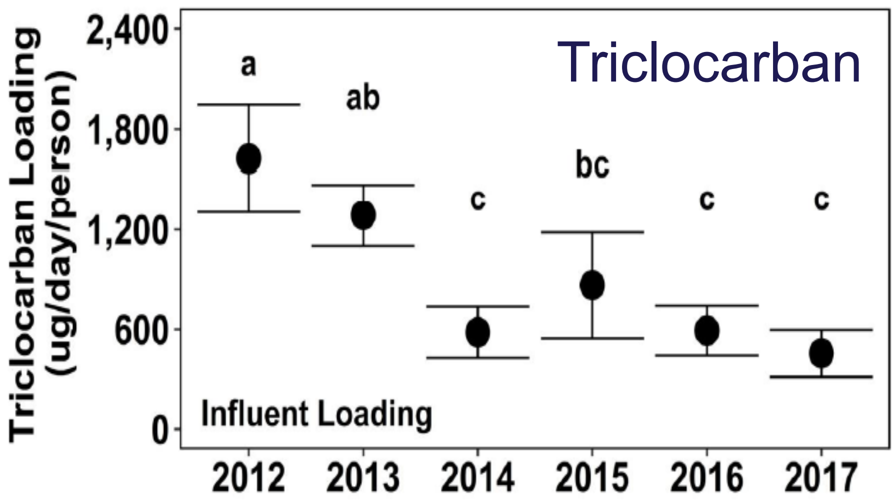
We have experienced similar trends with other chemicals

TRICLOSAN & TRICLOCARBAN (ANTIMICROBIAL AGENTS)
(INFLUENT: μG/DAY/PERSON VS SAMPLING YEAR 2012-2017)





- Fingerprint of regulations and consumer choices
- Consumer choices can lead to some volunteer removal from products prior to regulations
- Regulations in Sept 2016 and Dec. 2017 eliminated their use in many products

(Chicago MWRD: Brose et al., 2019, Water Environment Research, https://doi.org/10.1002/wer.1101

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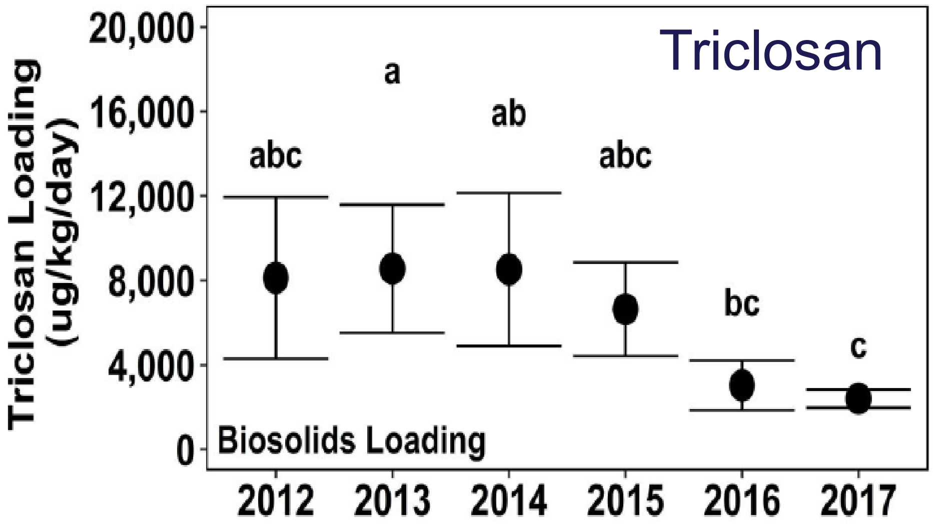
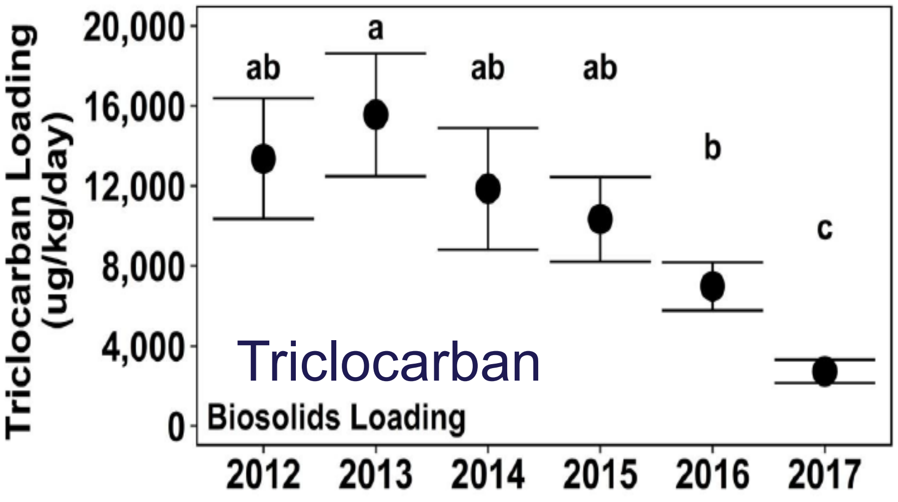
We have experienced similar trends with other chemicals

TRICLOSAN & TRICLOCARBAN IN BIOSOLID (ANTIMICROBIAL AGENTS)

(BIOSOLIDS LOADING: µG/DAY/PERSON VS SAMPLING YEAR 2012-2017)





- <u>Decline</u> over time also observed in biosolids
- <u>Consumer</u> opinions and choices make a difference

(Chicago MWRD: Brose et al., 2019, Water Environment Research, https://doi.org/10.1002/wer.1101

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Considering Hazards (EPA HCD, Comptox)

Concentration Range

- Very High (> 2500 ng/g d.w.)
- High (1000 - 2500 ng/g d.w.)
- Medium (500 - 1000 ng/g d.w.)
- Low (100 - 500 ng/g d.w.)
- Very Low (< 100 ng/g d.w.)

Hazard Rating

VH - Very High | H - High | M - Medium | L - Low

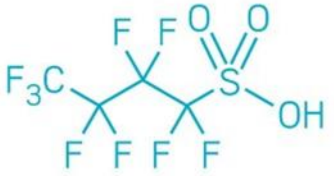
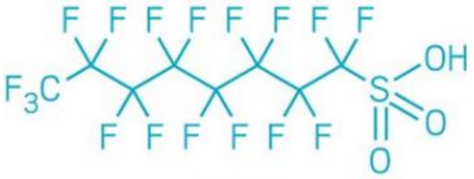
Compound Identification		Human Health Effects		Ecotoxicity (Aquatic)		Fate (QSAR Model)
Name	**Class**	EDC	Dev	Acute	Chronic	Bioacc
Methylparaben	**PCPs**	H	H	M	H	L
Tonalide		H	H	H	VH	L
Dicyclohexyl phthalate	**Phthalate**	H	H	H	H	H
Dihexyl phthalate		H	H	H	VH	L
Di-n-octyl phthalate		H	M	H		VH
Dibutyl phthalates		H	H	VH	H	M
Dinonyl phthalate		H	H	H		L
Benzyl butyl phthalate		H	H	VH	VH	H
Di(2-ethylhexyl) phthalate		H	H	H	VH	VH
Diisodecyl phthalate		H	H	VH		L
Bisphenol A	**Plasticizer**	H	H	H	VH	L
Nonylphenol		H	M	VH	VH	H
Octylphenol		H	H	VH	VH	M
Triphenyl phosphate	**Flame Retardant**	H	L	VH	VH	H
Tris(2-butoxyethyl) phosphate		H	H	M	L	L

Name	Class	EDC	Dev	Acute	Chronic	Bioacc.
Acetaminophen	**Analgesic**	L	L	M	VH	L
Doxepin	**Antidepressant**	H	H	H		L
Venlafaxine		H	H	H		L
Fluoxetine		L	H	VH	VH	M
Amitriptyline + Maprotiline		H	H	VH	VH	H
Diphenhydramine	**Antihistamine**	L	L	H	VH	M
Miconazole	**Antimicrobial**	L	L	VH	VH	M
Triclosan		H	M	VH	VH	L
Cannabigerol	Cannabinoid	H	H	VH		L
delta-8-Tetrahydrocannabinol		H	H	VH		M
Tetrahydrocannabivarin		H	H	VH		M
Caffeine		H	H	L	H	L
Ibuprofen		H	H	L	VH	L
Cannabichromene		H	H	VH		M
Cannabicyclol		H	H	VH		M
delta-9-Tetrahydrocannabinol		H	H	VH		M
Cannabidiol		H	H	VH		M
Cannabinol		H	H	VH		M
Amiodarone	**Other Pharm.**	I	H	VH	H	M
Hydroxychloroquine		H	H	H	H	L
Simvastatin		L	H	VH		I
Codeine	**Narcotics**	H	H	H		L
Fentanyl		H	H	VH		L
Methadone		H	H	H	VH	M
Naltrexone		H	H	H		L

- Concerns are for aquatics
- Some pharms, fragrances and plasticizers are of high concern

https://www.epa.gov/chemical-research/cheminformatics

MOVING ON TO PFAS IN BIOSOLIDS PROCESSING

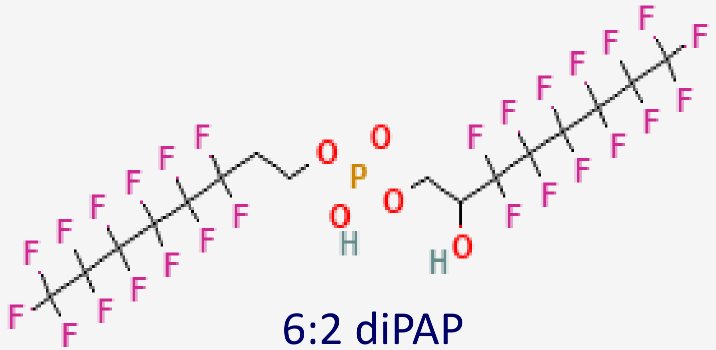
- Short chain homologues such as PFBS substituted PFOS  for 

PFBS PFOS

U.S. EPA Chain Length Categories

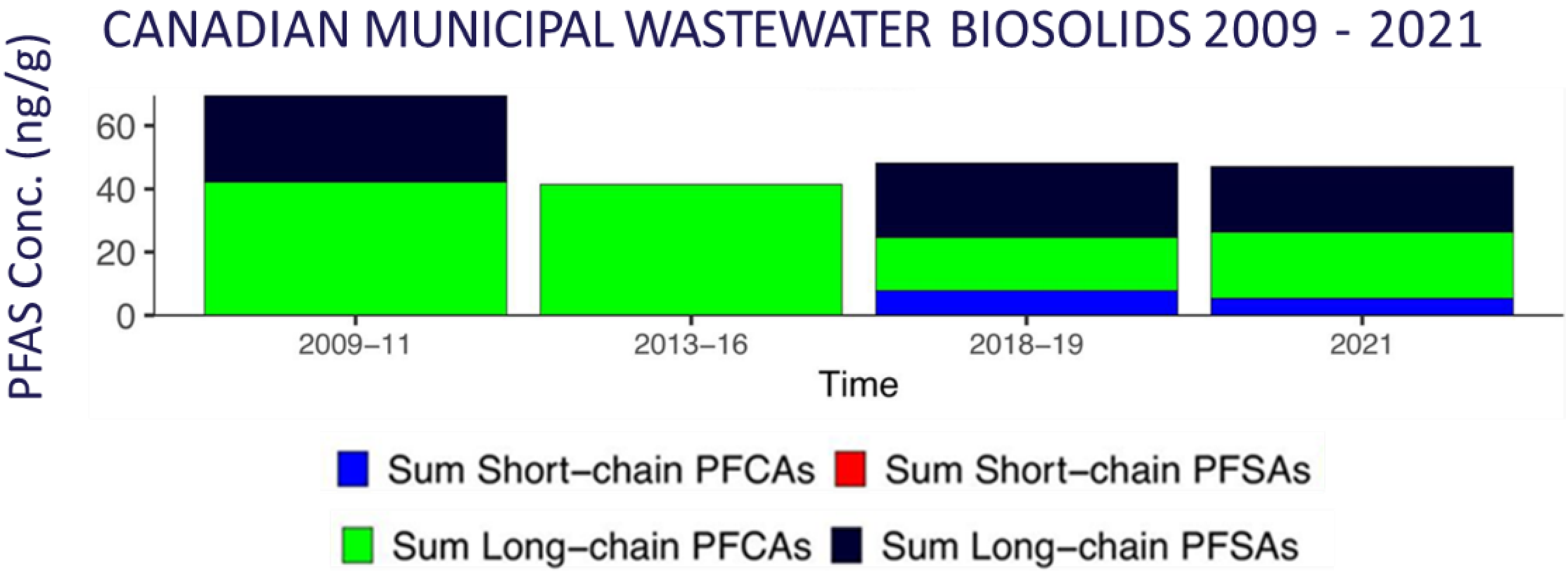
# of Carbons	4	5	6	7	8	9	10	11	12
PFCAs	Short-chain PFCAs				Long-chain PFCAs				
	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFUnA	PFDoA
PFSAs	PFBS	PFPeS	PFHxS	PFHpS	PFOS	PFNS	PFDS	PFUnS	PFDoS
	Short-chain PFSAs		Long-chain PFSAs						

•Precursor example: Fluorotelomer-based substitutes ≤ C6 example replacing C8



6:2 diPAP

PFAS Occurrence in biosolids over time



- Except for PFOS, long- chain PFAS generally decreased over time.
- PFOS did not change with time indicating slow response to phase-outs/regulations and PFOS' overall stickiness.

https://doi.org/10.1016/j.scitotenv.2023.168638

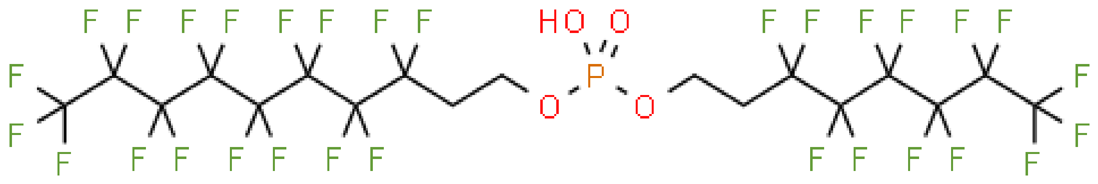
USA EXAMPLE: PFAS IN 2018-2025 BIOSOLIDS (PPB DRY WEIGHT)

	PFAS	~Min	~Max
Perfluoroalkyl acids (PFAAs) -terminal metabolites	PFOS	< LOD	130
	PFHxS	< LOD	50
	PFOA	< LOD	30
	PFHxA	< LOD	30
PFAA precursors/ intermediates	6:2 FTS	< LOD	15
	8:2 FTS	< LOD	30
	MeFOSAA	< LOD	100
	EtFOSAA	< LOD	50
PFAA intermediates	7:3 FTCA	< LOD	100
	5:3 FTCA	< LOD	220
	3:3 FTCA	< LOD	220

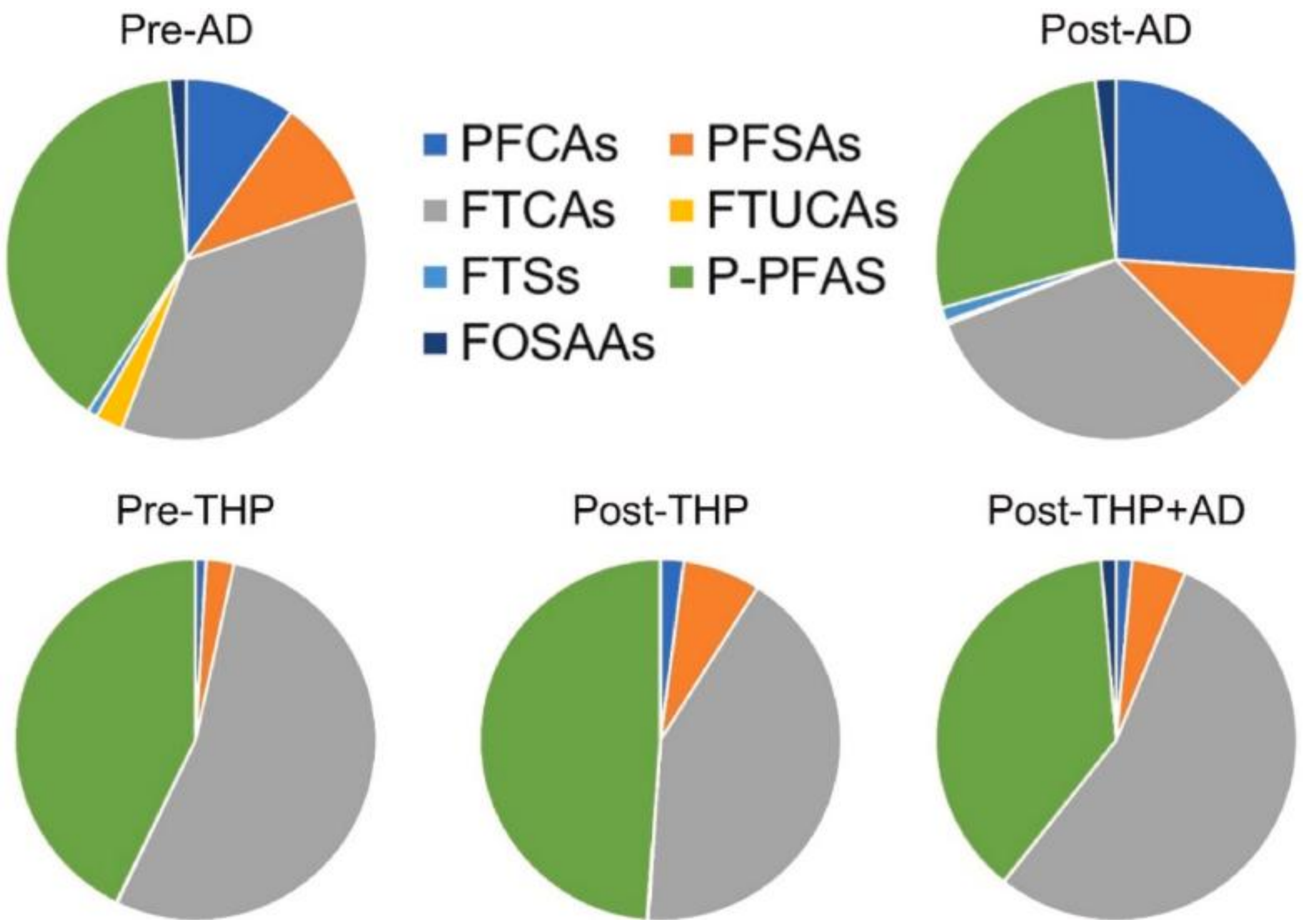
Some Additional Precursors

PFAS	~Min	~Max
6:2 diPAP	10	400
8:2 diPAP	0	200
6:2 PAP	20	340
6:6 PFPI	0	9
6:8 PFPI	0	4.4

- For most utilities, identified precursors are typically at least 75% of the quantifiable PFAS fluorine mole balance



PFAS Transformation Example in Solids Processing to Class B Biosolids



AD: Anaerobic Digestion

- Bulk of the PFAS are precursors and most not measured in the current EPA 40 targets list
- Digestion to remove pathogens, etc. leads to PFAS conversion to PFAAs (orange and blue)

THP + AD

- THP prior to AD reduced/slowed transformation to PFAAs leaving a larger fraction of FTCA intermediates in the final biosolids.

