

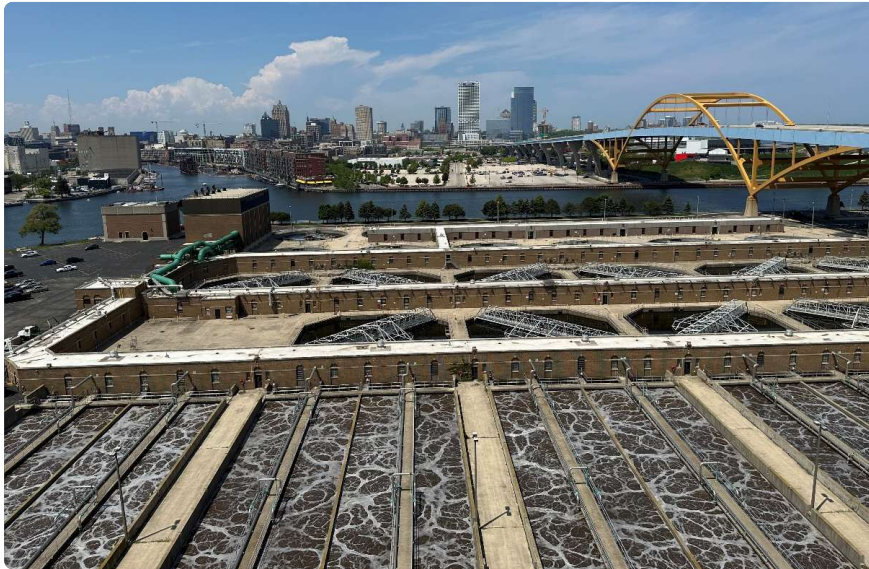
Research as A Tool for Utility Management and Planning: Biosolids End Uses and PFAS

Prepared for the Second Annual
Midwest Biosolids Association
Conference



Presented by: Matt Magruder &
Patrick McNamara, PhD, PE

WHAT DOES MMSD DO?



Water Reclamation



Flood Management



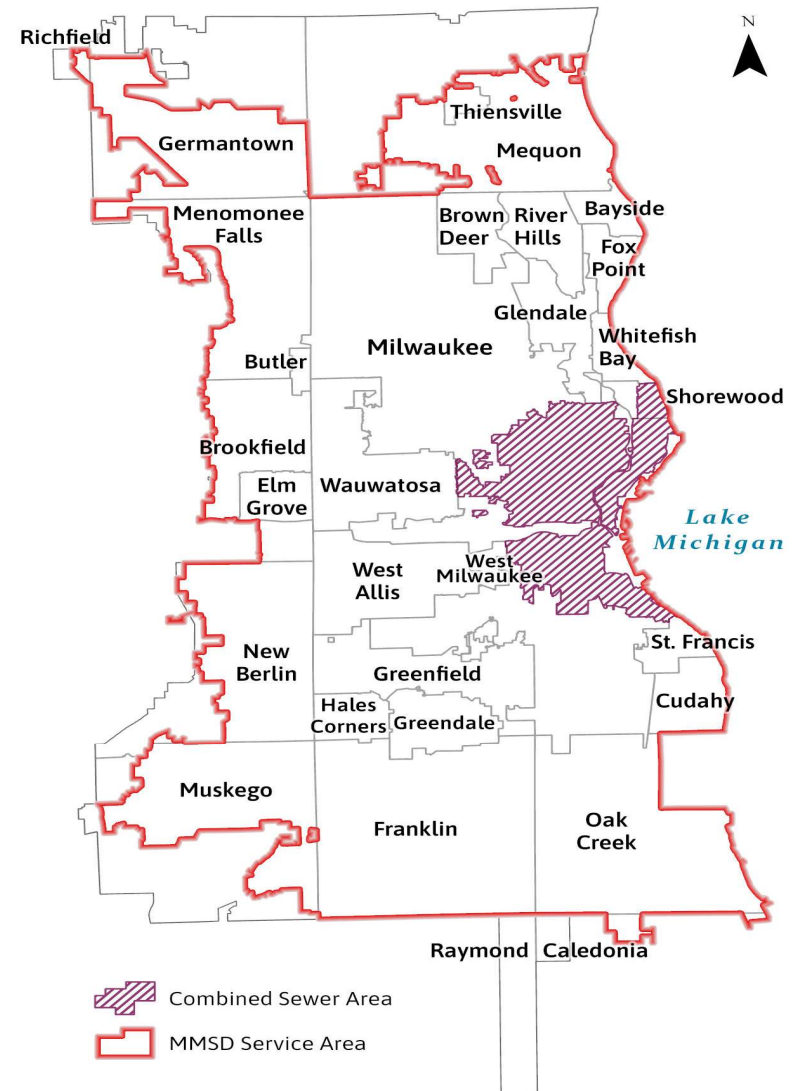
2035 VISION

A Sustainable Bottom Line

- Integrated Watershed Management
 - Balancing Green & Grey Infrastructure
- Climate Change Mitigation and Adaptation
 - Energy Efficiency
 - Net 100% Renewable Energy Sources

WHO DOES MMSD SERVE?

