PFAS, Fate, and Transport in Land-Applied Biosolids

Purdue-related PFAS-related research efforts

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Chesapeake Bay Program Toxicant Contaminants Working Group Meeting
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PFAS, Fate, and Transport in Land-Applied Biosolids

Purdue-related PFAS-related research efforts

- Quick overview of current projects
- PFAS Transformation and Release from Biosolids
- PFAS Field Updates
- Ongoing Field Study Status Updates
- Brief Perspective

Projects Specific to Land-Application and PFAS

(co-PI on several ecotox and human health projects not noted here)

EPA STAR G18B112718486 *(Just wrapping up)*
Decreasing polyfluoroalkyl substances (PFAS) in municipal wastewater effluent and minimizing release from land-applied biosolids
L.S. Lee (PI, Purdue), J. Judy (co-PI, UF) & B. Chaplin (co-PI. UI-Chicago)

EPA NATIONAL PRIORITIES G20B113019085 *(in end of Year 3, 2025 target completion)*
Evaluating PFAS Occurrence and Fate in Rural Water Supplies and Agricultural Operations to Inform Management Strategies (R840082) Lead at Purdue University
L.S. Lee (PI, Purdue), H. Preisendanz (co-PI, PSU) & Kurt Pennell (co-PI, Brown University)

EPA NATIONAL PRIORITIES 84042501 *(in end of Year 2, 2025 target completion)*
Unregulated Organic Chemicals in Biosolids: Prioritization, Fate and Risk Evaluation for Land Applications, Lead WRF (Lola Olabode)
L.S. Lee (co-PI, Purdue), J. Gan (co-PI, UC-Riverside) & Drew McAvoy (co-PI, U. oc Cincinnati)

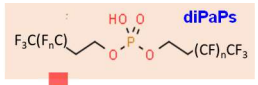
SEVERAL WRF FUNDED PROJECTS

A FEW OTHERS: USDA AND USGS

PFAS Biotransformation

during WRRF processes and after land application

Telomer-based PFAS Example



Intermediates

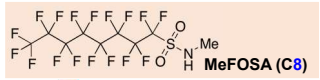
Perfluorocarboxylic acids (PFCAs) e.g., PFOA plus

PFAA Precursors

Multiple steps, pathways, and rates

PFAAs
Terminal Metabolites
Persistent
Anionic (-)
More soluble
More mobile

Electrochemical/y derived PFAS Example



Intermediates

C8, PFOS
Perfluoroalkyl sulfonic acid (PFSA)

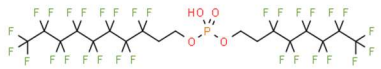
Example: PFAS in 12 2018-2022 Biosolids (µg/kg Dry Weight)

	PFAS	~Min	~Max
Perfluoroalkyl acids (PFAAs) -terminal metabolites	PFOS	5	130
	PFHxS	5	50
	PFOA	3	30
	PFHxA	5	30
PFAA precursors but may also be intermediates from other precursors	6:2 FTS	1	15
	8:2 FTS	1	30
	MeFOSAA	10	100
	EtFOSAA	1	50
	7:3 FTCA	10	40
	5:3 FTCA	0	220

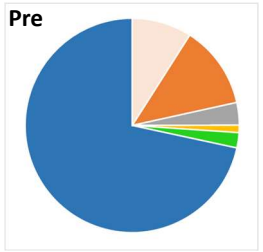
Some Additional Precursors

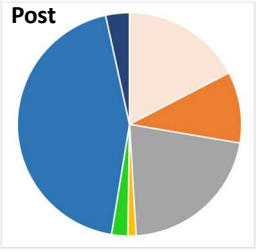
PFAS	~Min	~Max
6:2 diPAP	10	400
8:2 diPAP	0	200
6:2 PAP	20	340
6:6 PFPI	0	9
6:8 PFPI	0	4.4