Alukkal, Lee et al., 2024 https://doi.org/10.1016/j.chemosphere.2024.143406

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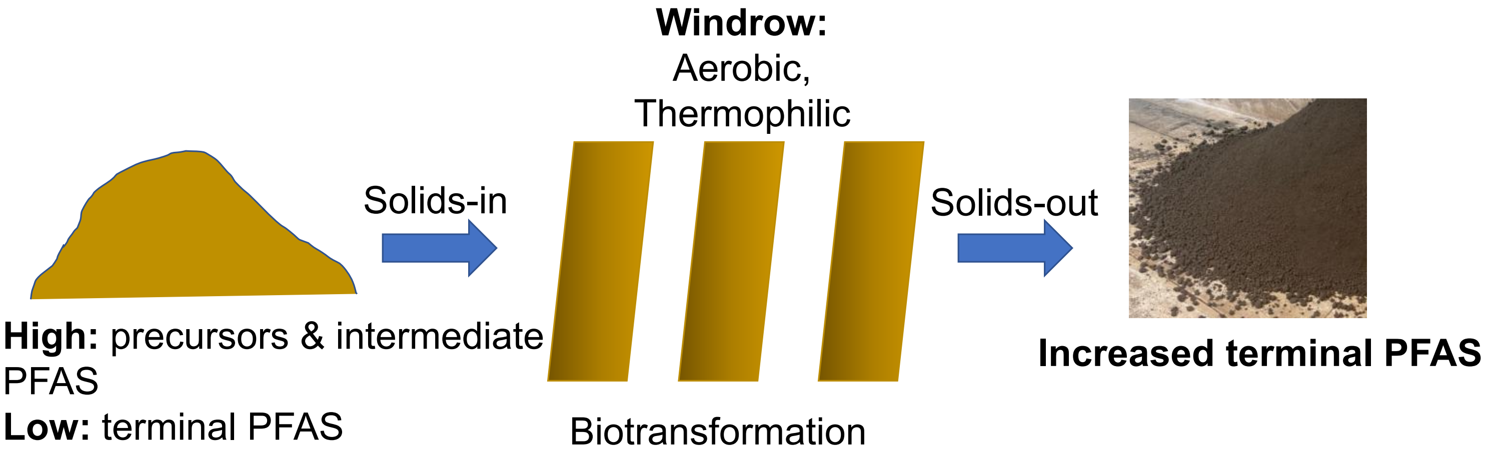
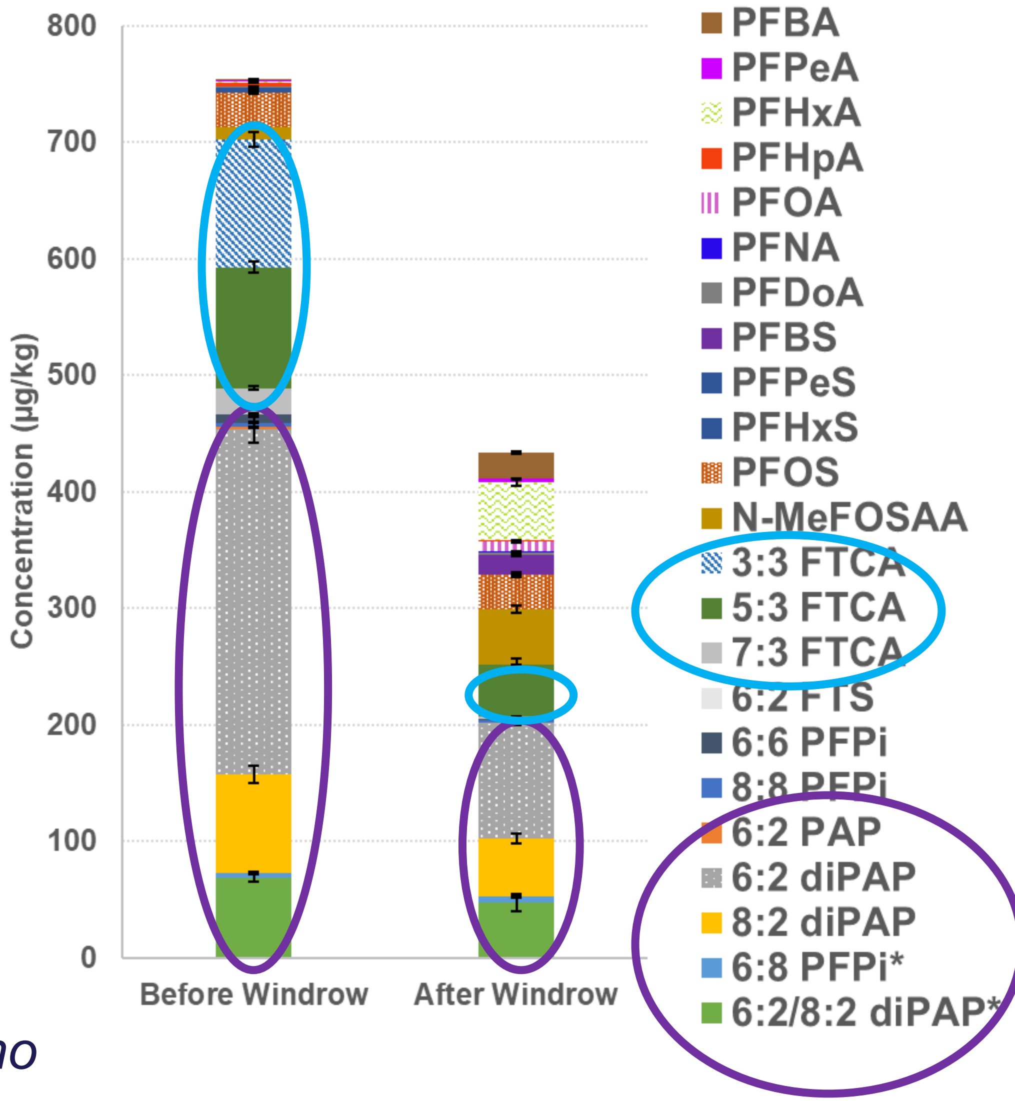
PFAS Transformation in Solids Processing to Biosolids for Application

Solids are from a Municipal WRRF that uses THP + AD Treatment

Windrow Composting



- Overall, moles of PFAS detected decreased by > 40% with windrow composting
- FT precursors, intermediates, and even terminal PFAS decreased after windrow composting
- Possible reasons
  - Expected biotransformation, yes
  - Volatilization, highly likely
  - Heat + mineral-induced oxidation? *Initial data suggests no*



Alukkal, Lee, Gonzalez manuscript in preparation

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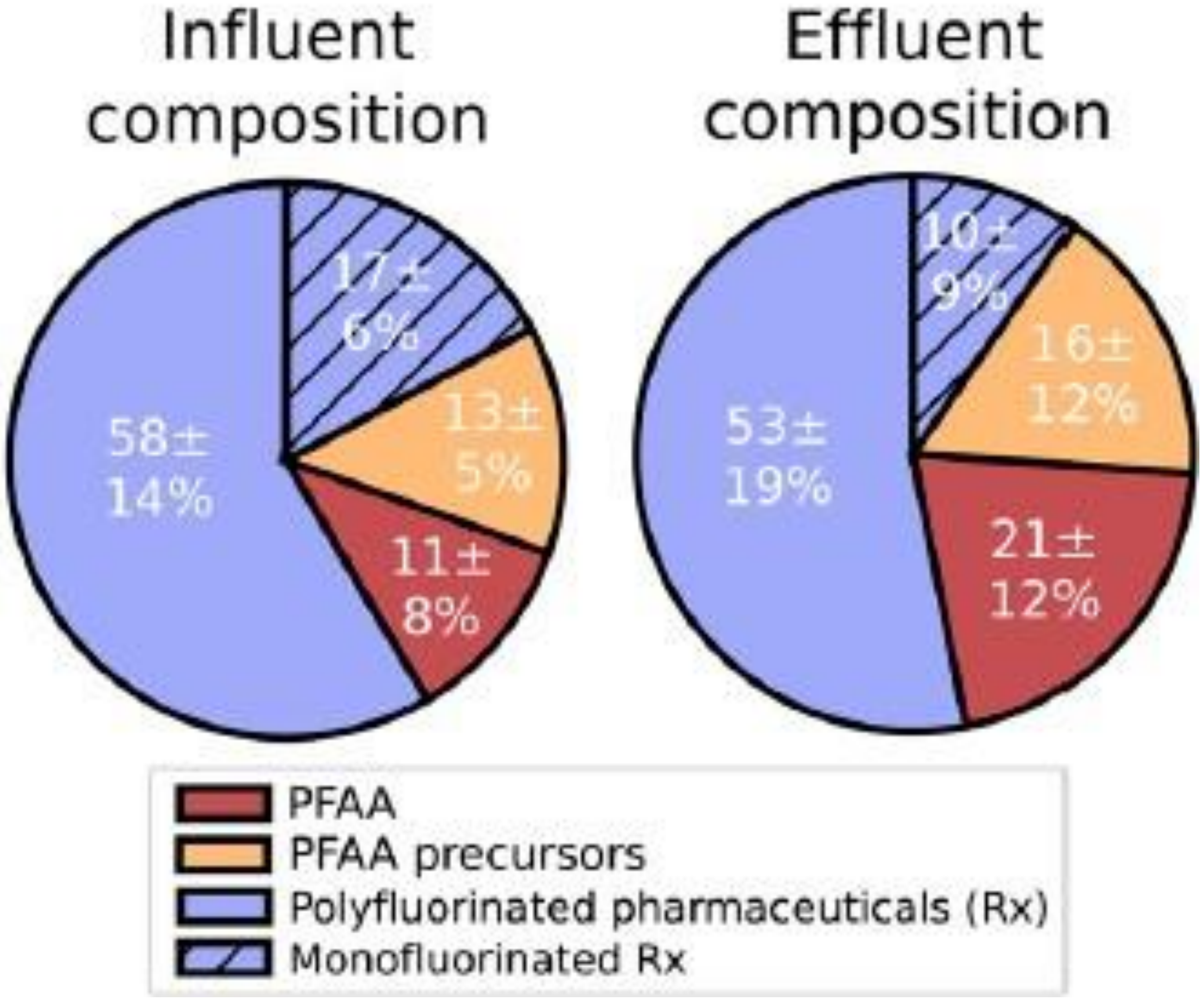
WHAT ABOUT TOTAL ORGANO-FLUORINE SOURCES

- Only about 25% may be PFAS
- Fluorinated pharmaceuticals make up the bulk of organofluorine in wastewater (snapshot from 8 facilities)
- Total organo-fluorine does not change much between influent and effluent

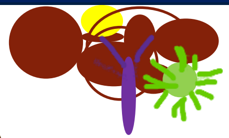


https://doi.org/10.1073/pnas.2417156122

COC FATE AFTER DISCHARGE/APPLICATION TO LAND

COC Fate

- **Chemical Properties**
- **Soil Properties**

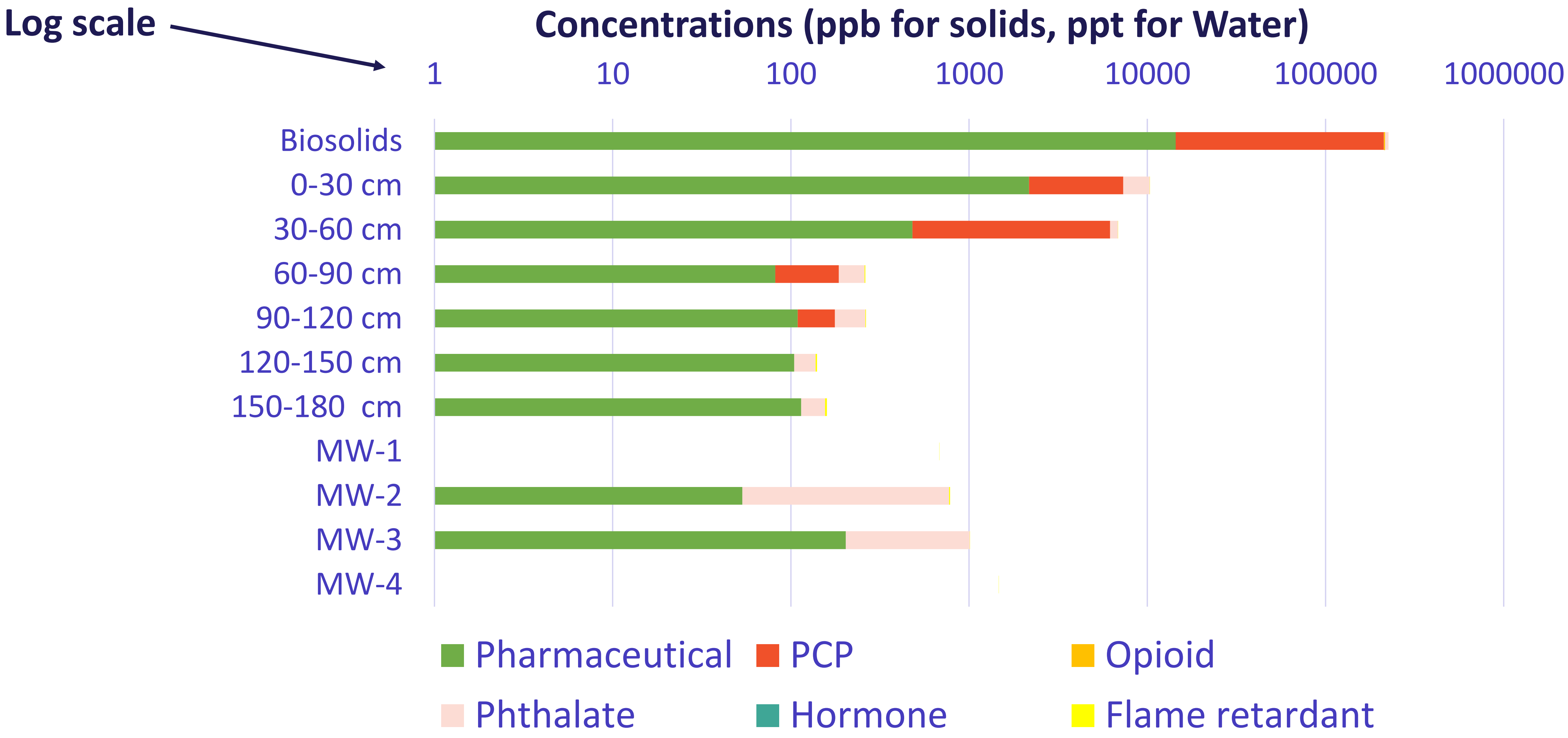


- **Air-water interface accumulation (PFAS)**
- **Solid Phase adsorption**
- **Biotransformation**

- **Plant Uptake**

- **Runoff**
- **Leaching**
- **Tile-drain discharge**

40-Y DEDICATED LAND DISPOSAL SITE (WESTERN USA): NON-PFAS COCS



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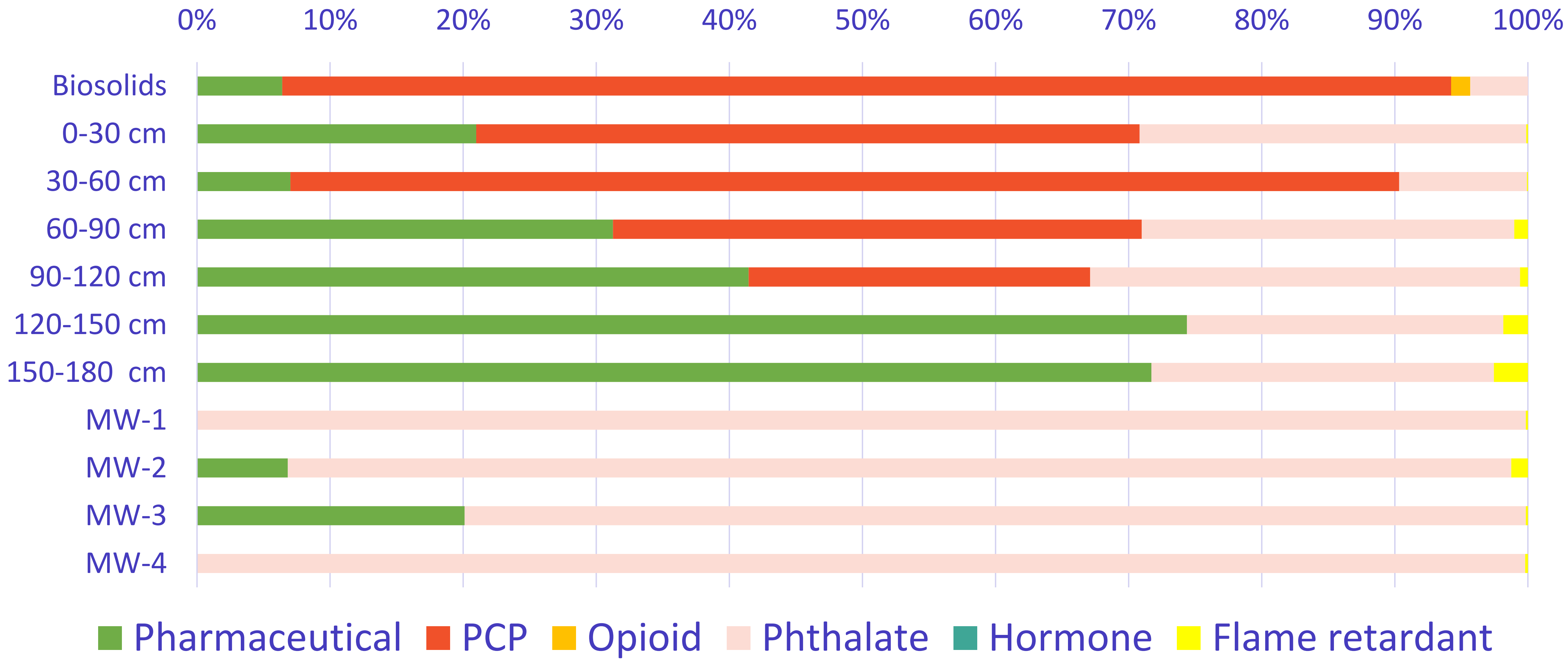

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Alvarez, et al. 2025 in preparation