- Over 1 Million Customers
- 29 Municipalities
- 423 Square Mile Planning Area



Treatment and Storage



Jones Island – 330 MGD
+ 60 MGD Wet Weather Capacity



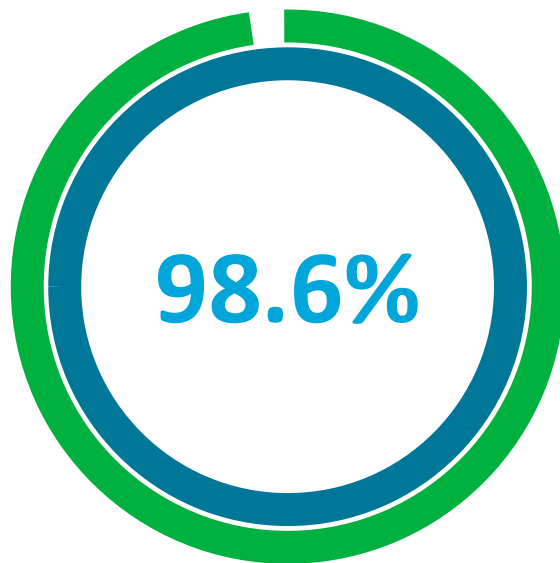
ISS – 521 MG Capacity



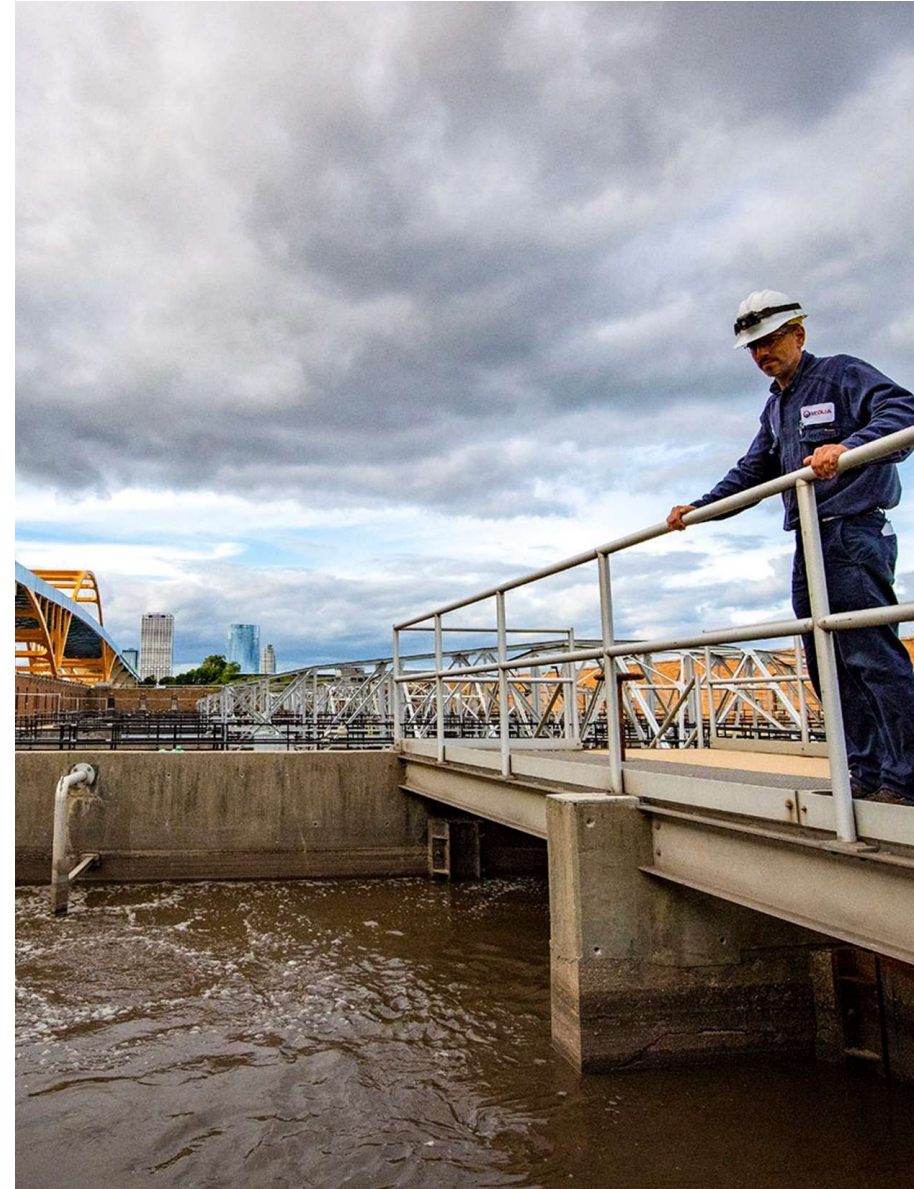
South Shore - 300 MGD Capacity

CAPTURED & CLEANED

Since 1994



MMSD





MILORGANITE® Slow-Release Fertilizer

For Your Lawn & Garden

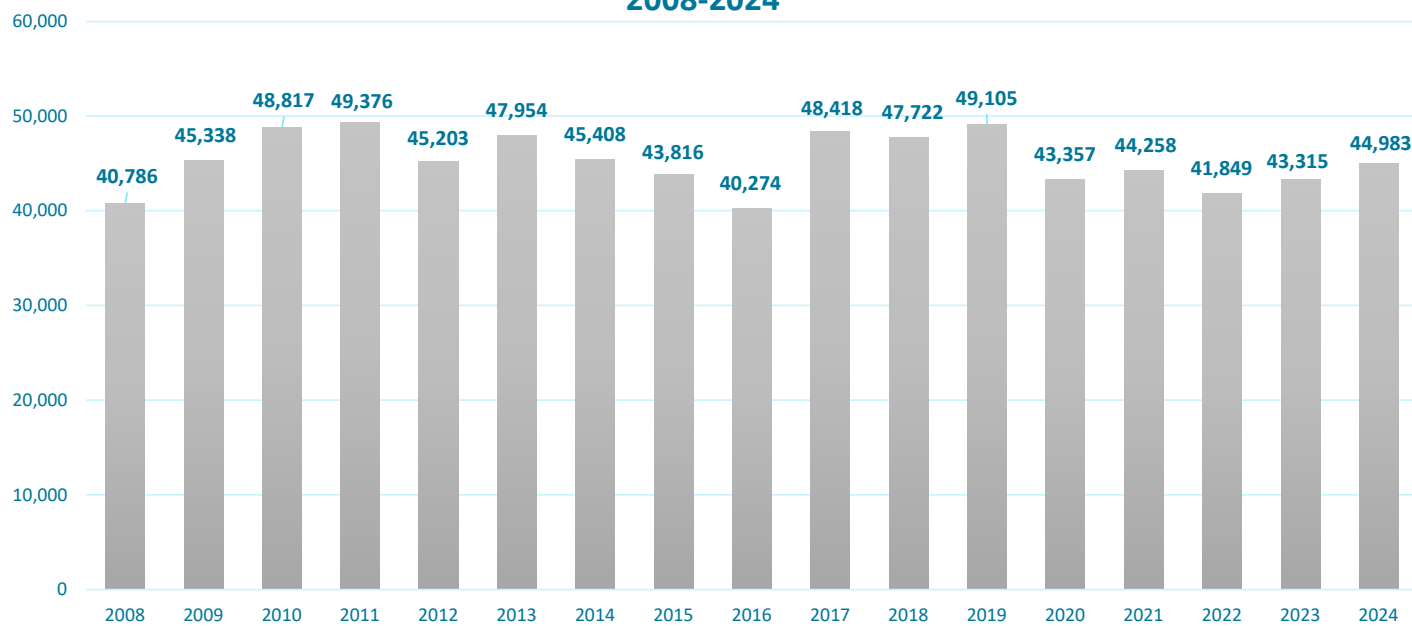


History of Milorganite

- Demand to improve water quality
- Reclaiming wastewater using the biosolid since 1900s
- Oyvind Juul (O.J.) Noer was instrumental in the success of Milorganite
- Milorganite (MILwaukee ORGANic NITrogen)
- Since 1926: over 10 billion lbs. of nutrients have been diverted from landfills



Tons Produced 2008-2024



Milorganite Partners



Jones Island
Water
Reclamation
Facility



Distributors



Outsourced
Packaging



Milorganite Bagged Products



32lb Bag

- Most Popular Product
- Sold in Retail stores Nationwide
- Covers 2,500 sq. ft.
- Feeds for 8-10 weeks