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



Anaerobic Digestion: Total PFAS Quantified Pre- and Post
Mass % Distribution





PFCAs ■ PFSAs ■ FTCAs/FTUCAs ■ FTSs ■ FOSAAs ■ diPAPs* ■ PFPis*

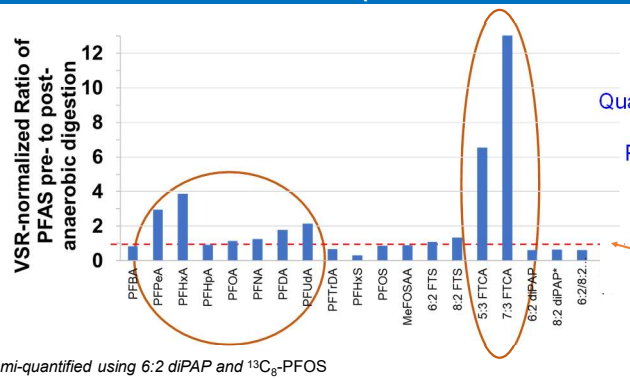
Terminal — Intermediates — Precursors

*Semi-quantified using 6:2 diPAP and $^{13}C_8$-PFOS

Caroline Alukkal
PhD student

Manuscript in process

Typical Anaerobic Digestion
PFAS Pre- to Post Ratios *(after Volatile Solids Reduction)*



Changes in Total Quantifiable PFAS on a F-mole basis: Pre- to post ≈ 1.6

No change

*Semi-quantified using 6:2 diPAP and $^{13}C_8$-PFOS

Manuscript in process

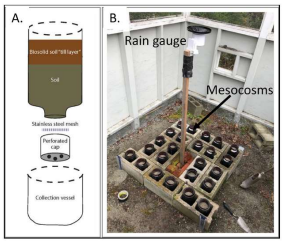
Generation of PFAAs and intermediations even greater under aerobic processes

Caroline Alukkal
PhD student

PFAS Sources to and from Agriculture Operations

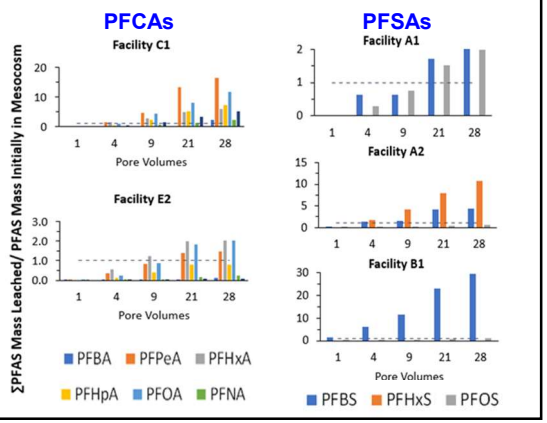
- Accumulation & Transformation
- Crop uptake
- Leaching
- Run-off

WRF 5042: PFAA Leached Relative to Initial Mass in Biosolids In 6-mo outside mesocosms



PFAA mass eluted typically much higher than initially found in biosolids

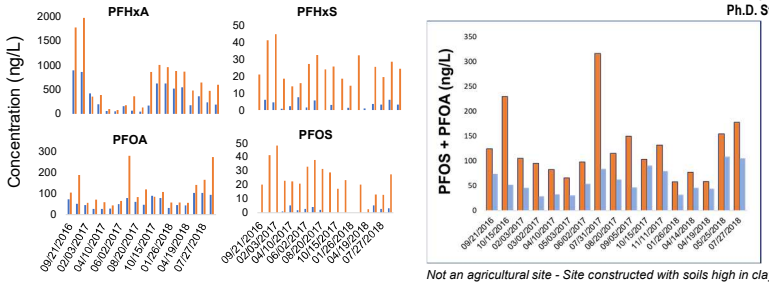
WRF 5042 (CDM Smith, Purdue)
Water Research 217 (2022) 118405



Example of blending: Reduced PFAS leachate concentrations *(Constructed reclamation site, 15-cm zero-tension lysimeters, x5 ag rate)*

Orange bars (Treatment A): biosolids
Blue bars (Treatment B): biosolids diluted 43% by mixing with mulch
Dilution effect observed, most pronounced for PFHxS and PFOS

Lynda Peter
Ph.D. Student, AGRY

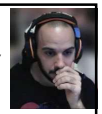


Unpublished data; Manuscript in process

Not an agricultural site - Site constructed with soils high in clay with poor structure dug up from a site targeted for reclamation using biosolids

Dedicated Land Disposal Site (40 years)