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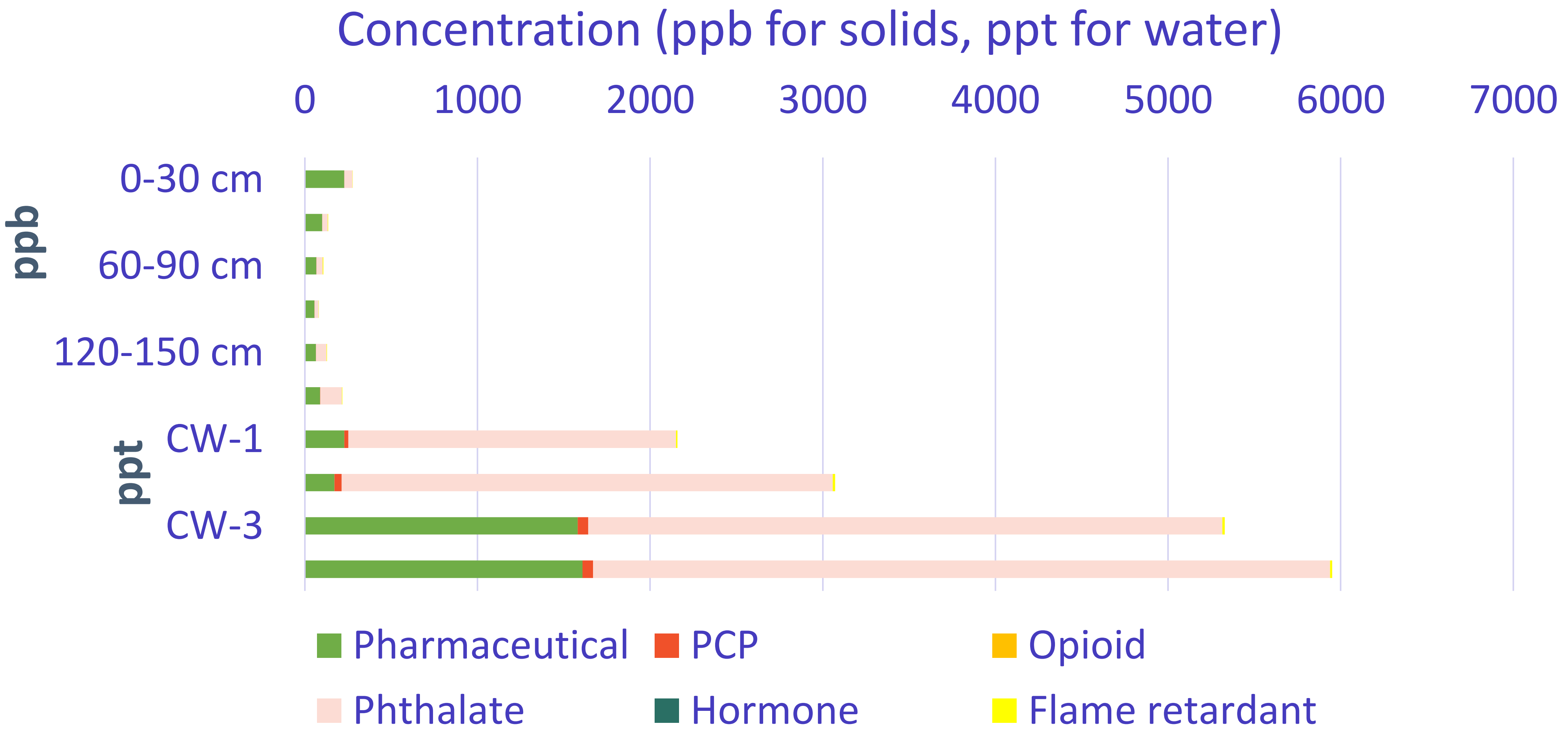
Non-PFAS Mobility at DLD

Monitoring Well Samples

		water W1 (ng/l)	water W2 (ng/l)	water W3 (ng/l)	water W4 (ng/l)	Present in soil	Present in biosolids
Pharmaceuticals	Salicylic acid	n.d.	n.d.	75	n.d.		
	Sebacic acid	n.d.	32	39	n.d.		
	Azelaic acid	n.d.	21	89	n.d.		
PCPs	DEET	18	67	47	21		
	Tributyl phosphate	n.d.	7.9	1.9	4.8		
Phthalates	Benzyl Butyl phthalate	227	297	316	415		
	Di(2-ethylhexyl) phthalate	96	n.d.	155	352		
	Dibutyl phthalates	178	211	168	348		
	Diisodecyl phthalate	10	n.d.	38	22		
Flame retardants	Triphenyl phosphate	1.0	9.8	1.6	3.0		
	Tris(2-butoxyethyl) phosphate	457	434	600	633		
	Total	**987**	**1080**	**1530**	**1800**		

CONTROL SITE: NON-PFAS COCS



- Pharmaceuticals include some natural occurring ones in nature)
- PCP includes DEET

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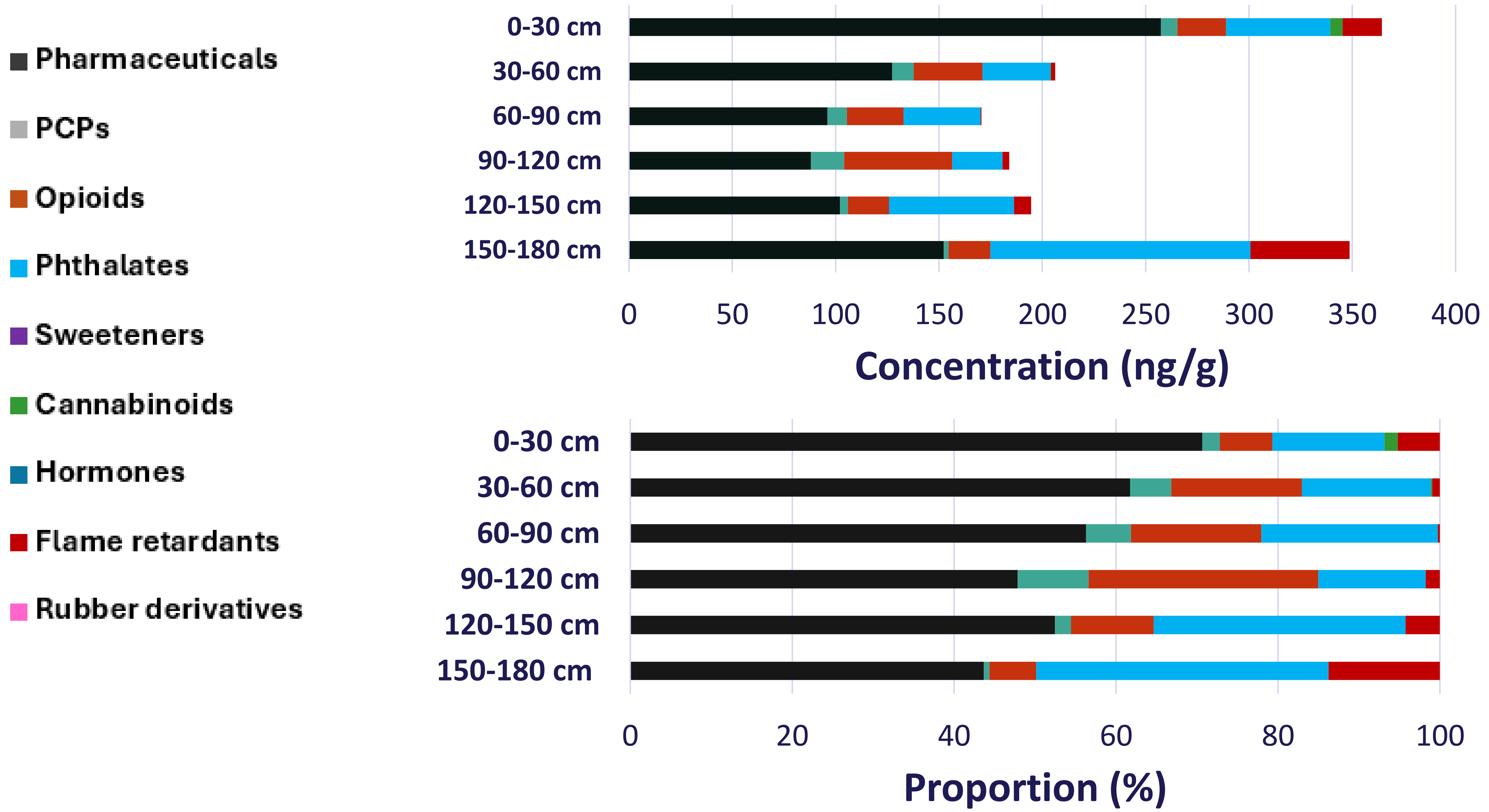
Persistence of Non-PFAS COCs one year post biosolids application, dry farm



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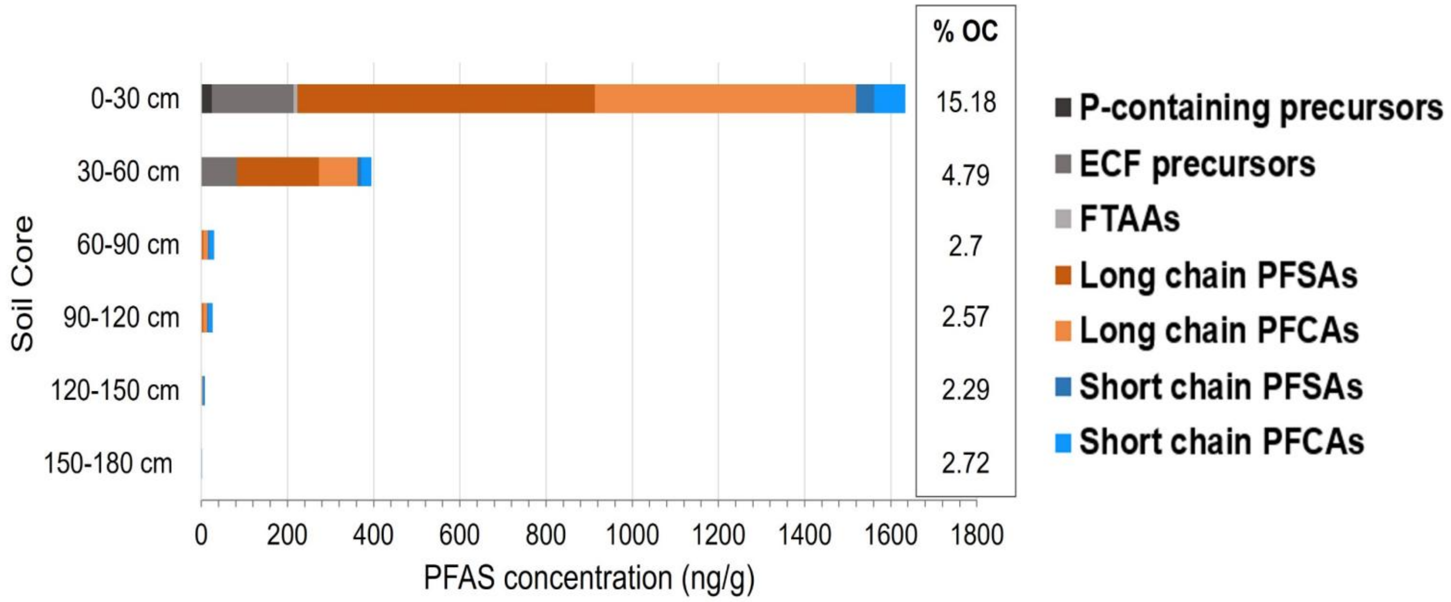
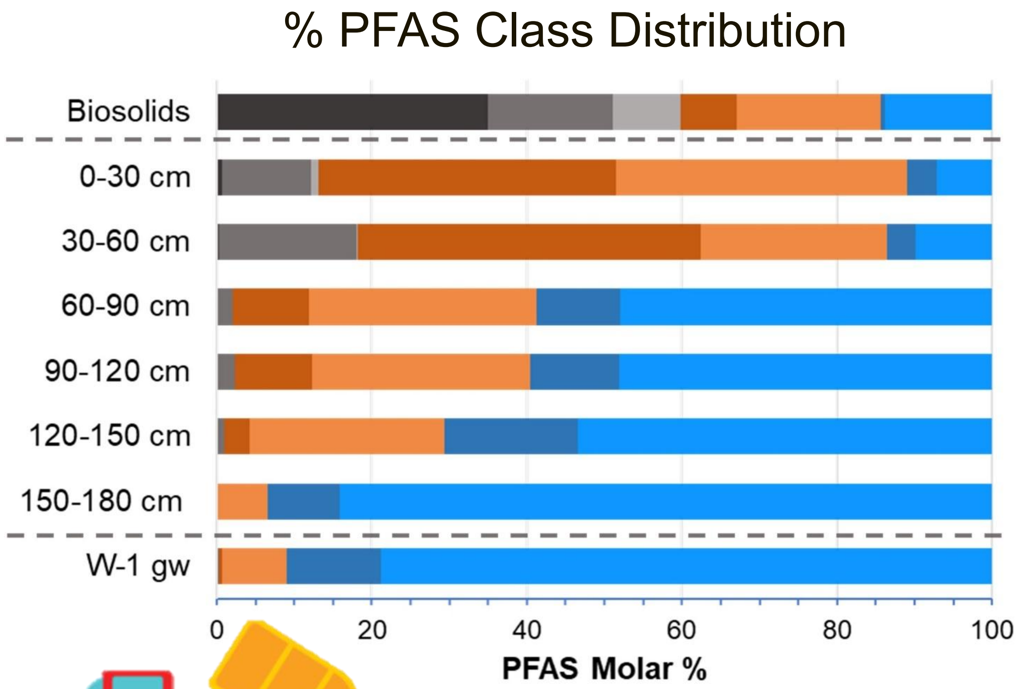
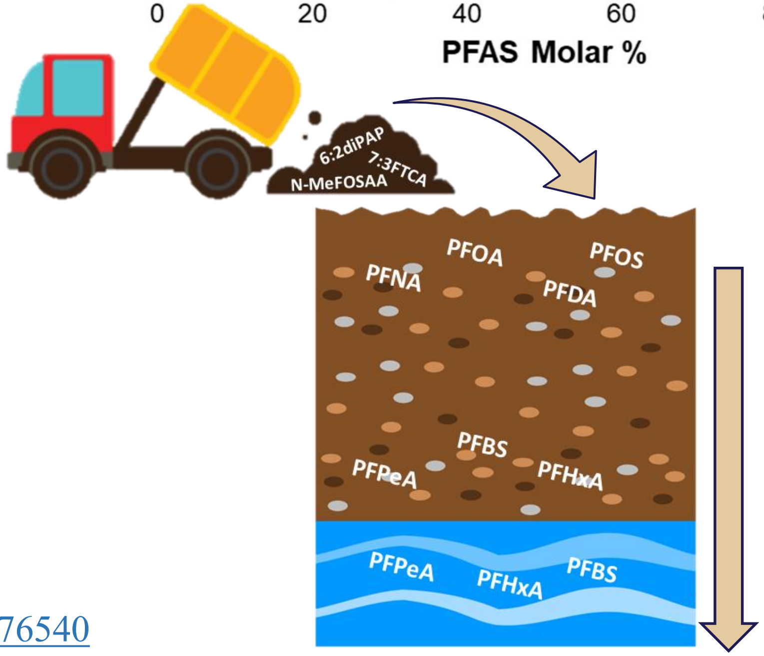
40-Y DEDICATED LAND DISPOSAL SITE (WESTERN USA)





- Repetitive (annual) and high rate of biosolids application leads to PFAS and organic carbon (% OC) accumulation in soil over time
- Most precursors breakdown to PFAAs within 1 year
- Long-chain PFAS retained in the upper soil profile
- Short-chain PFAAs dominate what is getting to groundwater
- Interestingly, only PFOA exceed new EPA MCLs



United States Environmental Protection Agency

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Alvarez, Lee et al. 2024
https://doi.org/10.1016/j.scitotenv.2024.176540

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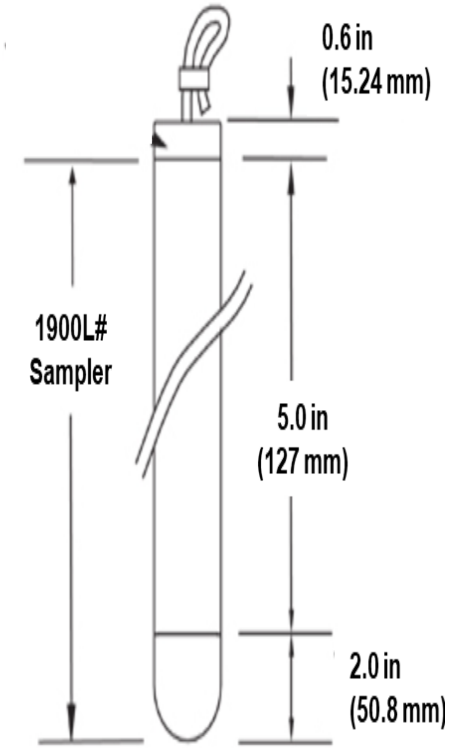
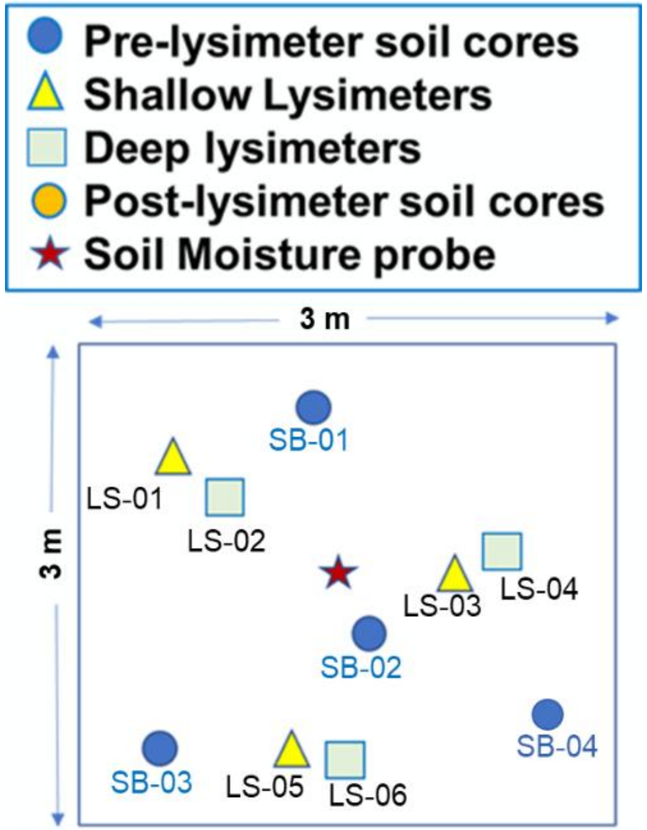
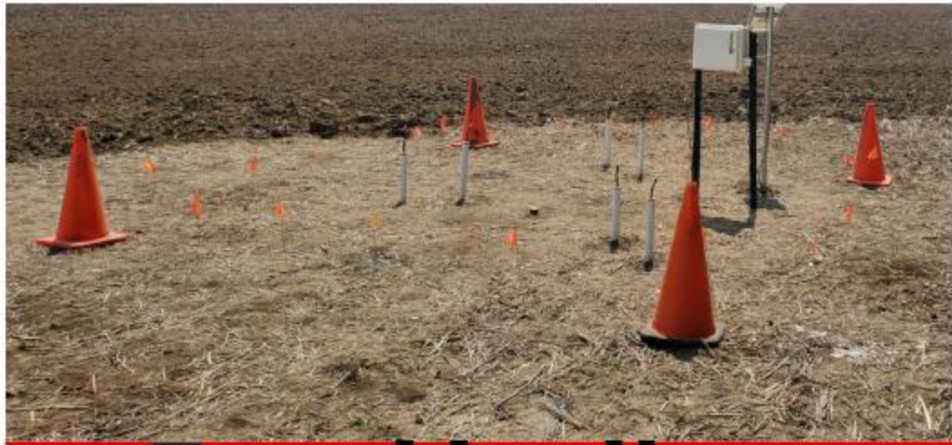
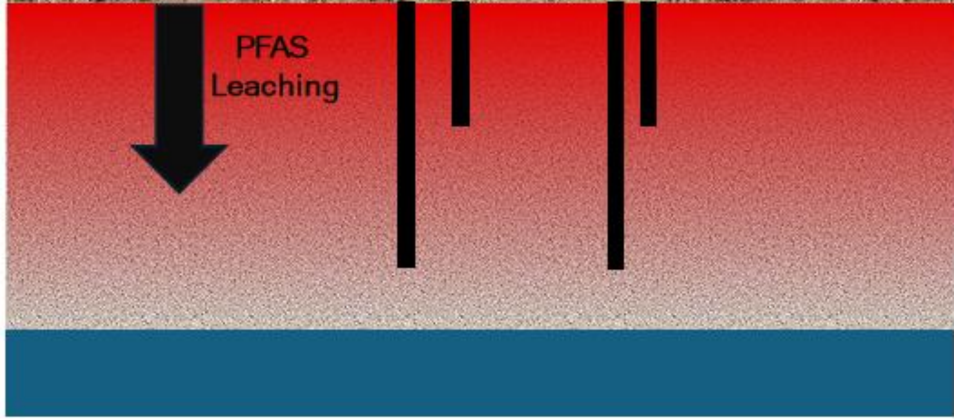
BIOSOLID-APPLIED MIDWEST AGRICULTURAL SITE