5lb Bag

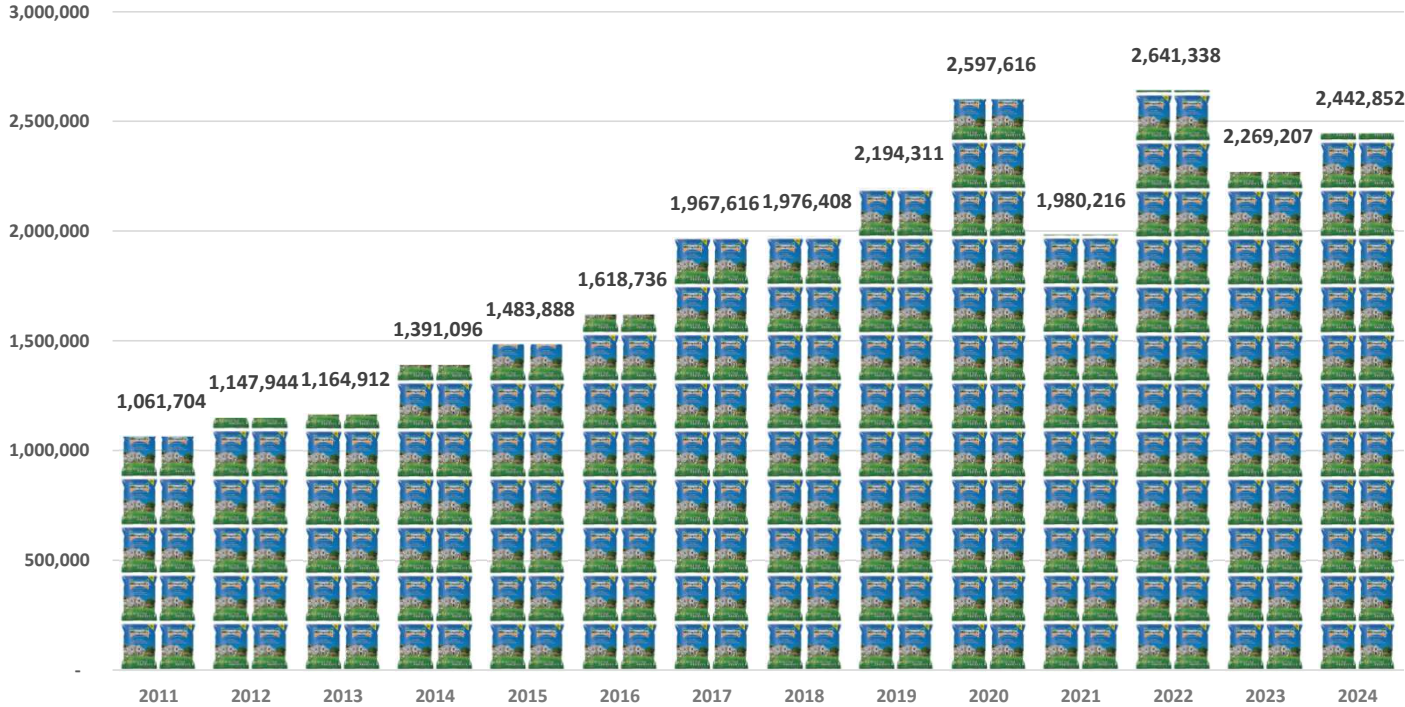
- Ideal for Gardens, vegetables, and small containers



50lb Bag

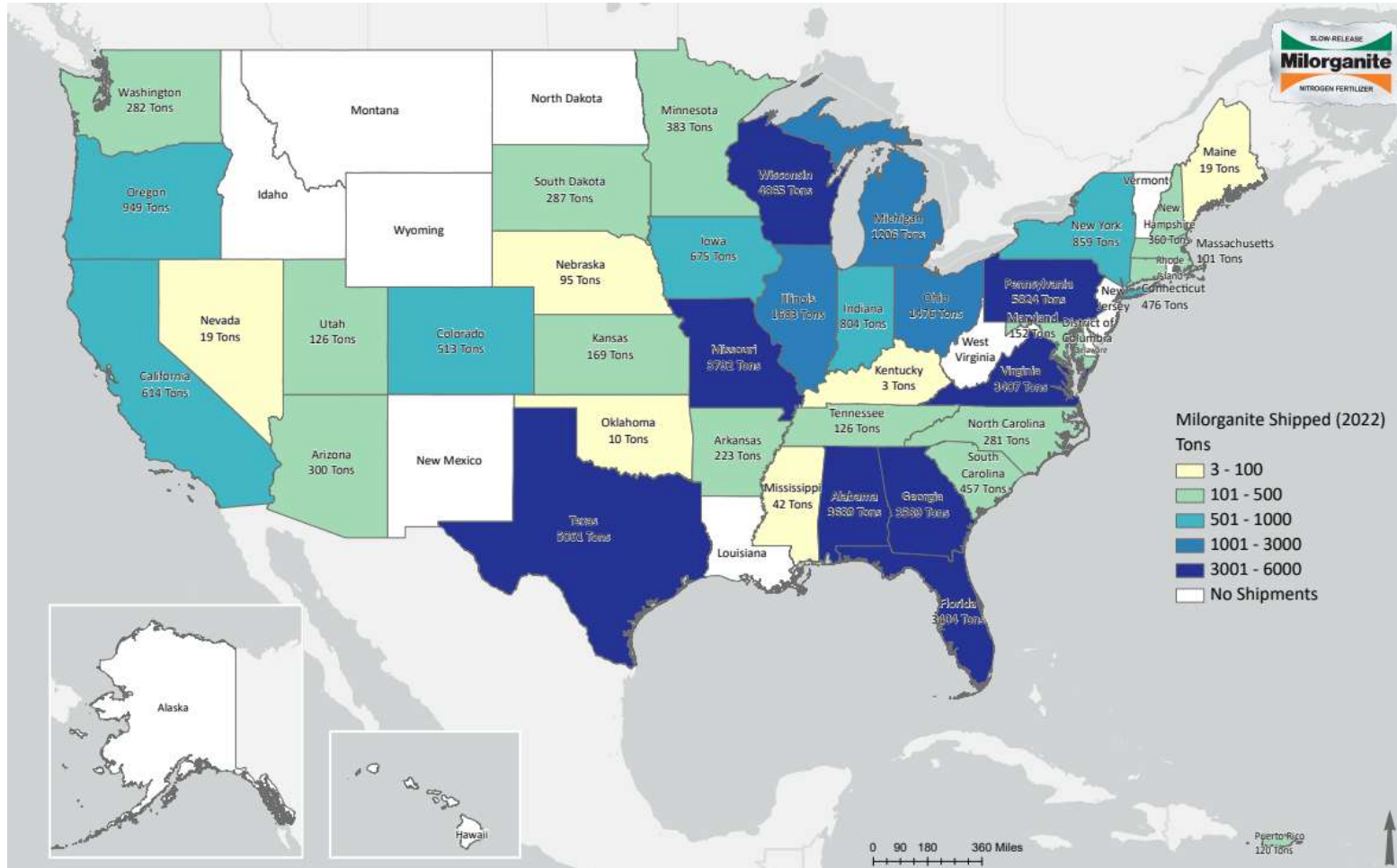
- Professional Product
- Smaller granule
- Most common for Golf Courses, Landscapers

Retail Bags Shipped 2011- 2024



Where is Milorganite Shipped?

+10k retailers nationwide





...what could go wrong?

- [illegible]

Enter Pyrolysis

A long-term partnership with Marquette University.