Roy Alvarez
Postdoc, AGRY

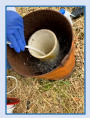


Surface soil

- 6 surface soil (first 10") samples randomly distributed
- Mixed in the laboratory
- Freeze dried
- Moisture content ≈40%

Groundwater

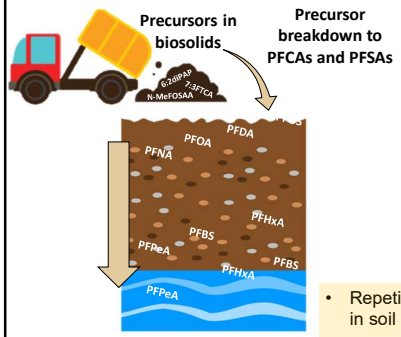
- 4 wells were sampled
- 1 well sample not used
- Extracted within 1 week from sampling

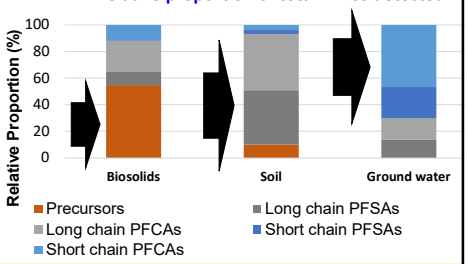


Biosolids

- 4 samples in 90 min intervals
- Mixed in the laboratory
- Freeze dried
- Moisture content ≈96%

Field Study: 40-y Historical Dedicated Land Disposal Site





- Repetitive biosolids application can lead to PFAS accumulation in soil over time
- High retention in surface soils even after long term application - PFAS sorption at the air-water interface
- Precursors breakdown to PFAAs
- Short-chain PFAAs dominate what is getting to groundwater

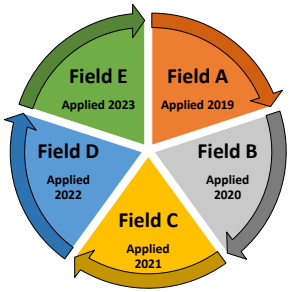
Unpublished data; Manuscript in process

Future Investigations at the Site:
DLD, New 1st time Biosolids-Application Site, & Irrigated Site

- Biosolids
- Treated effluent irrigation water
- Surface soil composites
- Soil cores
- Crops
- Groundwater
- Run-off

Moving forward: new sampling areas

5-year biosolids application cycle



Site characteristics
- Biosolids stored outside until applied
- 1 field applied per year in a 5-y cycle
- Low depth to water table

Objectives
- Accumulation assessment
- Persistence assessment
- Crop uptake assessment

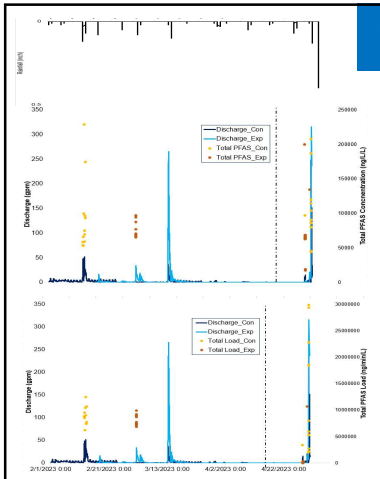
Hampton Roads Sanitation District (HRSD), VA

Soil types: Acredale, Bojac, Tomotley

- Class A biosolids (Cambi THP)
- Three soil types
- Surface soils and cores
- Crop uptake (corn)
- Run-off
- Some MWs
- Analyzing other materials being land applied

Lynda Peter
Ph.D. Student, AGRY

Hampton Roads Sanitation District (HRSD), VA
Run-off Sampling

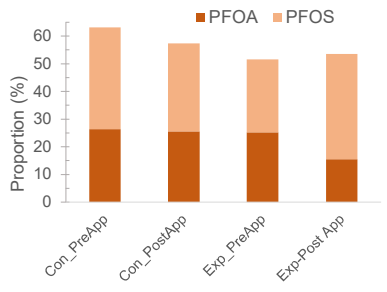


- Last historic application was in 2017 – Class B biosolids (Typical Anaerobic process)
- **Exp** = Acredale soil plots that received Class A application in April 2023
- **Con** = Control Acredale soil plot – no new application
- Total PFAS concentrations in run-off ~1300 – 3500 ppt in both 'control' and pre-2023 application for Exp plots
- Difference post application was limited after accounting for difference in rain/run-off events
- Apparent long-term effect from PFAS in historical applications *(?)*