- Agricultural Field - ~40 y of land-application
- Agronomic rate for corn biannually, last app 2022
- Crops cleared so transpiration not a factor
- Depth to water table: 4.3 m *(pre-installation river flooding,*
- 3-mo study with 2 ft & 4-ft suction cup lysimeters
- 58 PFAS targeted



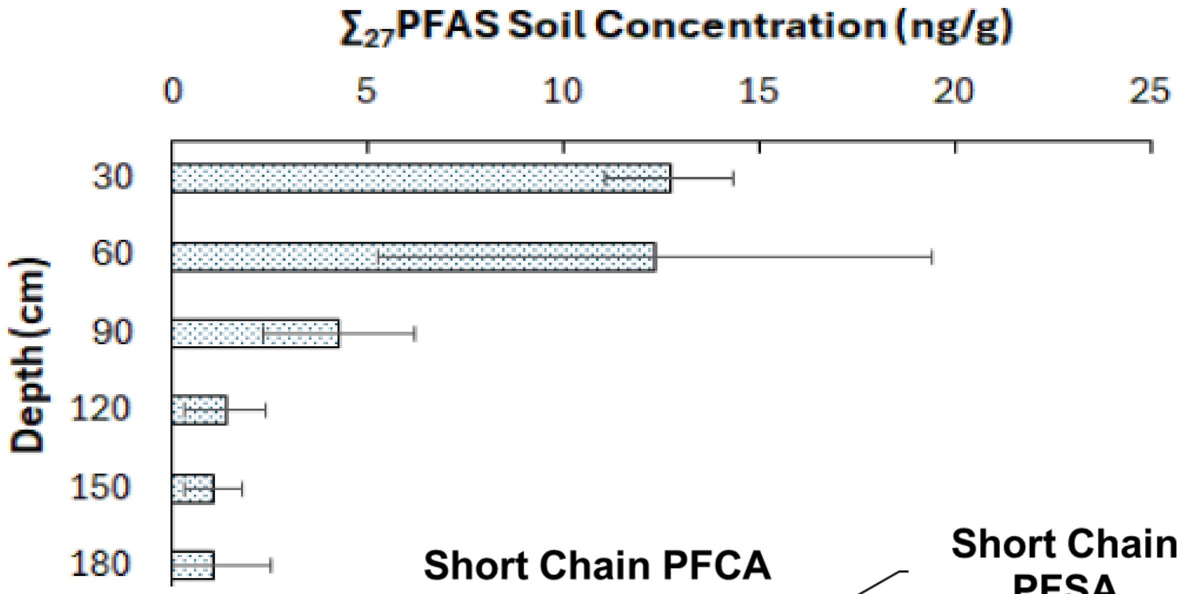


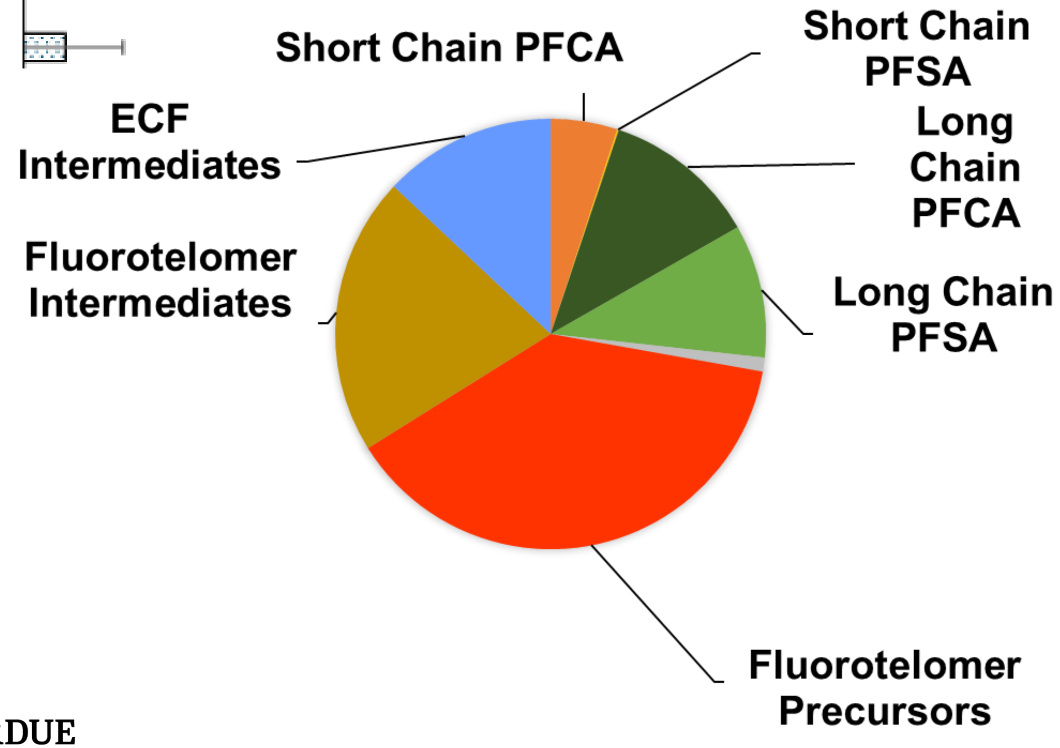


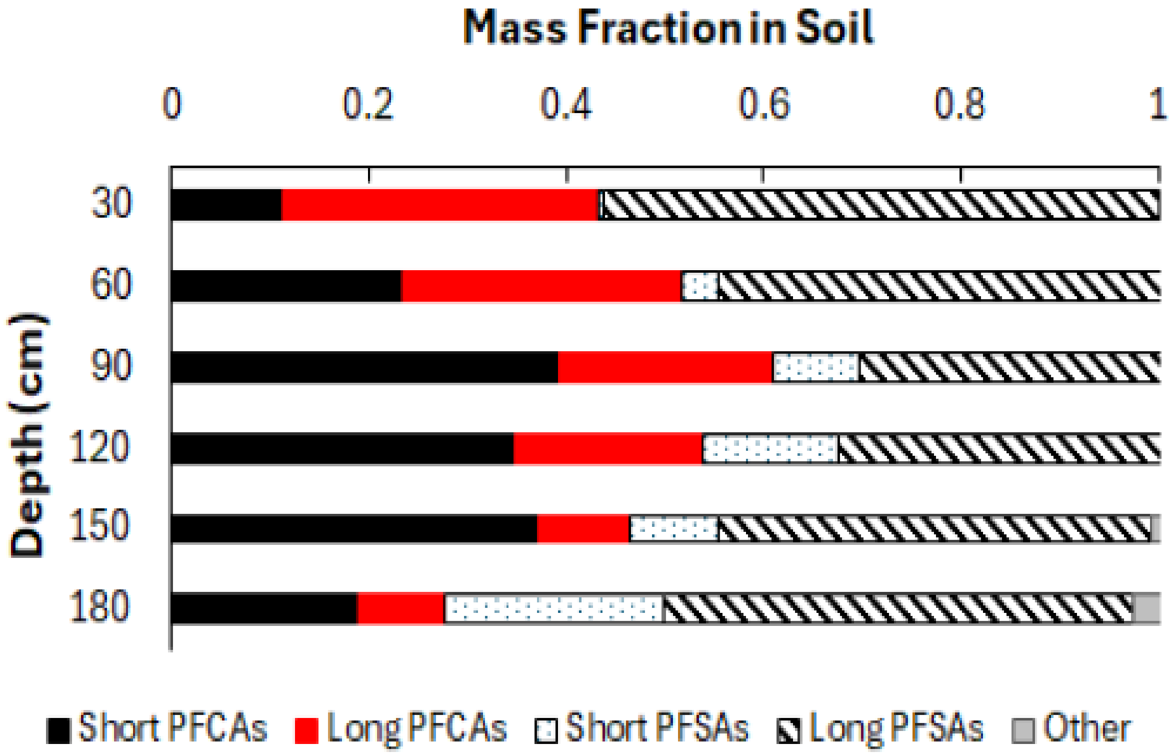


Depth (cm)	% OC	Type, % Clay
0-60	2	Loam, 15% clay
60-110	2.3	Silt loam, 20%
110-180	< 1.5	Loam, 17%

40-Y BIOSOLIDS-APPLIED MIDWEST AGRICULTURAL SITE: PFAS IN SOILS & BIOSOLIDS





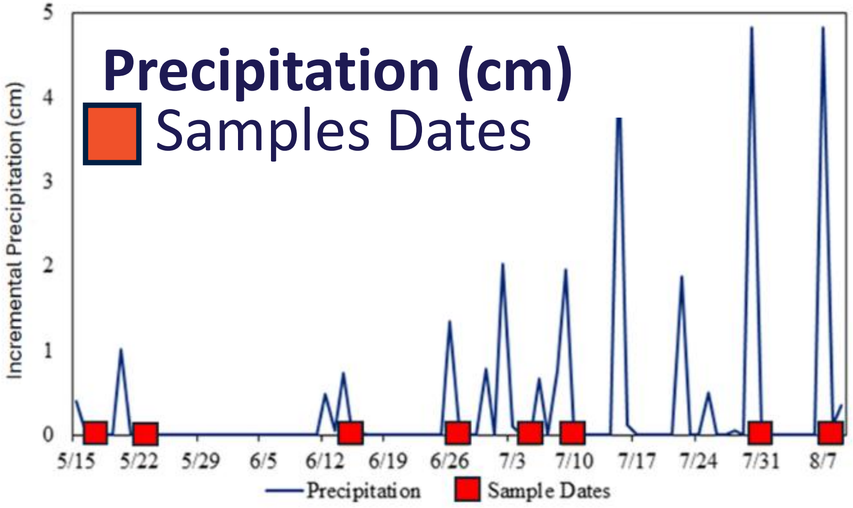


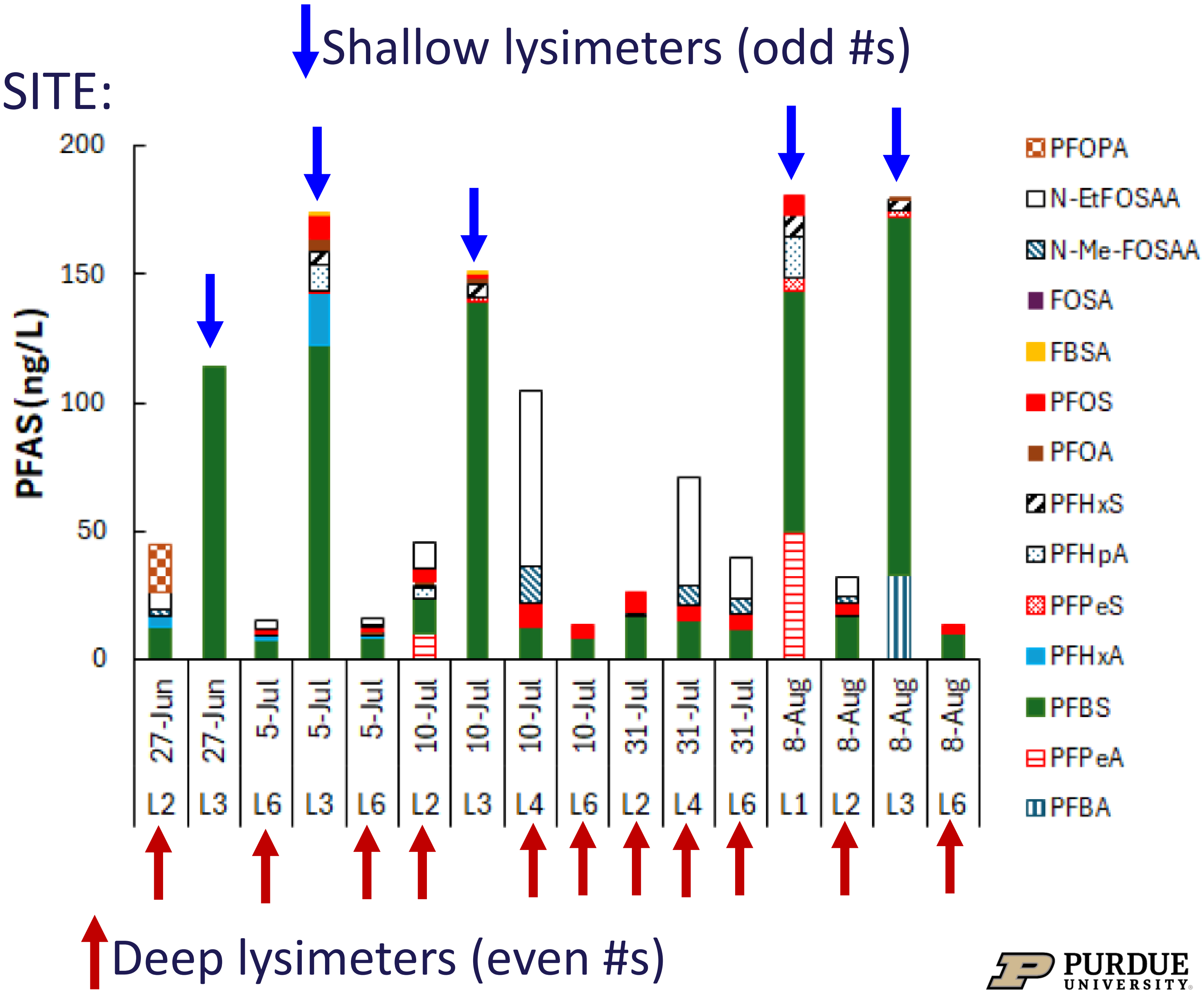
- Precursors degrade, most < 1-y post application (not ECFs)
- Long-chain PFAS retained in the upper soil profile

WRF 5214 (CDM Smith, Purdue)

Klamerus, Lee, Schaefer et al., EST, *es-2025-080256*

40-Y BIOSOLIDS-APPLIED MIDWEST AGRICULTURAL SITE: LEACHING TRENDS





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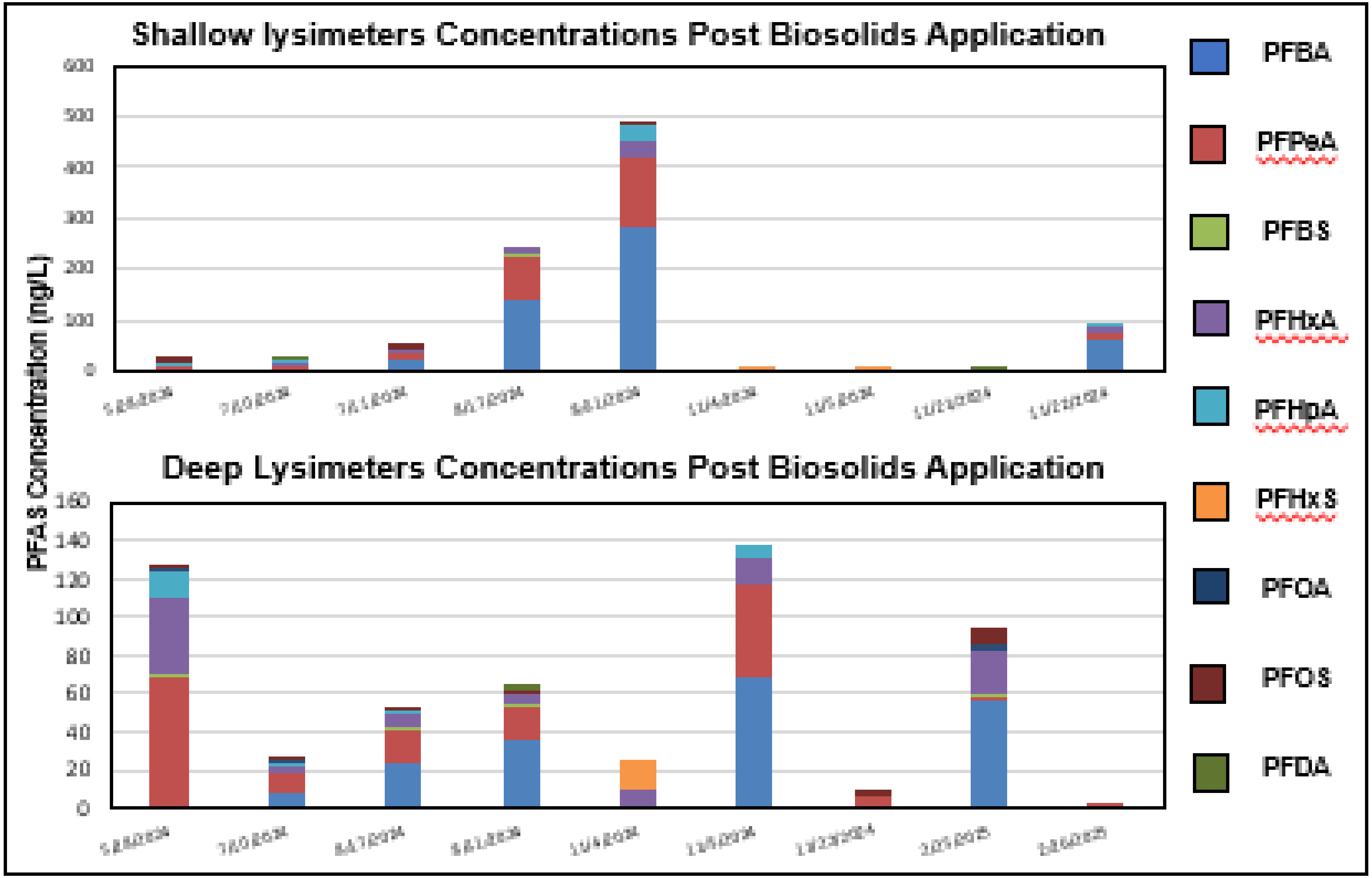
BIOSOLIDS-APPLIED MIDWEST AGRICULTURAL SITE:

FIRST TIME APPLICATION LEACHING TRENDS



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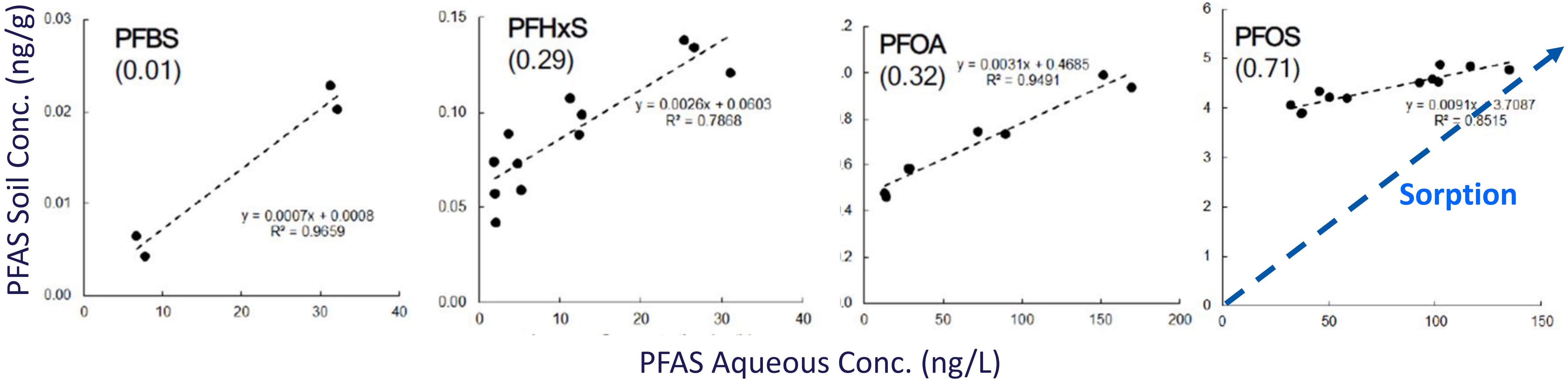
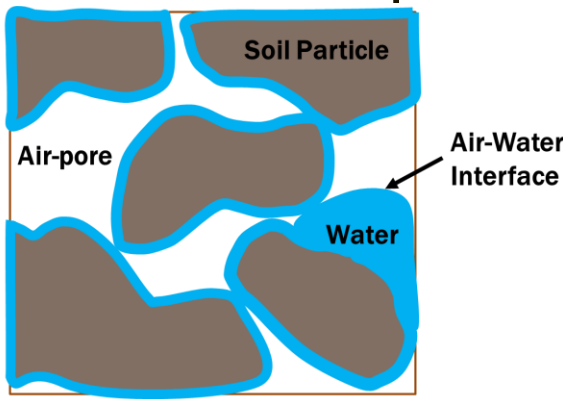
SOIL FACTORS IMPACTING TRANSPORT: DESORPTION HYSTERESIS

Desorption Isotherms from Historic Biosolids-applied soil



Desorption hysteresis - chemical release (desorption) does not mirror chemical adsorption

- Desorption hysteresis – increases with increasing chain length
- Air-water interfacial retention – increases with increasing chain length
  - Contributes to longevity of long-chain PFAS in the soil profile
  - Decreases movement to groundwater



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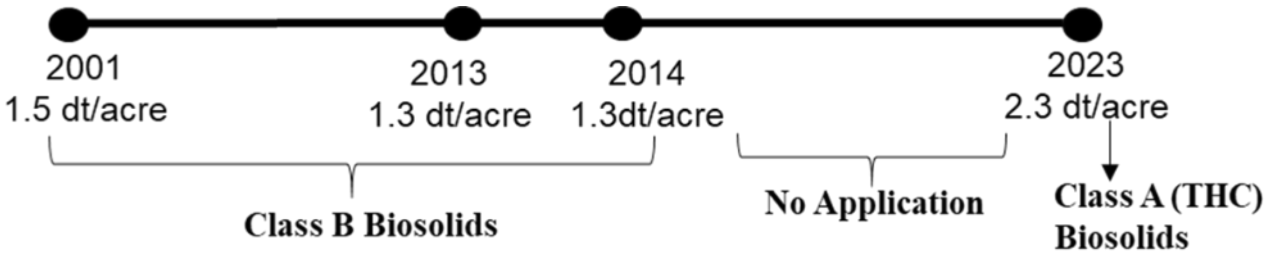
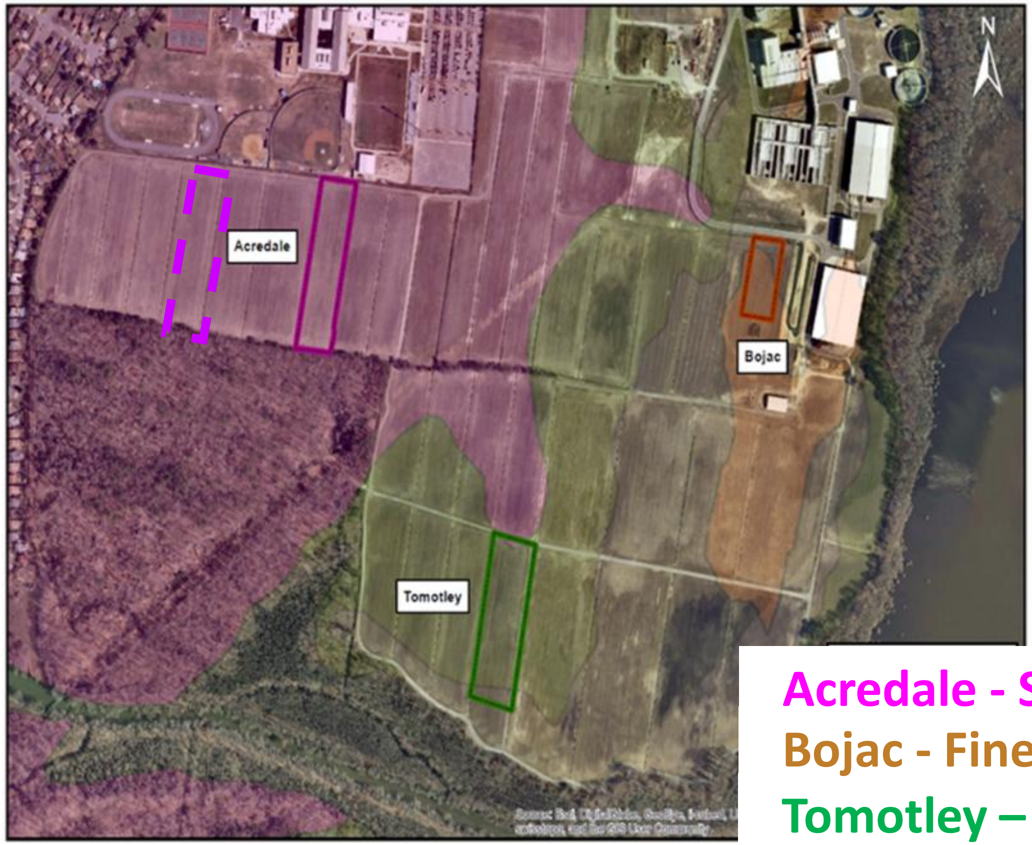
EAST COAST USA STUDY SITE



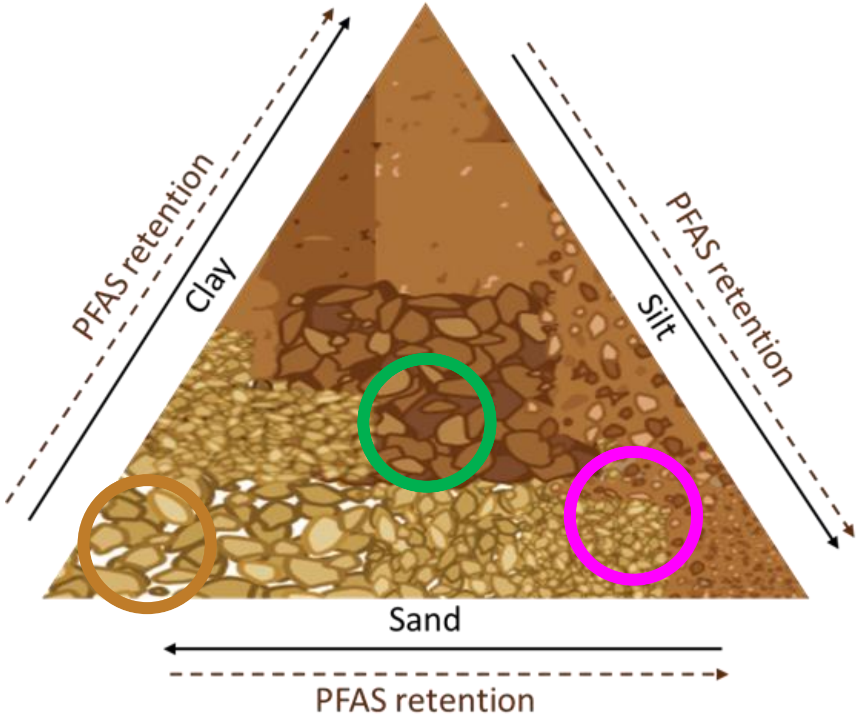


Acredale - Silt Loam

Bojac - Fine Sandy Loam

Tomotley – Loam/Clay loam

- Corn/soybean rotations
- Municipal biosolids: Class B to Class A
- 3 soil types
- Organic carbon ~ 2% in surface soils decreased with depth, Lower average in Bojac Sandy loam



Peter, Lee et al. 2025, Manuscript in review

United States Environmental Protection Agency

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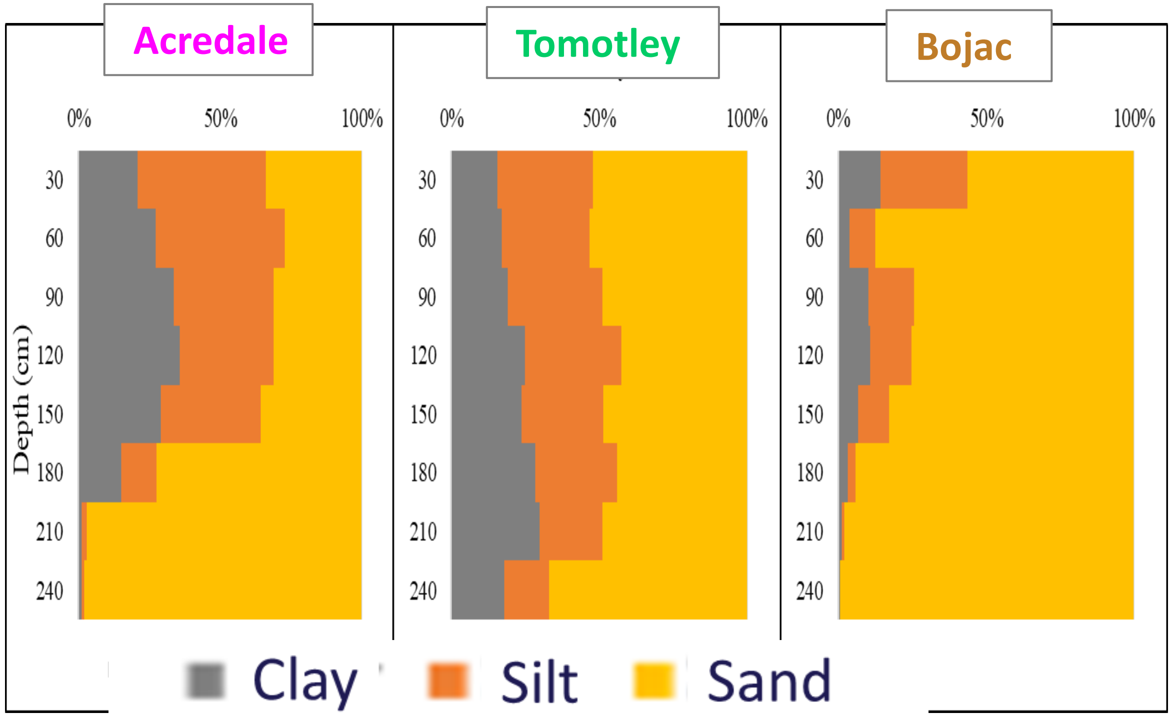
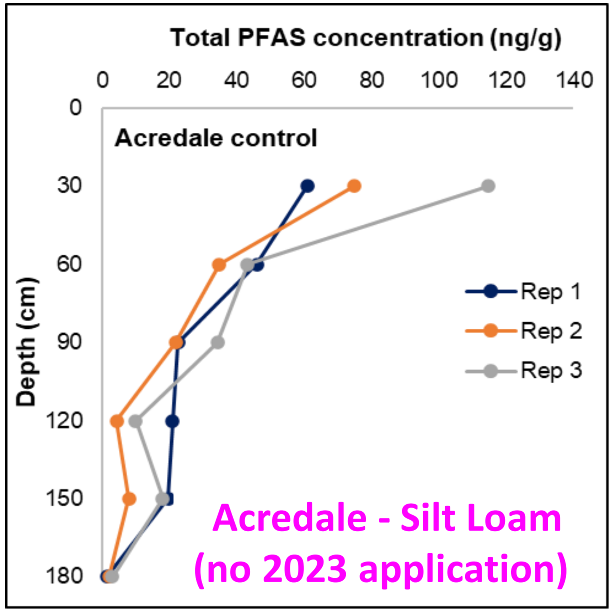
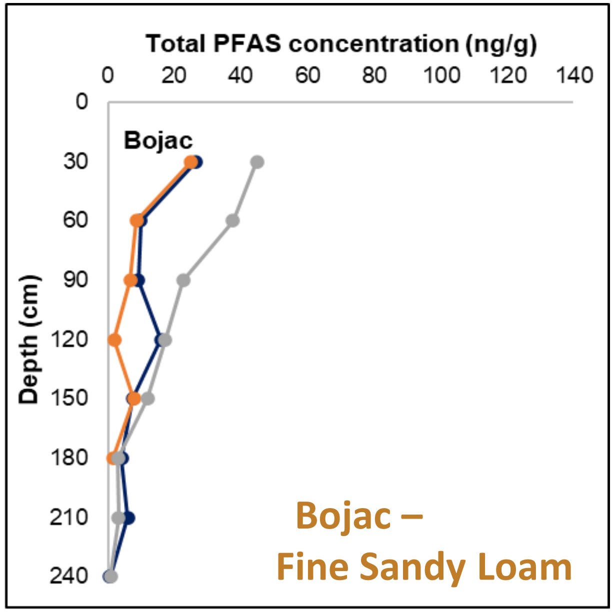
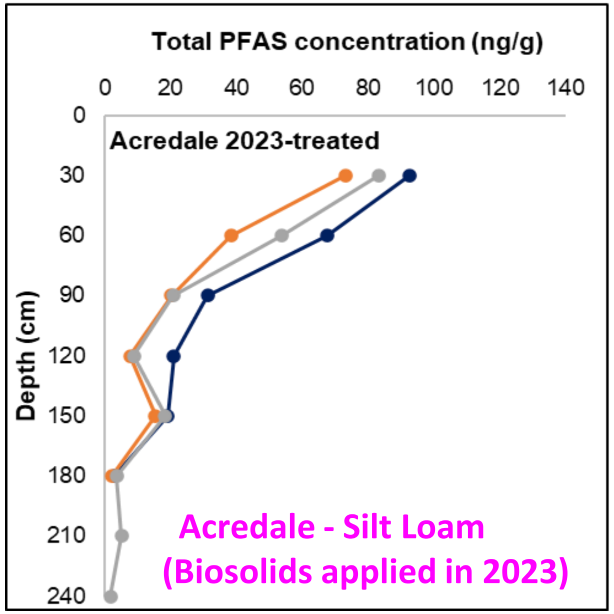
EAST COAST USA STUDY SITE

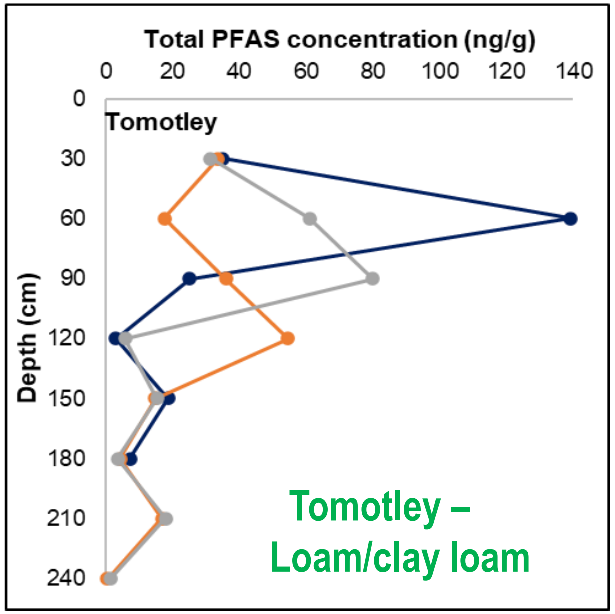
- PFAS profiles in cores taken prior to 2023 application were not statistically different
- PFAS longevity
- Sandy soil – less retention
- Finer texture soil, greater retention