- Started in 2012
- Six research projects
- One lab-scale system developed
- Five students trained

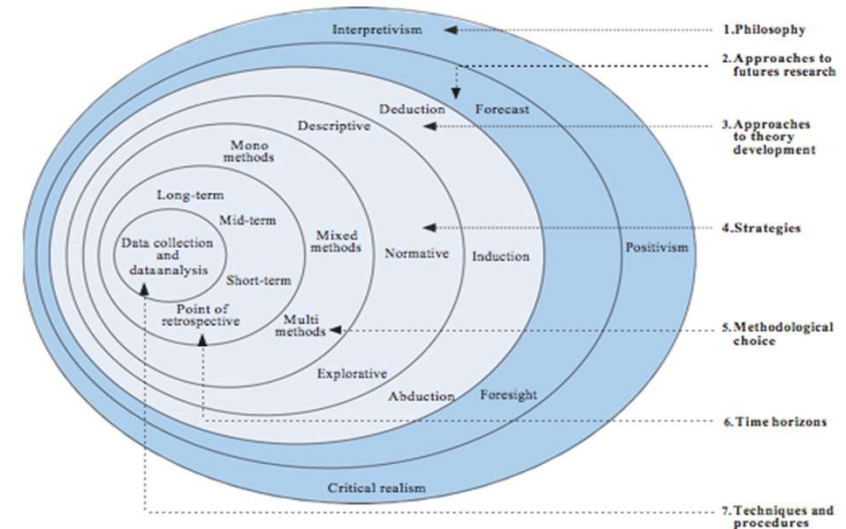
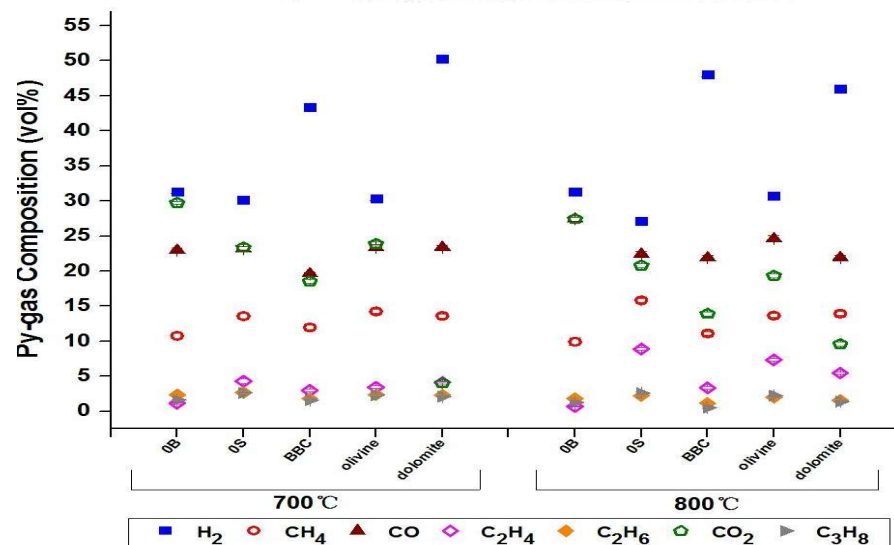
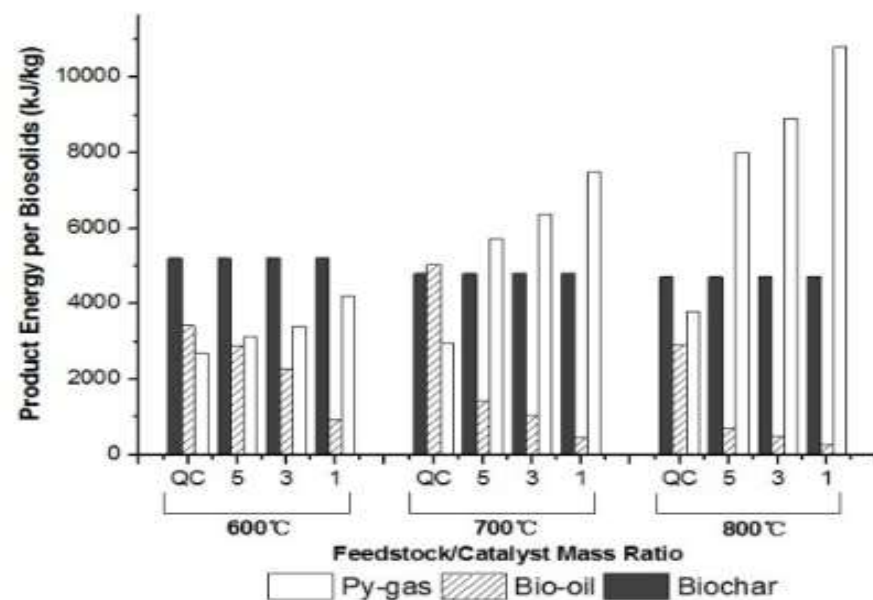


Figure 2. Research onion for futures studies
Source: author following Saunders et al. (2016)

Research Projects

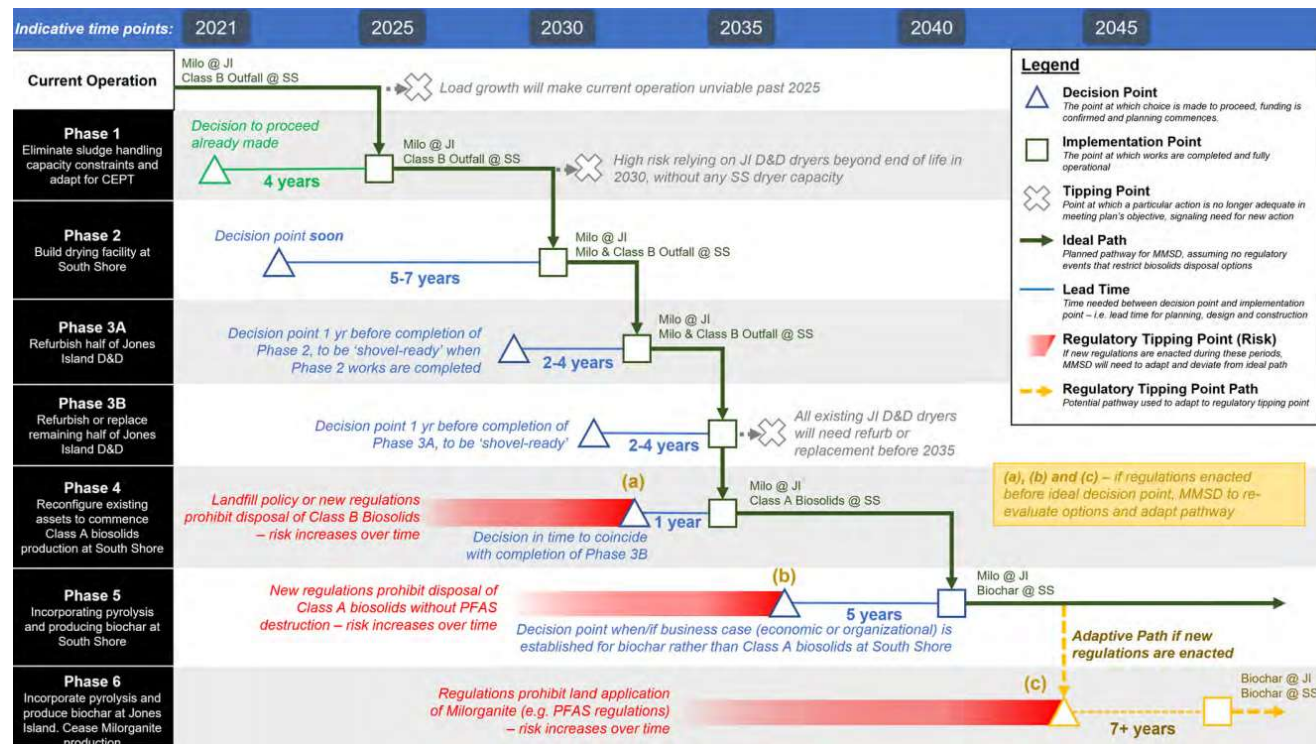
1. Development of Energy and Product Mass Balances
2. Use of Modified Biochar as a Fertilizer
3. Removal of Estrogens and Micropollutants Using Pyrolysis
4. Catalytic Process to Eliminate Bio-oil and Increase Py-gas Production
5. Lab Pilot Scale Pyrolysis: Auto-Catalysis to Improve Yields and Quality
6. Bio-oil Condensate Degradability and Anaerobic Co-digestion