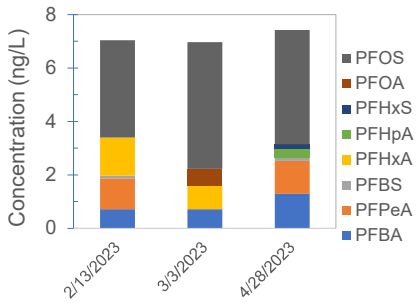
Unpublished data; Manuscript in process

Hampton Roads Sanitation District (HRSD), VA

Relative PFAS Distribution in Run-off



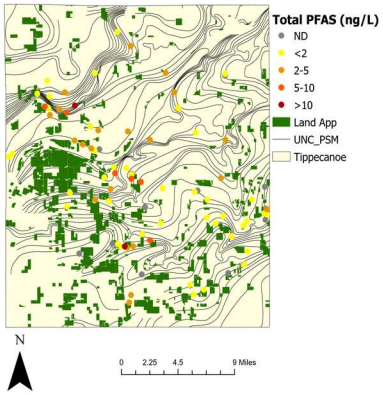
PFAS in Rainwater at the Site



- Last historic application was in 2017 – Class B biosolids (Typical Anaerobic process)
- **Exp** = Acredale soil plots that was to and then did receive Class A application in April 2023
- **Con** = Control Acredale soil plot – no new application

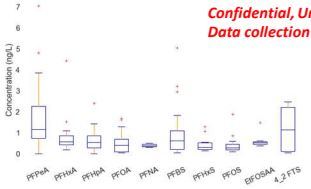
Confidential, Unpublished data
Data collection continues

Data Summary for 95 Wells to Date in Tippecanoe County



- 95% of wells have total PFAS < 5 ng/L (ppt)
- Only 4% have total PFAS > 20 ng/L with the max < 35 ng/L total PFAS
- Most PFOA and PFOS levels were < 1ng/L
- No 'clear' trend with land-applied biosolids
- Critical data synthesis and more sampling in process

Confidential, Unpublished data
Data collection continues

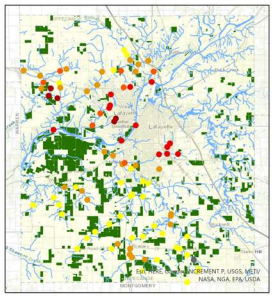


Lynda Peter
Ph.D. Student, AGRY

*Data from Purdue
EPA National Priorities G20B113019085, Lee PI

1 ppt equal one second in 32,000 years

Summary of 93 Stream Samples (July '23) in Tippecanoe County



- Total PFAS ranged from <LOQ to 93 ng/L
- 33% had total PFAS > 5 ng/L
- Max Individual PFAS: PFBS (85 ng/l), PFPeA (7.02 ng/L), PFHxA (5.68 ng/L) and PFOA (5.26 ng/L
- PFOS detected at > 4 ng/L (< 5 ng/L) in 2 locations
- Spatial distribution of PFAS detected in wells and surface water was similar; the higher concentrations in all samples were clustered around in the NW.
- Comparing surface and well water results indicates that surface water is more vulnerable to PFAS contamination from land application of biosolids (e.g., run-off) and other PFAS sources (e.g., direct discharge, urban storm run-off, CSOs)

Confidential, Unpublished data
Data collection continues

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*Data from Purdue
EPA National Priorities G20B113019085, Lee PI

1 ppt equal one second in 32,000 years

Ongoing Research for PFAS (and UOCs) and Funding Acknowledgements

- Ongoing outreach and data synthesis
- Additional well water sampling and associated biosolids
- Field studies to assess transport, transformation, and various management strategies
- Tile drain study Fall 2023
- Wetland studies

EPA United States Environmental Protection Agency

THE Water Research FOUNDATION

HRSD

"Let's move fast to stop non-essential uses of PFAS while working carefully and more slowly on balanced regulation as research continues to inform."
…because soils love affordable biosolids!

Sampling of PFAS in streams - Lynda Peter and Ariana Lazo
Photo by Tom Campbell, Purdue University.