Peter, Lee et al. 2025, Manuscript in review

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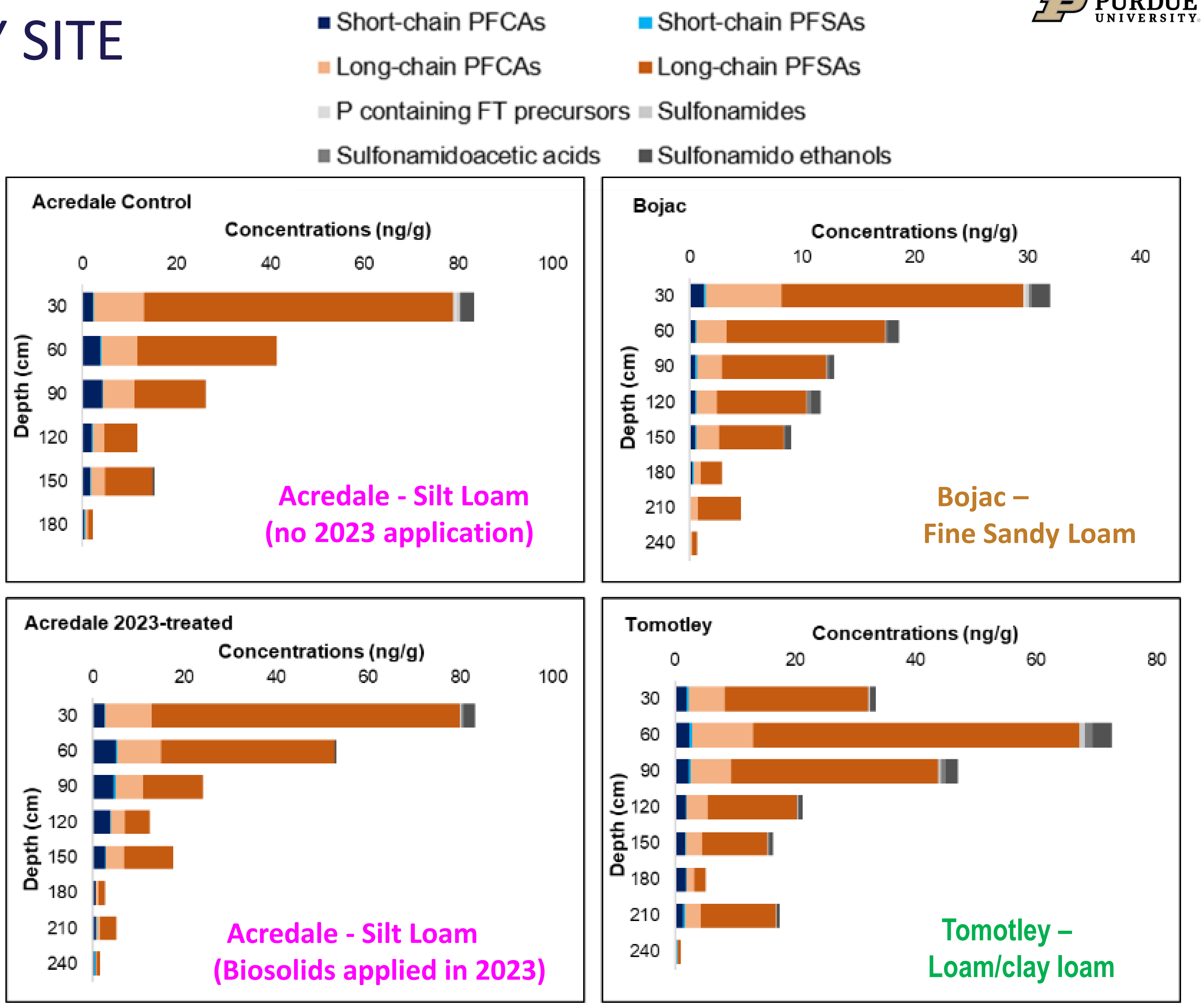
EAST COAST USA STUDY SITE

- Long-chain PFAS dominated the upper soil profile
- PFAS in surface soil subject to runoff and available for uptake
- Less PFAS residing in the soil for the loan and sandy loam

Acredale - Silt Loam
Bojac - Fine Sandy Loam
Tomotley – Loam/Clay loam



EAST COAST STUDY SITE: OTHER PFAS SOURCES

Monitoring Wells

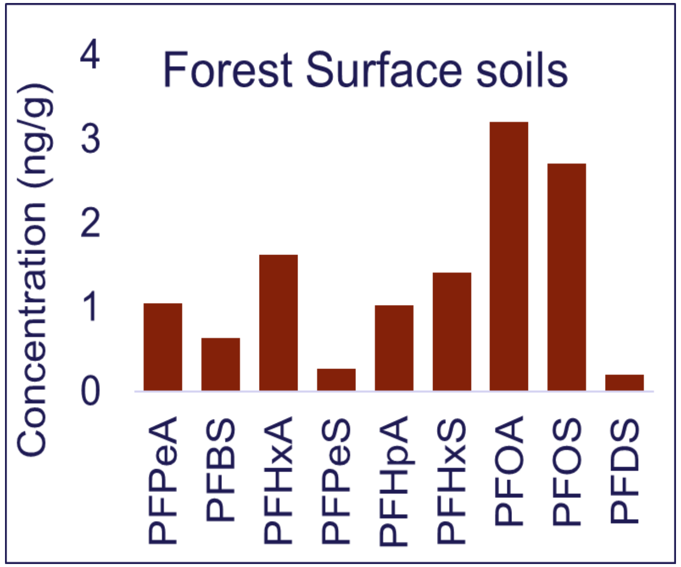
Total PFAS (ng/L)

- 0 - 20
- 21 - 100
- 101 - 200
- 201 - 620

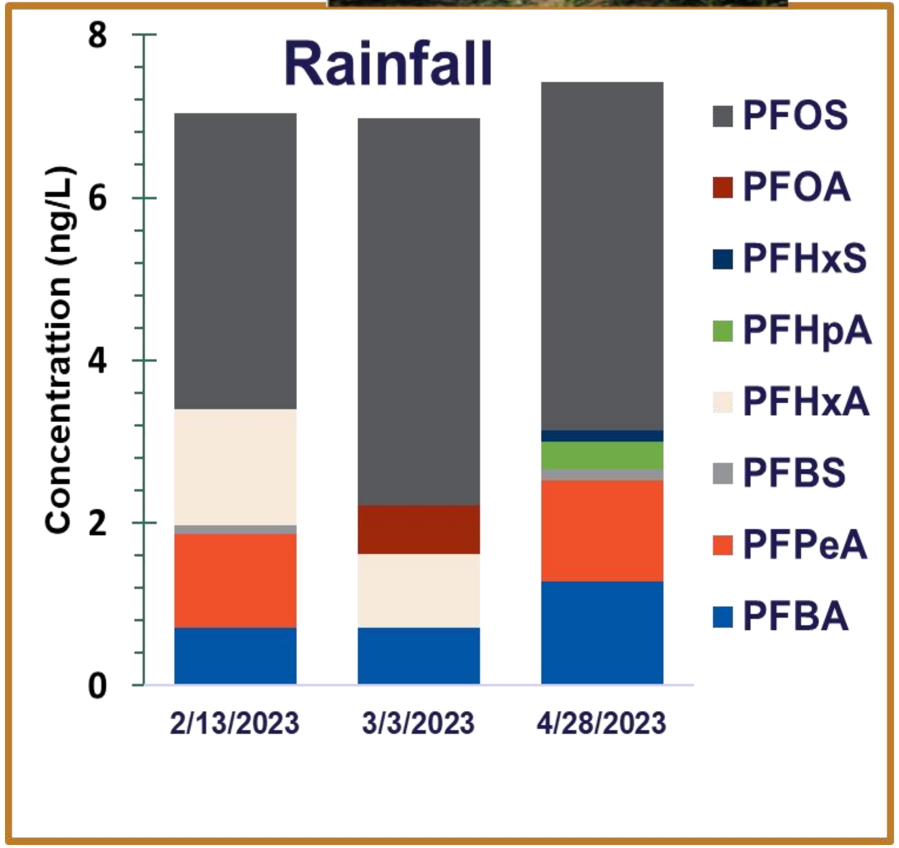
Plots

Soil Type

- Acredale_Control
- Acredale
- Bojac
- Tomotley



Wet/dry deposition



- Assessment complicated near the lake
- Military base, airport within 5-mi radius

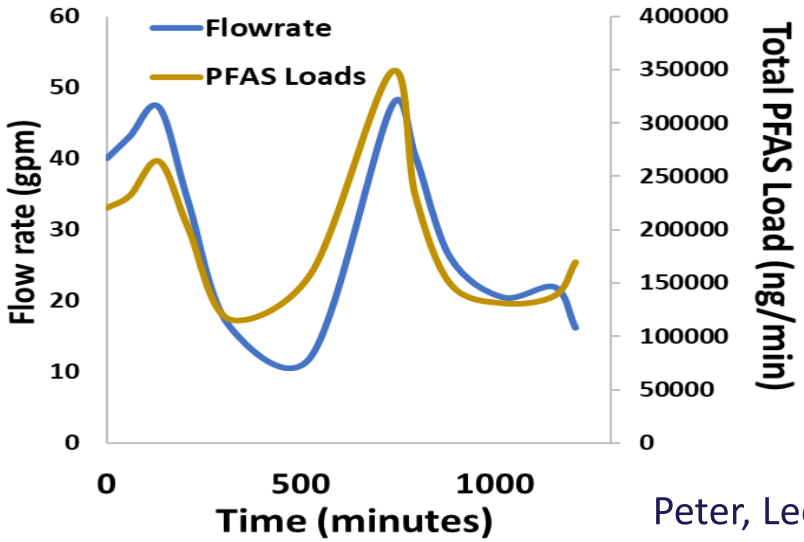
2025 Banned Biosolids Application on this site ☹

Peter, Lee et al. 2025, Manuscript in preparation

WHAT ABOUT IMPACT OF RUNOFF FROM LAND-APPLICATION?

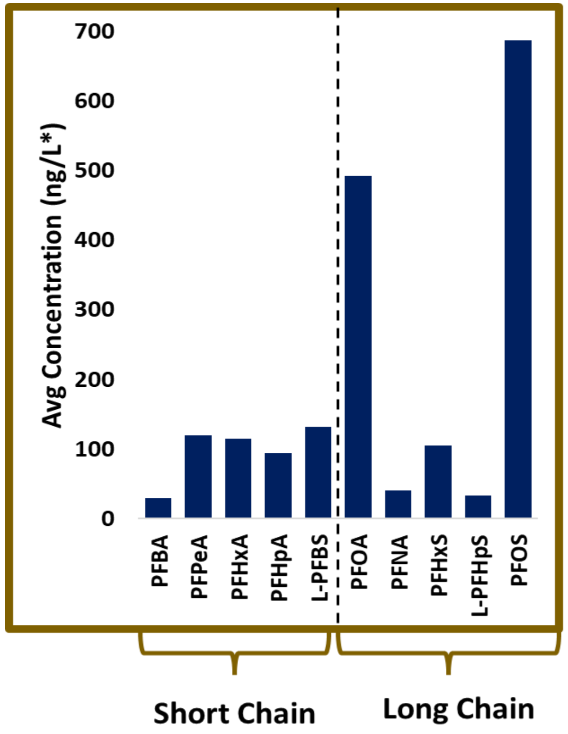
USGS 104B

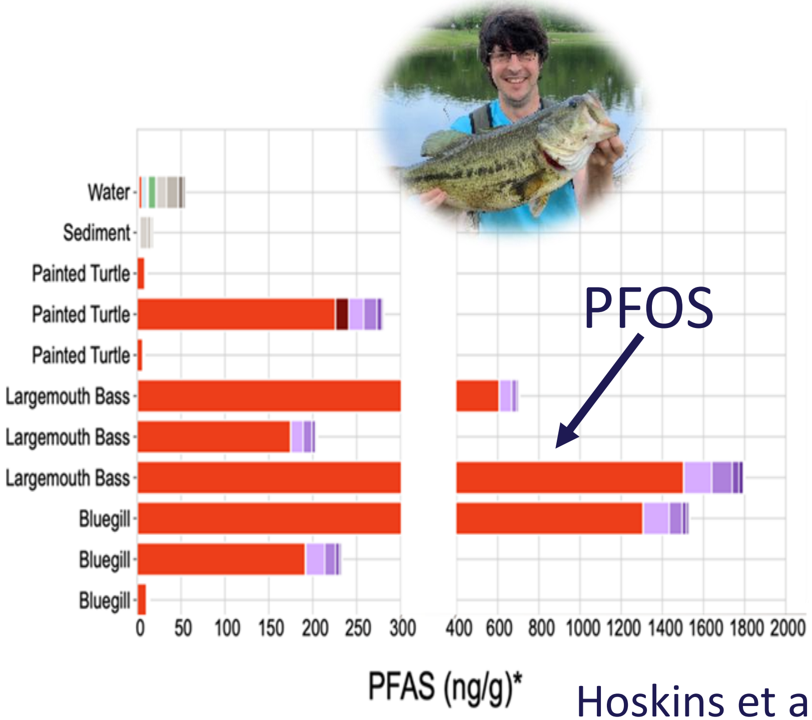
INDIANA WATER RESOURCES RESEARCH CENTER



Peter, Lee et al.

United States Environmental Protection Agency





Hoskins et al.

With high PFAS retention in surface soils, runoff into streams, wetlands, and farm ponds may be a significant PFAS exposure pathway to fish, wildlife, and grazing cattle, and subsequently, humans

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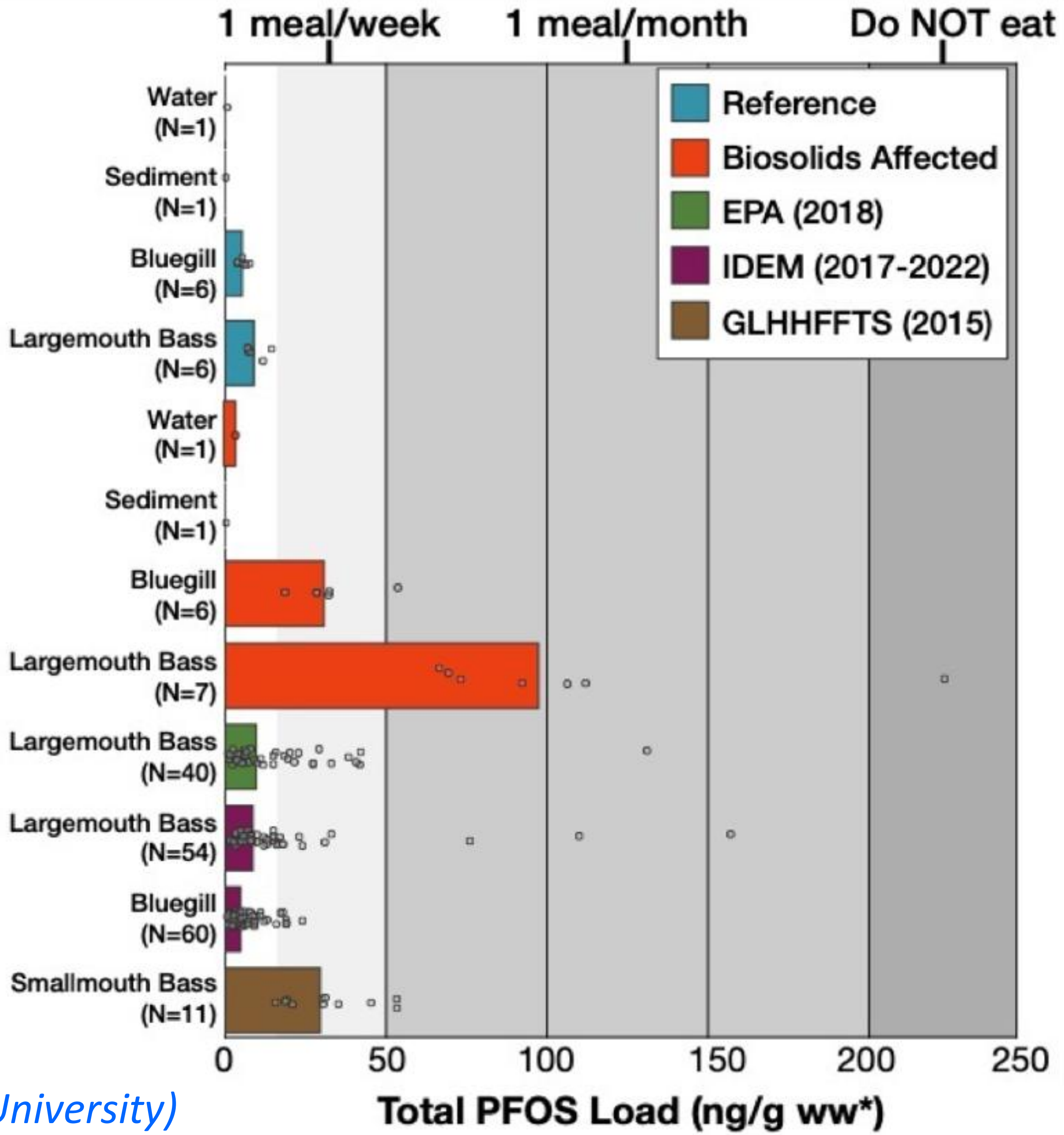
Do not cite, Manuscripts in preparation, Peter, Lee et al. and Hoskins, Sepulveda, et al.