Biosolids Advanced Facilities Plan

○ MMSD's Biosolids Advanced Facilities Plan goals:

- What is the best way to make **Milorganite®**?
- What drivers influence the long-term viability of Milorganite?
- How can MMSD adapt to changing drivers?



Learn More about the BAFP:

<https://www.mmsd.com/government-business/2050-facilities-plan/biosolids-advanced-facilities-plan>

The Next Layers

We have a plan, but how far does our existing infrastructure get us?

Is it responsible to invest so heavily in the baseline amidst the uncertainty?

What information gap(s) do we need to close?



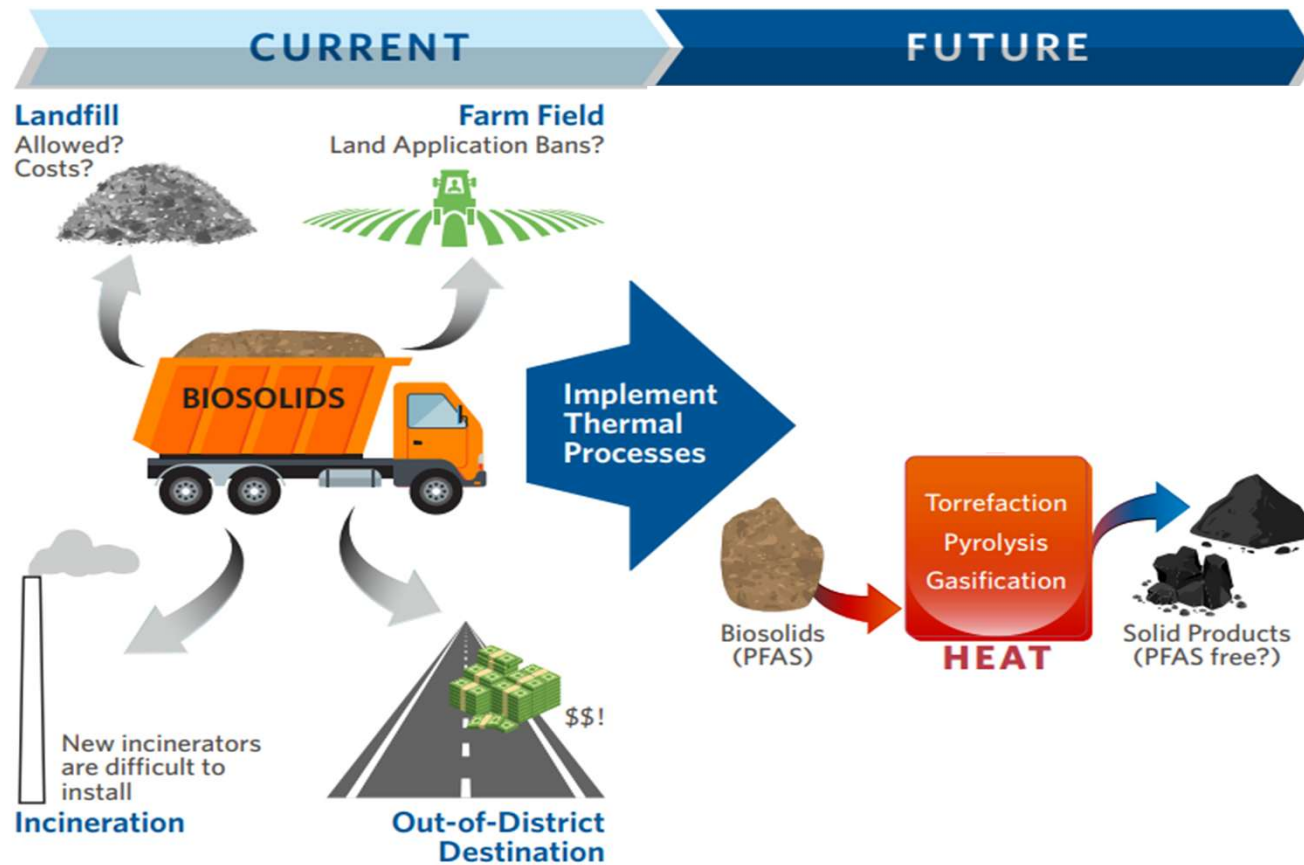


THE
**Water
Research**
FOUNDATION

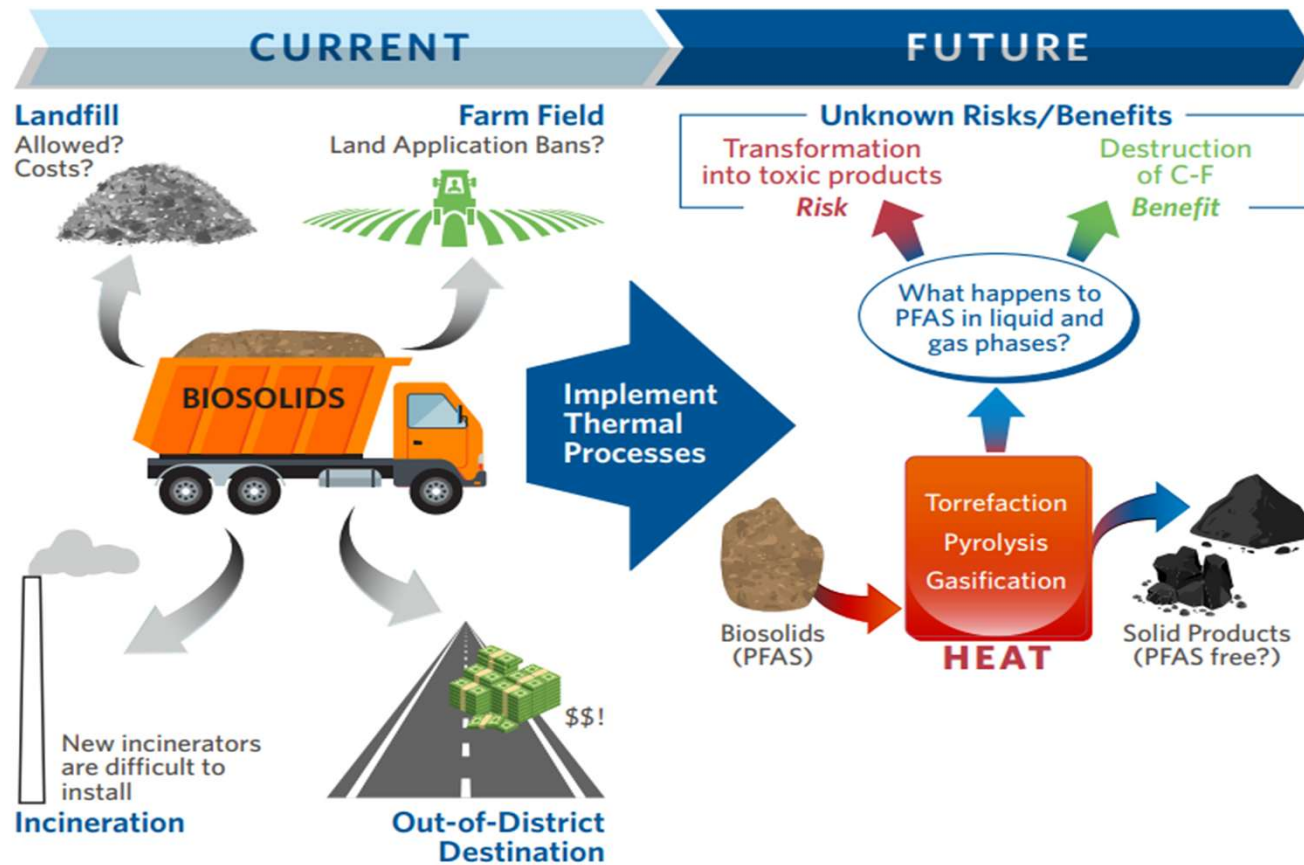
Project #5211

Understanding the Value Proposition for Thermal Processes to Mitigate PFAS in Biosolids