FARM POND FISH MUSCLE FROM BIOSOLID SITE HAD HEAVY PFAS LOADS

- Greater PFOS burdens at Biosolids Site than at Reference Site
- Reference site resembled concentrations in larger monitoring efforts
- Some perspective:
  - At geometric mean for Biosolids Site
    - **ONE 8 OZ MEAL OF BASS = 30 DAYS of DRINKING WATER AT 27,840 X HIGHER THAN EPA INTERIM GUIDELINE FOR PFOS**



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Do not cite: Sepulveda, Marisol and Hoskins, Tyler (Purdue University)

CROP UPTAKE: PFAS EXPOSURE AND BIOACCUMULATION

- **PFAS (particularly long chain like PFOS) bioaccumulates in meat and milk**
- Irrigation with PFAS-contaminated water
- PFAS-containing biosolids-based fertilizer
- PFAS in the feed
  - PFAS uptake is greatest into leaves and stalk
  - PFAS accumulate in grasses (hay)
  - PFAS uptake is small into fruit (e.g., tomatoes), seeds (e.g., soybeans, corn kernels and cob)
- Drinking PFAS-contaminated water
- Only Maine has guidance; currently
  - 3.4 ppb in meat
  - 211 ppt in milk
  - Expect 5x reduction in milk guidance

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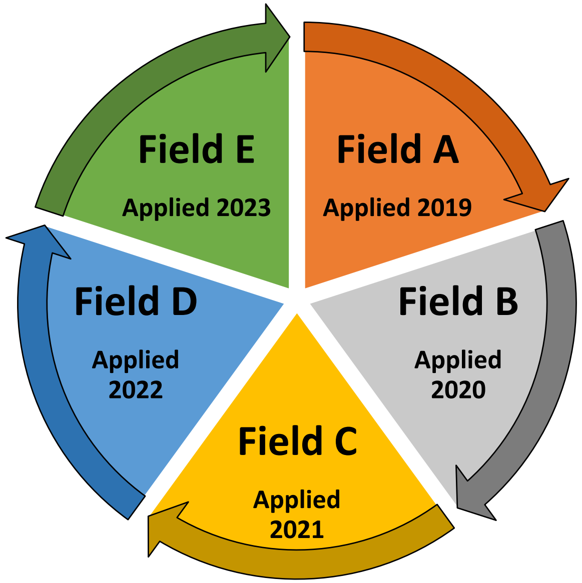
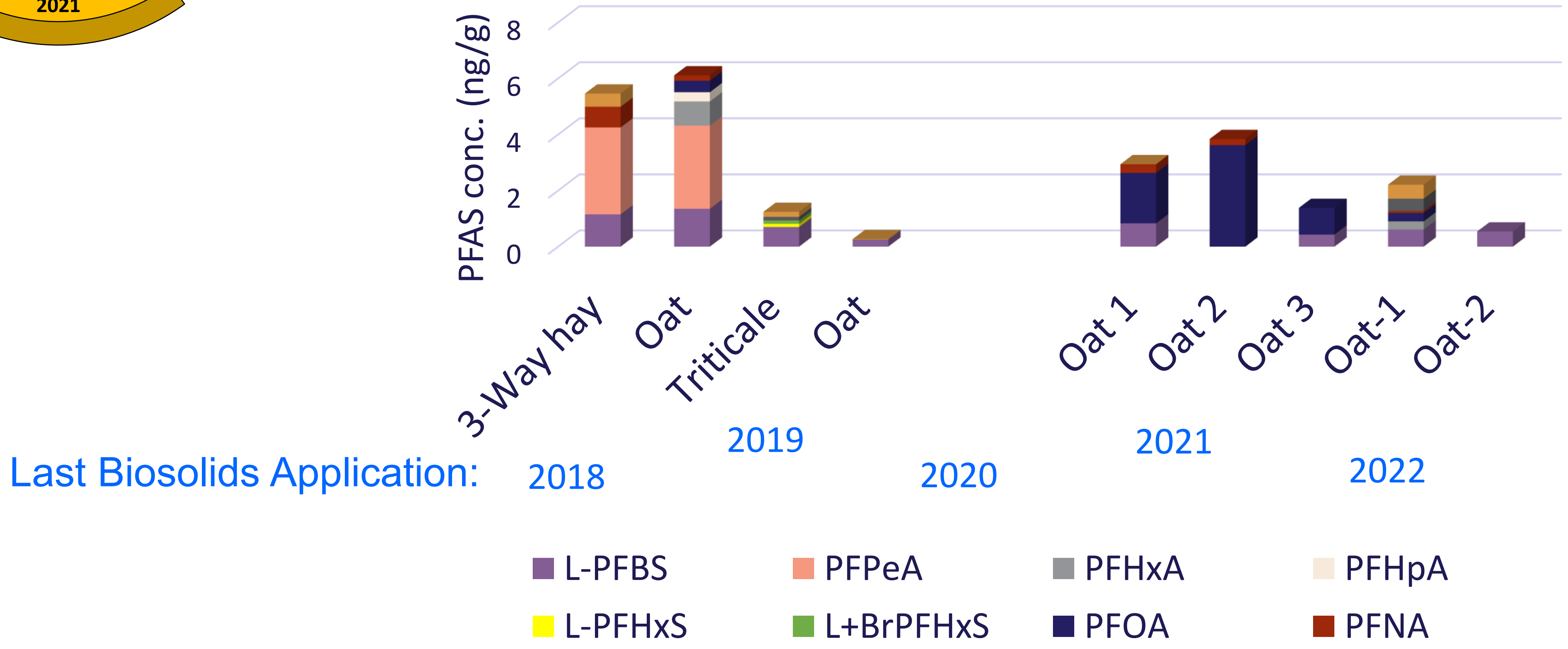
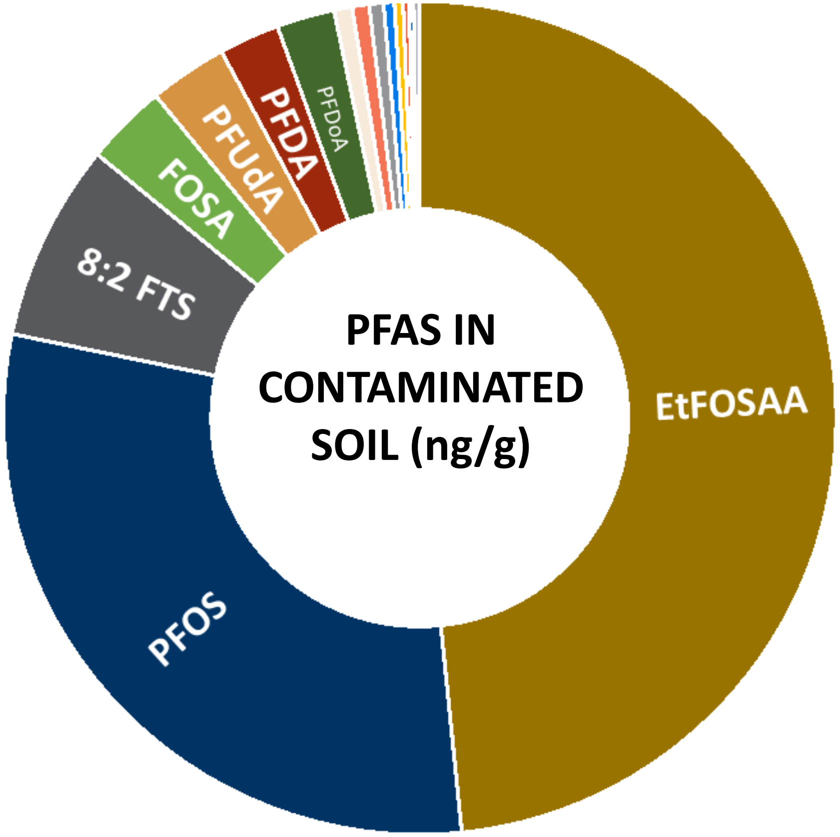
West Coast Biosolids-Applied Site: PFAS in Crops

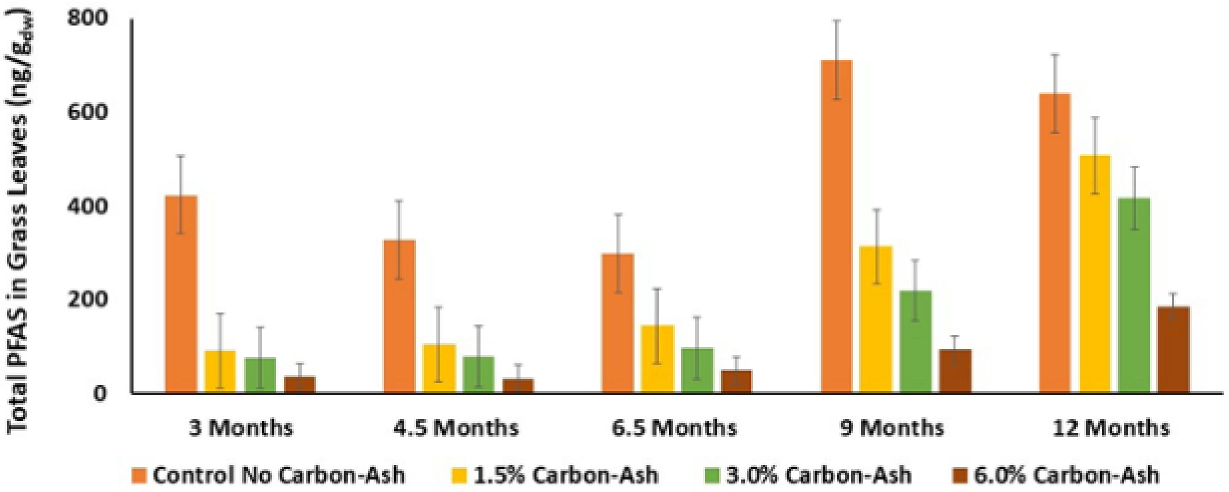




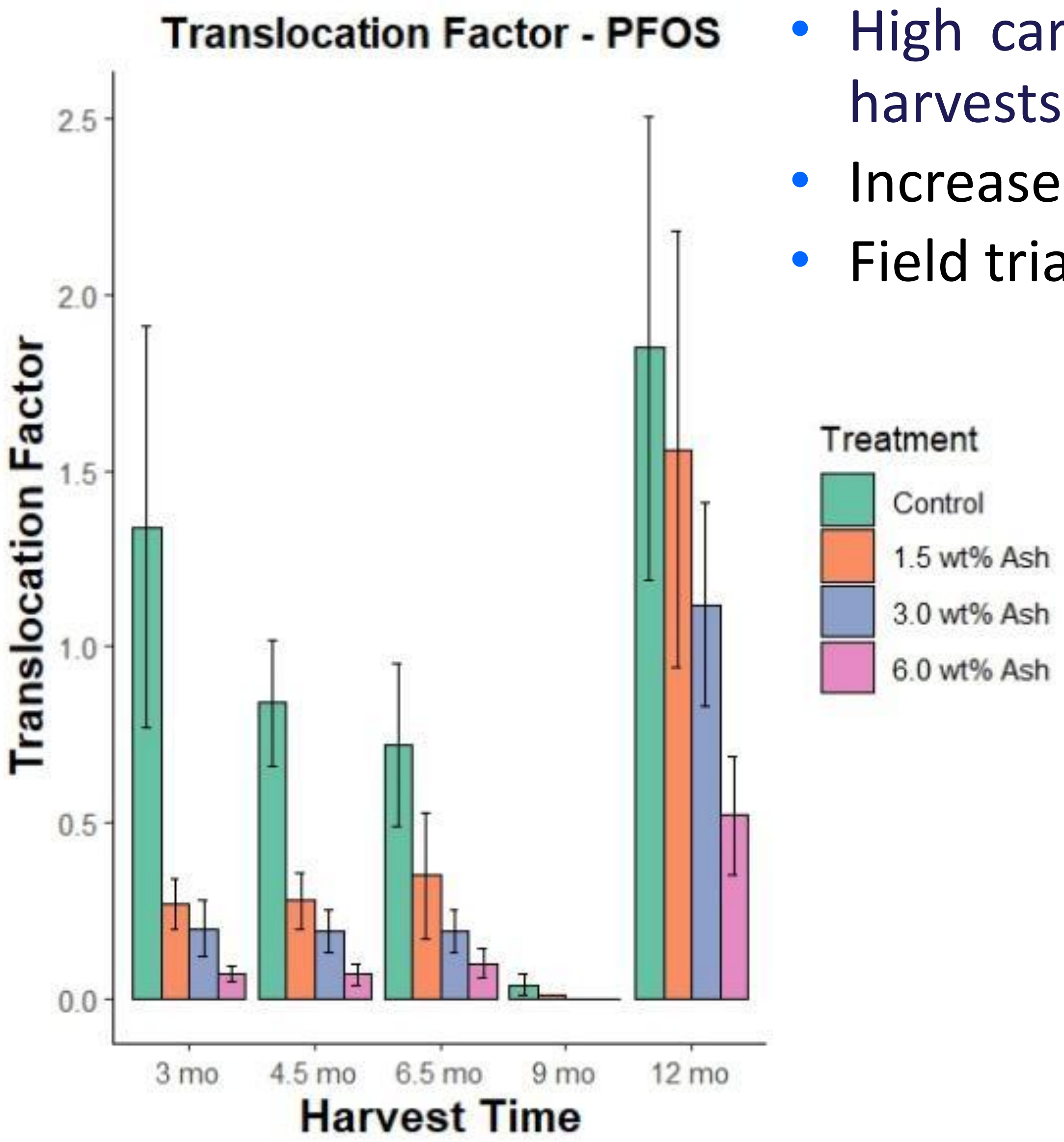
Grass Greenhouse Studies: Uptake and Mitigation

- Contaminated agricultural soil from Maine - ∑PFAS = 840 ng/g with most being PFOS and PFOS precursors (Me- & EtFOSAAs, FOSA)
- Biochar (**wood chips ash**) mixed at 3 rates (1.5%, 3% and 6%); n= 5
- Grass mix (40% Tall Fescue, 30% Orchard grass, 20% Festulolium and 10% Timothy) – typical feed grasses for cattle
- Soil seeded in March 2024
- Pots watered as needed weekly
- 4 Grass leaves harvest: *3, 4.5*, 6 and 7.5 months….

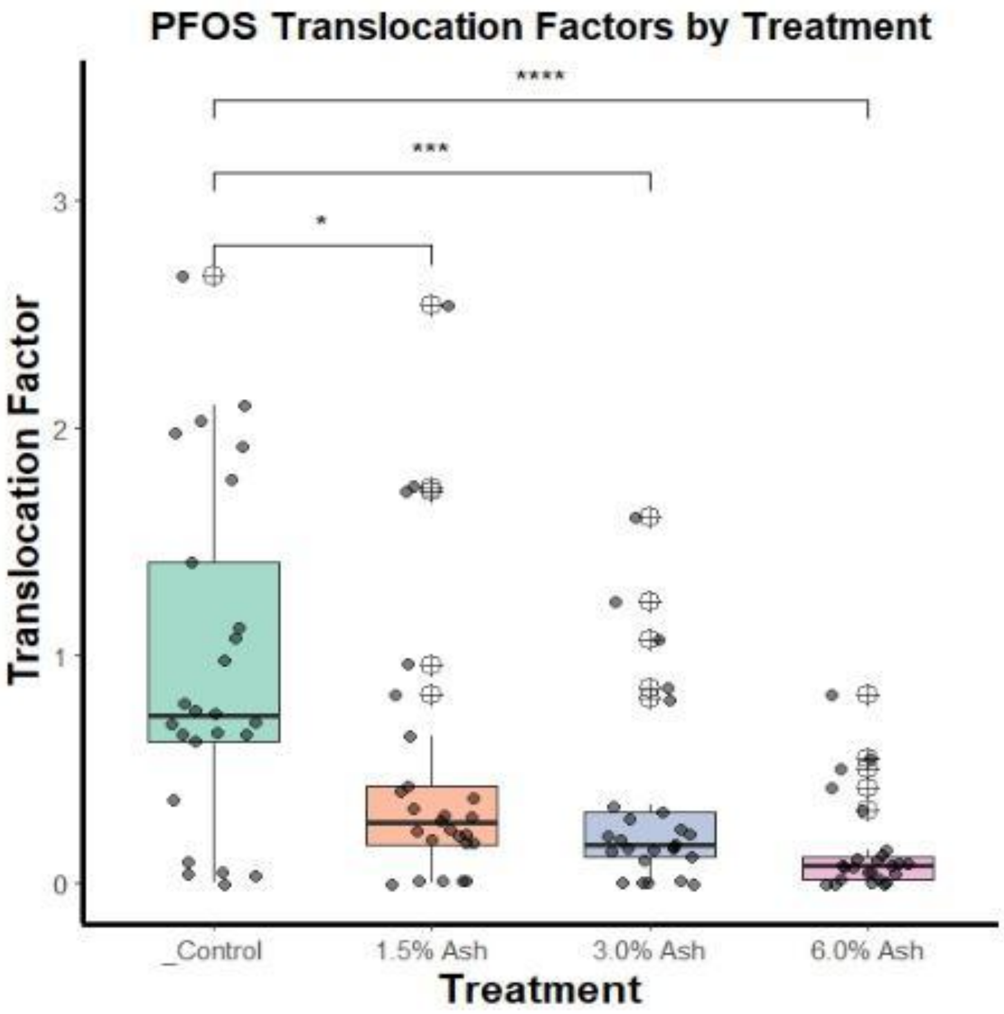




Grass Greenhouse Studies: Uptake and Mitigation



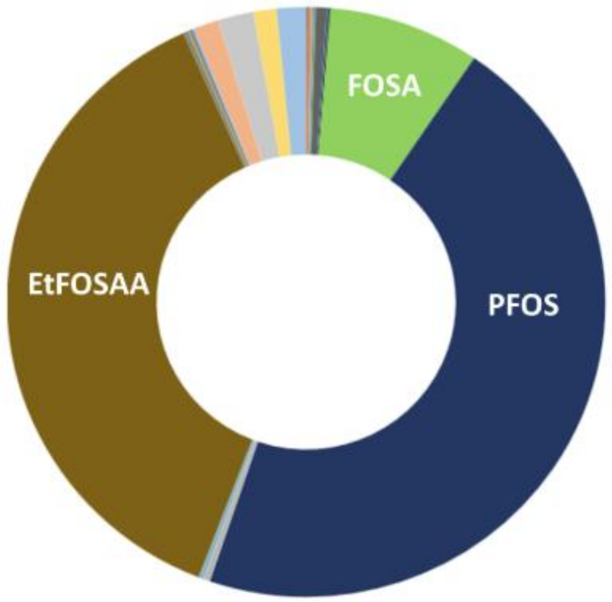
- High carbon wood ash reduced uptake for all harvests over one year
- Increased variability with time
- Field trials in process

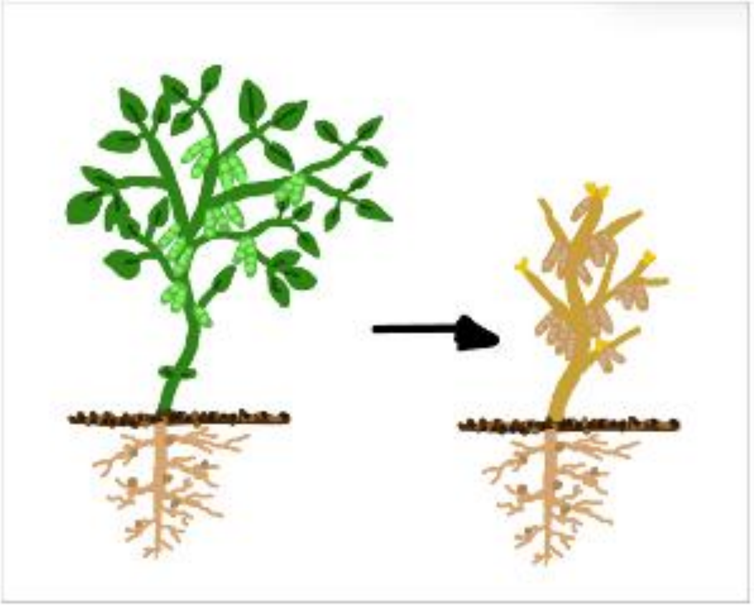


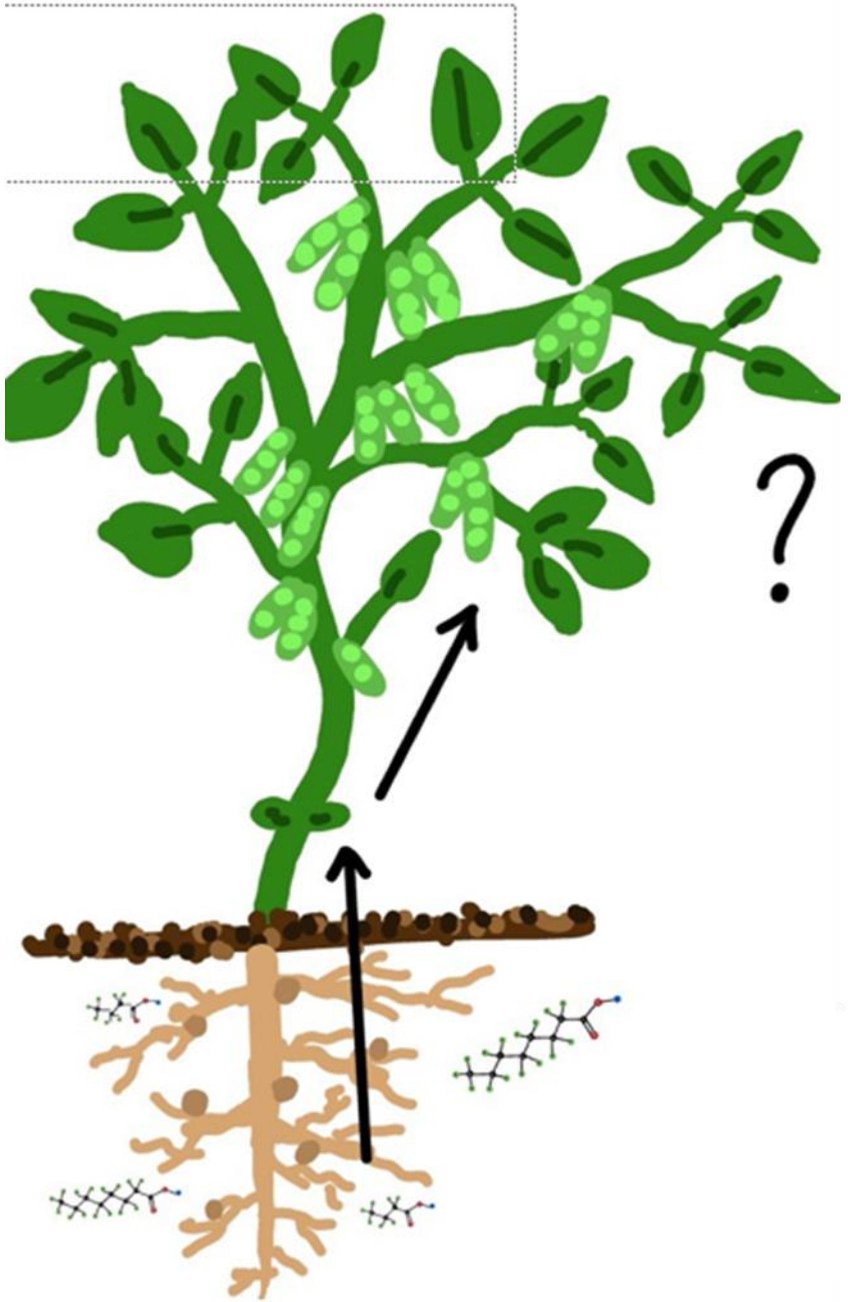
Openiyi, Lee, Carpenter et al., J. of Agricultural & Food Chemistry, revision in process

CROP UPTAKE HIGHLIGHTS: SOYBEANS

- Soils from years of **paper mill biosolids**-applied fields
- Soils had ∑PFAS ~2800 ppb, most are PFOS + ETFOSAA
- All pots were amended with Milorganite Biosolids at a rate of 1% for PFCA precursor addition
- 6 different soybean varieties grown through senescence
- No PFOS or ETFOSA in the bean
- Only primarily PFBA, PFPeA & PFHxA
- Higher % protein, higher uptake







USDA-NRCS CRP Lands
Linda S Lee, PI

EPA United States Environmental Protection Agency

Lazo, Lee, Ma, Cark et al., Manuscript in process

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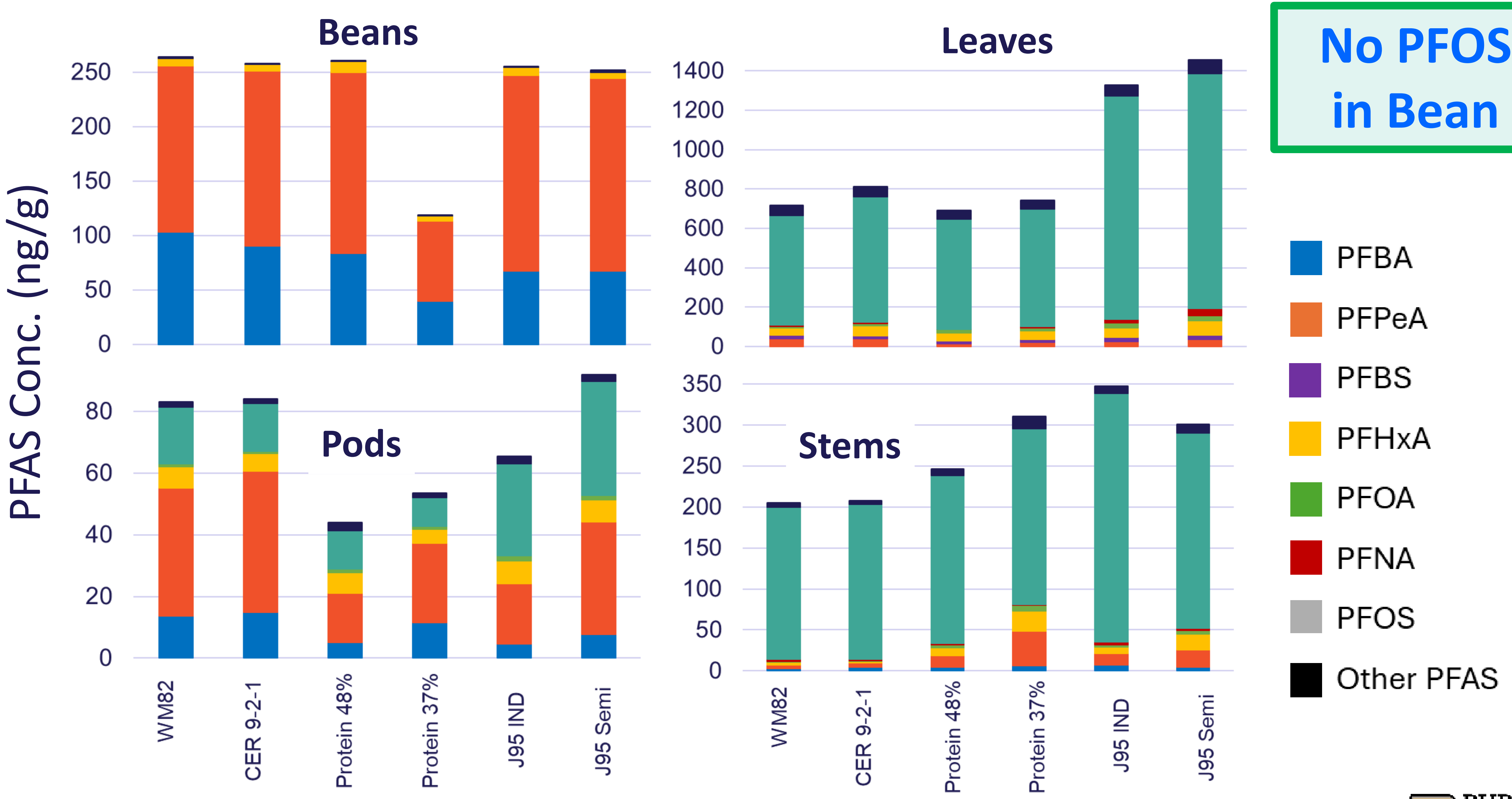
UPTAKE - SOYBEAN PLANTS: **LEAVES > STEMS >PODS**

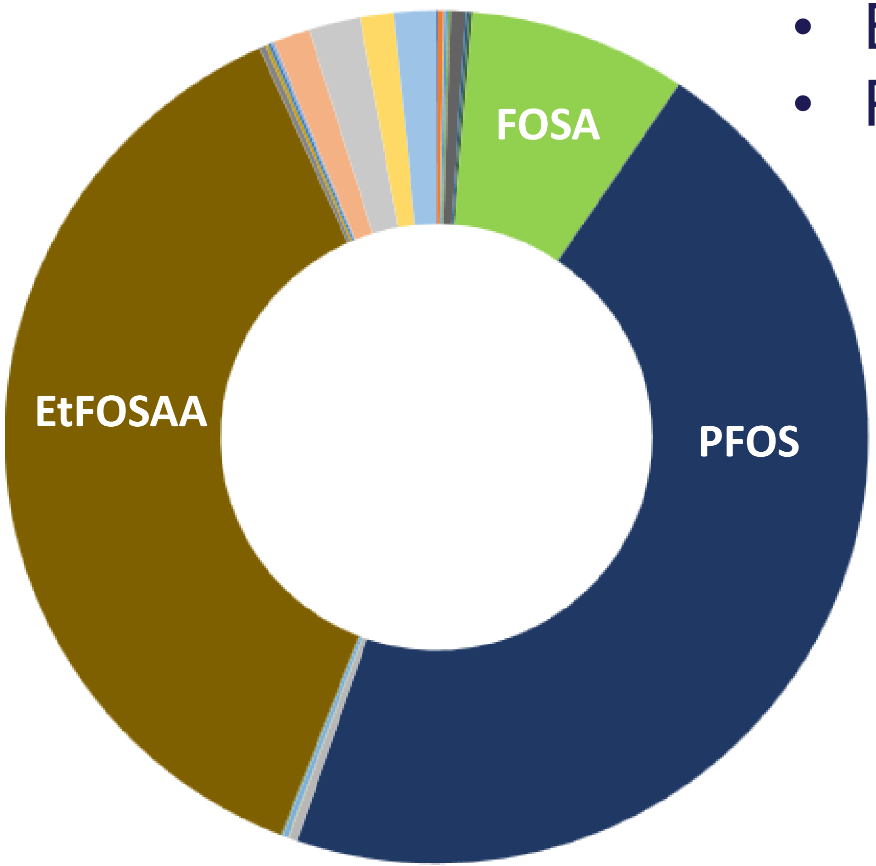


No PFOS in Bean

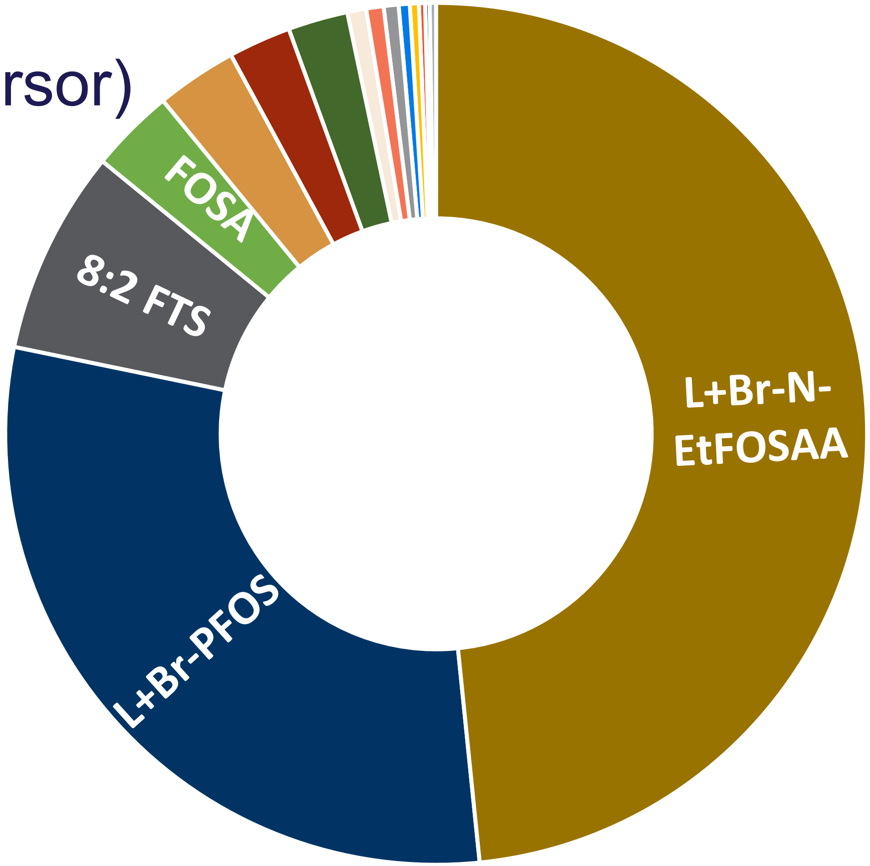
PFAS-Contaminated Soil (Municipal versus Industrial Signature)

Dominated by:

- EtFOSAA (PFOS precursor)
- PFOS



Received only papermill biosolids



Received papermill and municipal biosolids -
also impacted by paper mill discharge into WWTPs

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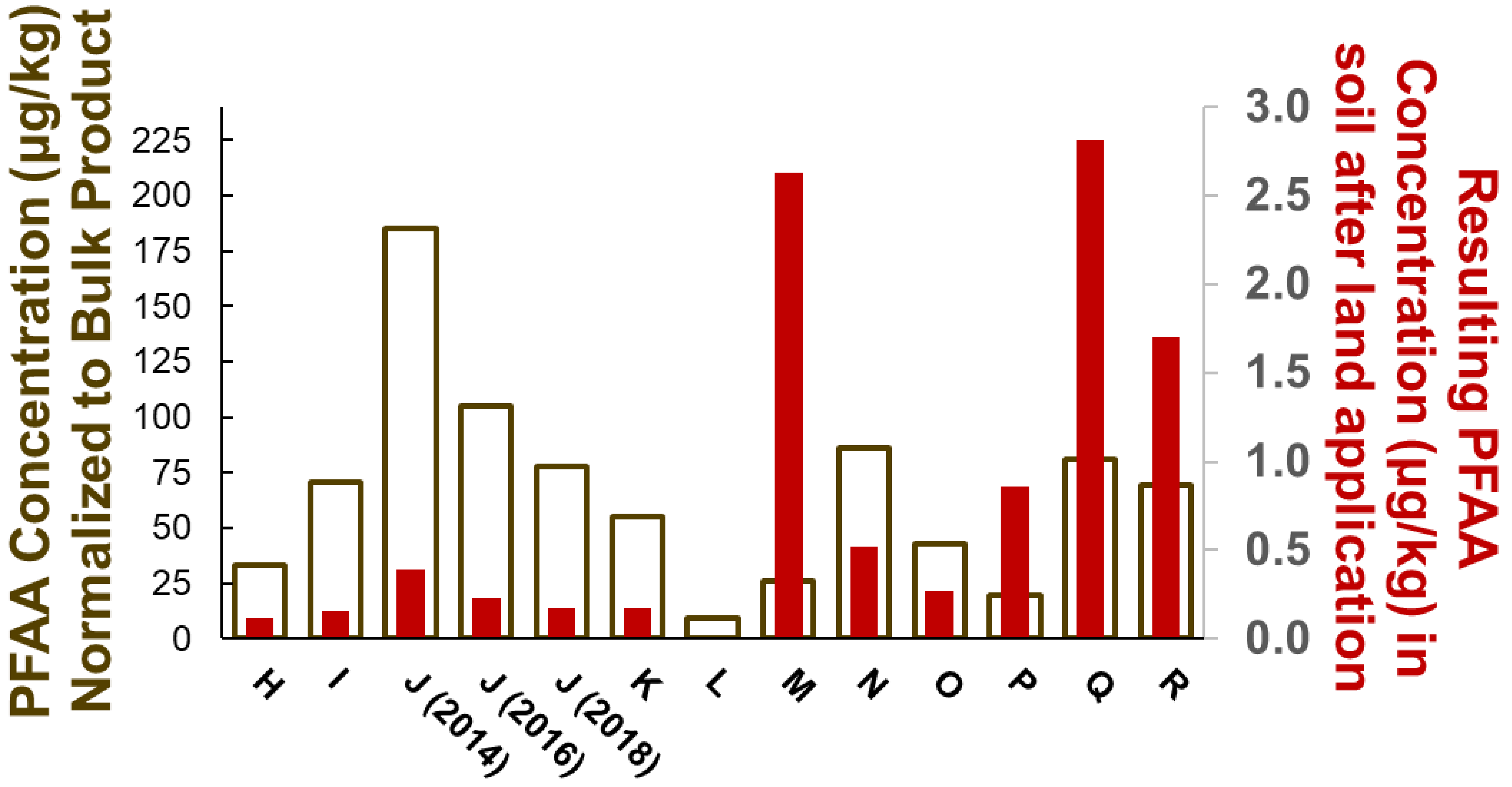
USDA-NRCS CRP Lands;
Linda S Lee, PI

USDA Agricultural Research Service

USDA-NRCS-Main CIG
Andrew Carpenter, PI, Northern Tilth, Lee co-PI,

Putting PFAS in Biosolids in Perspective *(Example)*



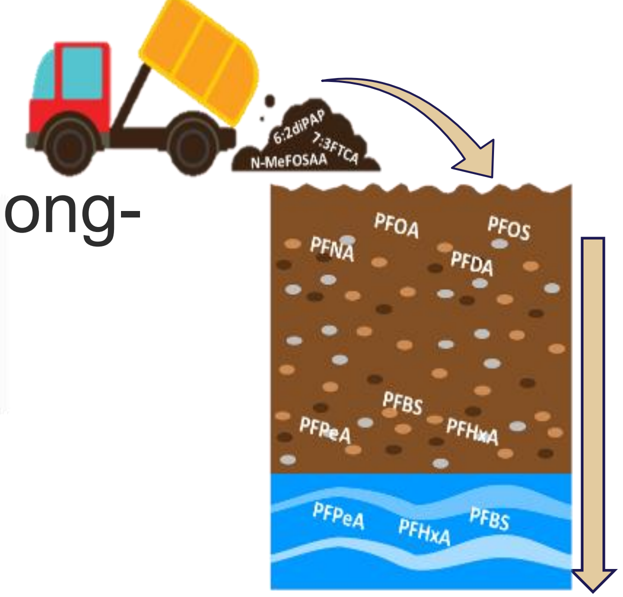
White bars: PFAAS in biosolids being applied at N recommendations

Red bars: PFAA concentrations in soil after mixing into the growing media where roots reside

- Soil amendments/fertilizers are often applied based on N requirements
- Products low in N could lead to higher PFAS loads with a single application

Lazcano-Kim, Choi, Mashtare, and Lee, 2020, EST. https://doi.org/10.1021/acs.est.9b07281

Synopsis and Insights



- Most non-PFAS unregulated COCs are not a short-term or long-term concern
- Our biggest PFAS issues are legacy (prior applications)
- PFAS precursors (many not measured) biotransform to measured PFAS after land application
- PFAS migration from soil to groundwater is dominated by short-chain PFAS
- Long-chain PFAS predominantly persist (with longevity) in the upper profile, thus subject to continual runoff – optimize application strategies and buffer zones, ALSO long chain are decreasing
- Fields under tile-drainage, direct transport to groundwater is minimized *(not shown*

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Perspectives and Path Forward towards a Circular Economy

- *Banning land application places a* ***heavy burden on public municipalities and can lead to numerous unintended consequences***
- **Control sources** contributing to PFAS levels in biosolids (e.g., **pretreatment** of influent from industry or landfills with *high* PFAA levels)
- **Focus on regulating nonessential PFAS uses** to reduce PFAS loads coming into our WRRFs
  Domestic sewage typically contributes the largest PFAS mass load coming into our treatment plants and most PFAS mass exits via effluent to surface waters not biosolids.
- Continue research on fate, effects, **application optimization**, & treatment/mitigation strategies
- **Innovate biosolids processing** to reduce PFAS in biosolids
- Consider **adaptable plans for PFAS-contaminated lands**

+

→

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WINNER'S
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THANK YOU! QUESTIONS?

Acknowledgements

PURDUE UNIVERSITY

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THE Water Research FOUNDATION

HRSD

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