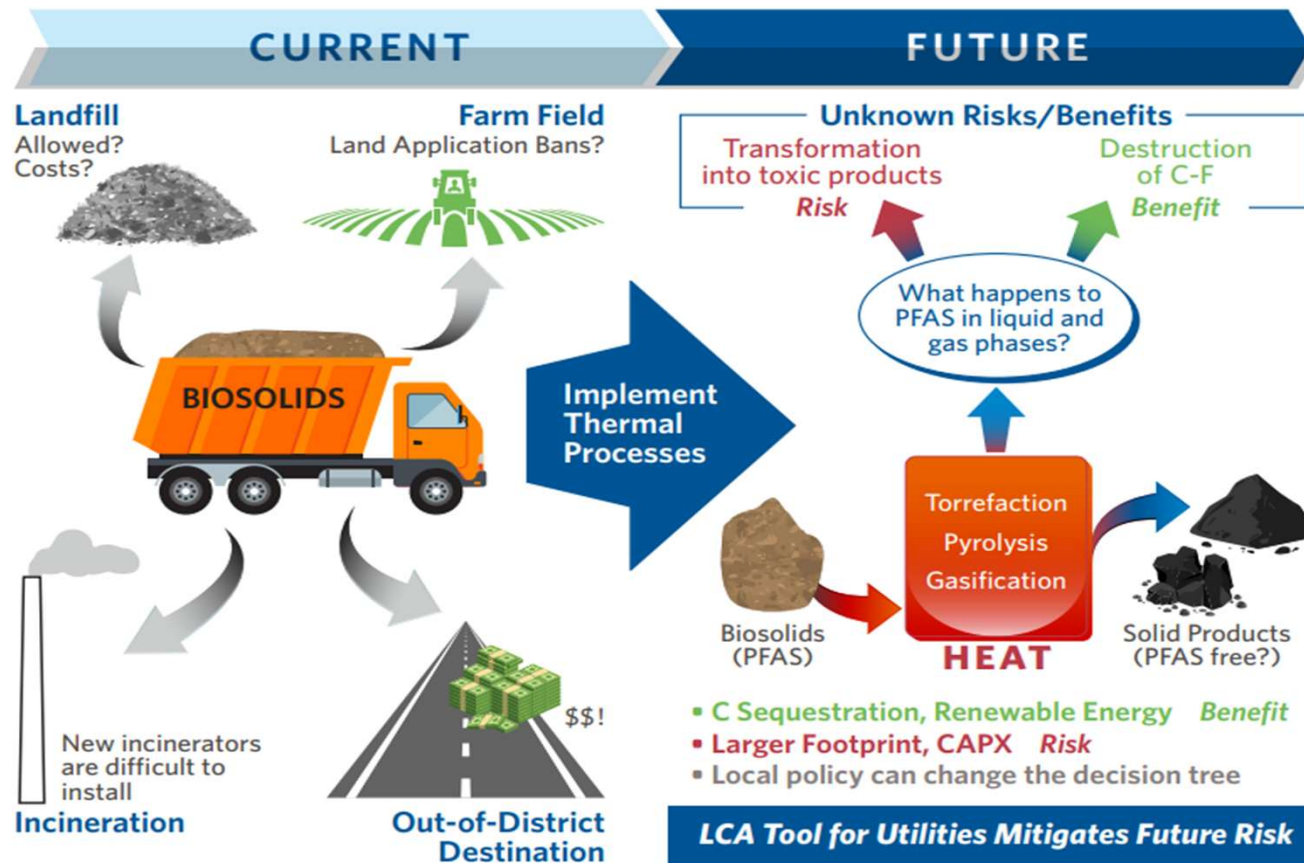
PFAS Risks in Biosolids Management



PFAS Risks in Biosolids Management



PFAS Risks in Biosolids Management



What Can Treatment Do to PFAS?

Start with Fate Definitions

Removal

- Compound is no longer present in its original phase (no bonds are broken)

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- Compound reacts to form new compound with modified chemical structure (carbon-carbon bonds are broken)

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Start with Fate Definitions

Removal

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- Compound reacts to form new compound with modified chemical structure (carbon-carbon bonds are broken)

Destruction

- Compound is mineralized (carbon-fluorine bonds are broken), inorganic F and CO₂ remain

What does drying do to PFAS?

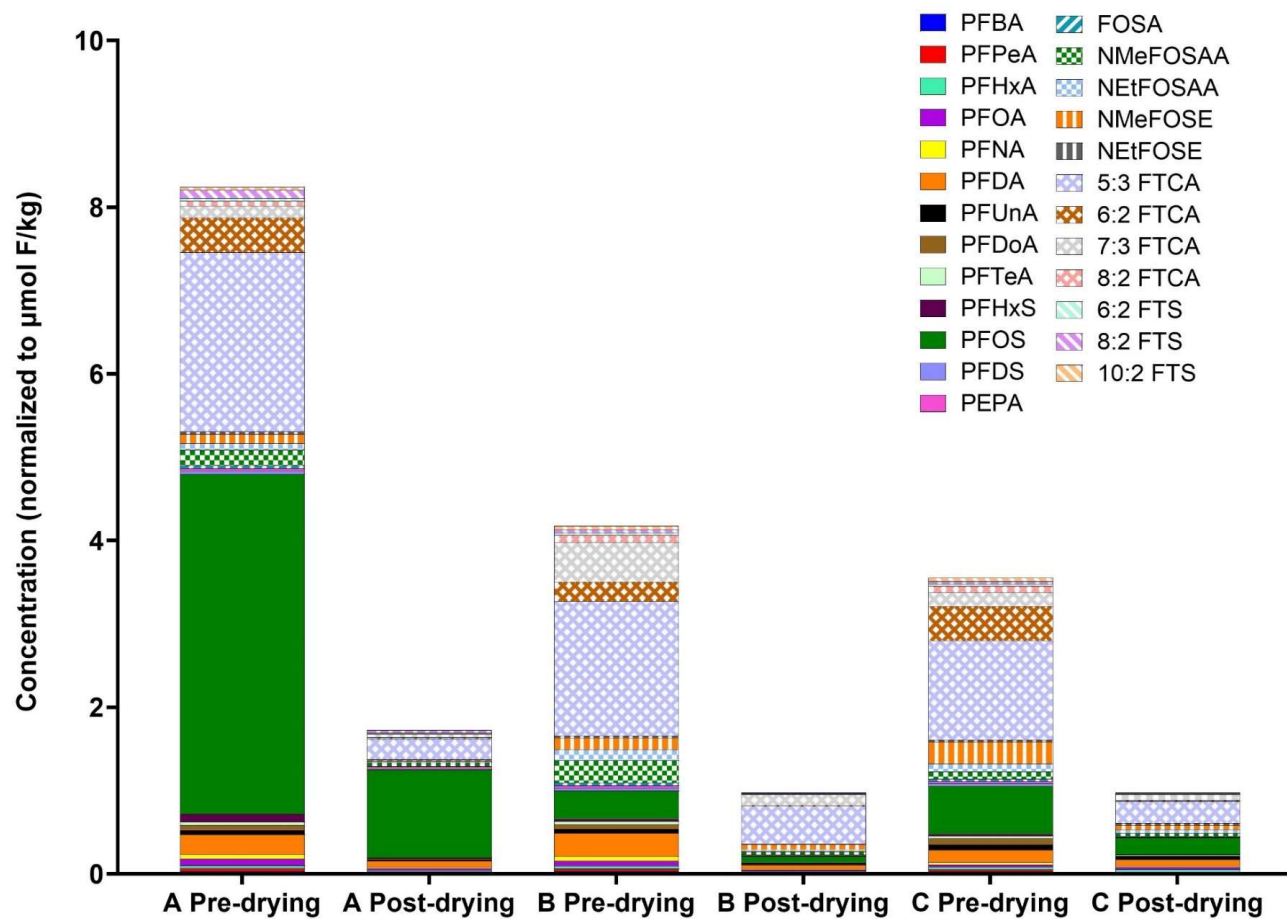
Drying Temperatures Are Too Low to Affect PFAS, Right?

Experimental Approach

- We tested samples from 3 utilities
- Dried in oven over night
- Measured PFAS in wet and dry samples



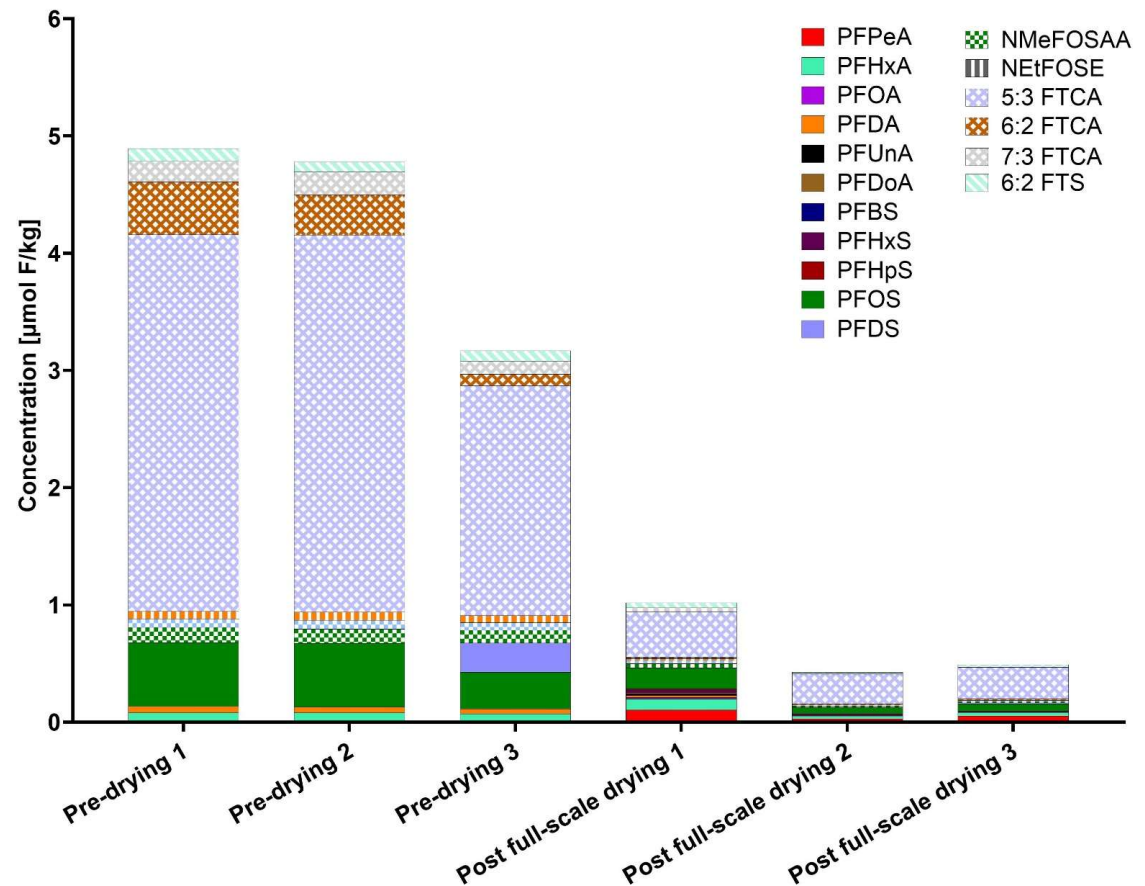
Drying Reduced PFAS Concentrations



Drying reduces the total PFAS concentration in biosolids and alters the PFAS profile. McNamara, Moss, Hoener et al., *Env. Sci.: Water Research & Technology*, 2025.

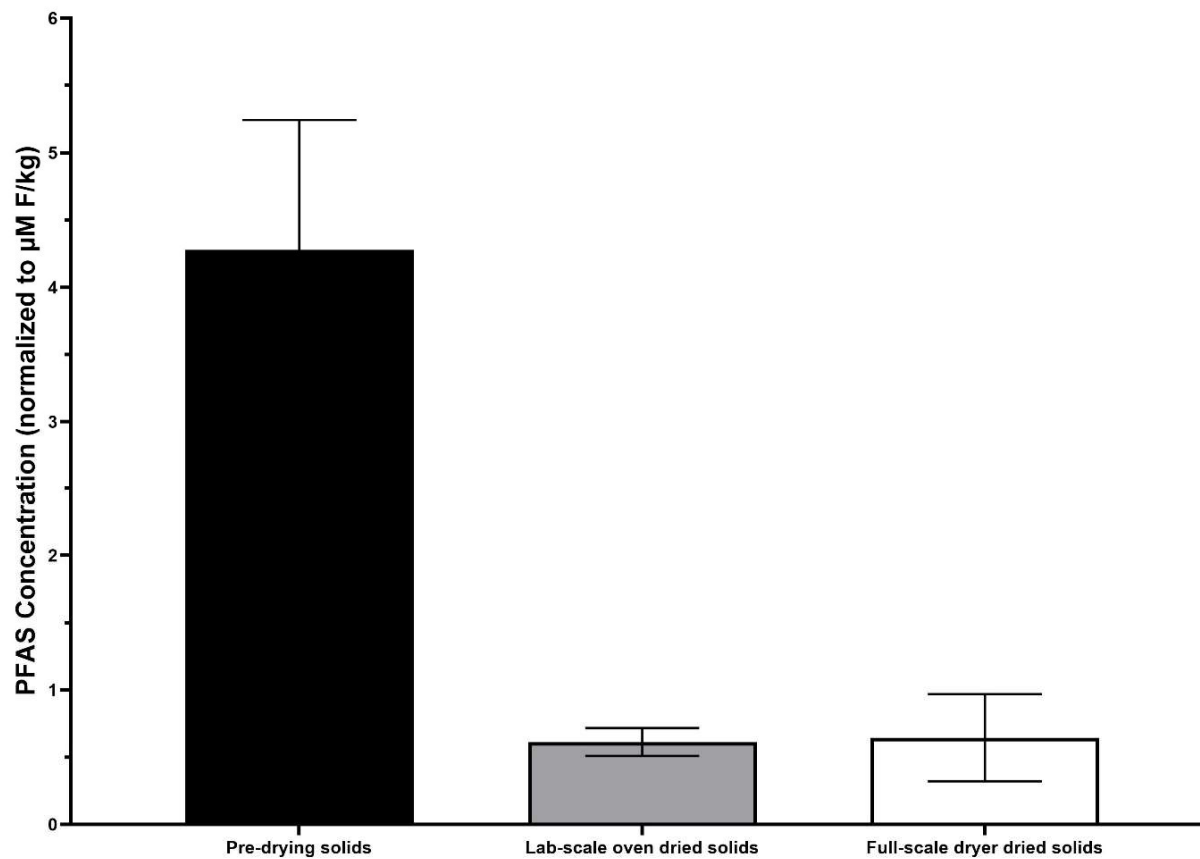
What happens to PFAS in a full-scale dryer?

Dried Biosolids Have Less PFAS by Total Mass in Full-scale Dryer



Drying reduces the total PFAS concentration in biosolids and alters the PFAS profile. McNamara, Moss, Hoener et al., *Env. Sci.: Water Research & Technology*, 2025.

Dried Biosolids Have Less PFAS (80% Removal)



PAPER

**Drying reduces the total PFAS concentration in
biosolids and alters the PFAS profile†**

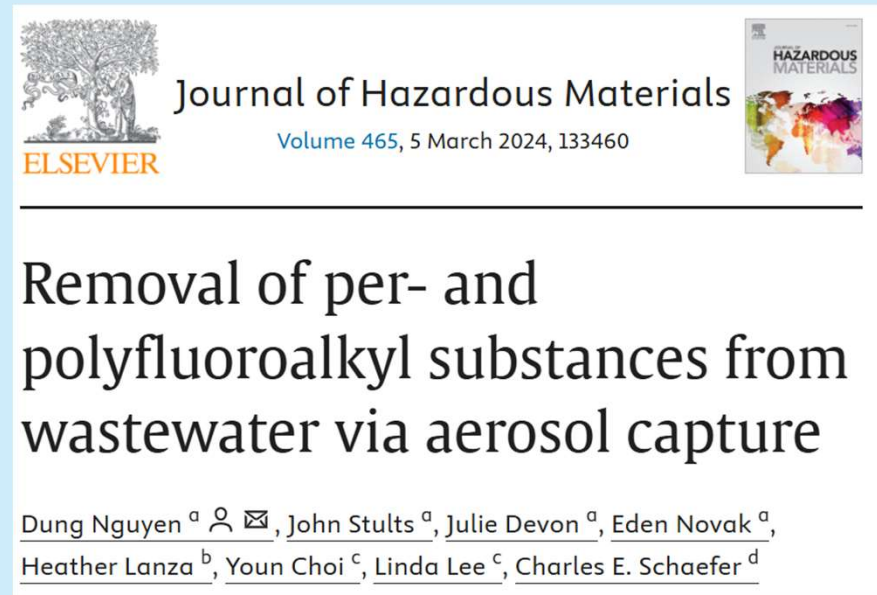
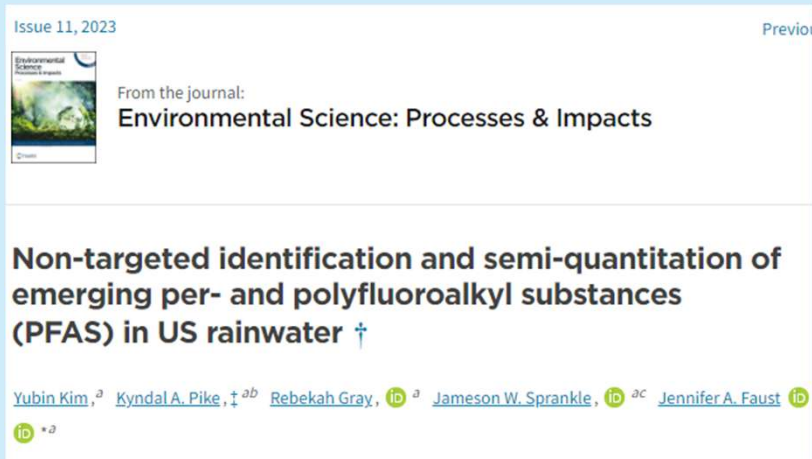
Cite this: DOI: 10.1039/d4ew00890a

Patrick J. McNamara, ^{ab} Jessica Calteux,^b Eric Redman,^c Taryn McKnight,^c
Lynne Moss,^a Webster Hoener,^a Scott Carr^a and Zhongzhe Liu^d

Possible Explanations

- PFAS like air-water interface
- PFAS are detected in rain & aeration
- PFAS leave with water as water droplets (aerosols) leave

More research is needed to confirm removal mechanism

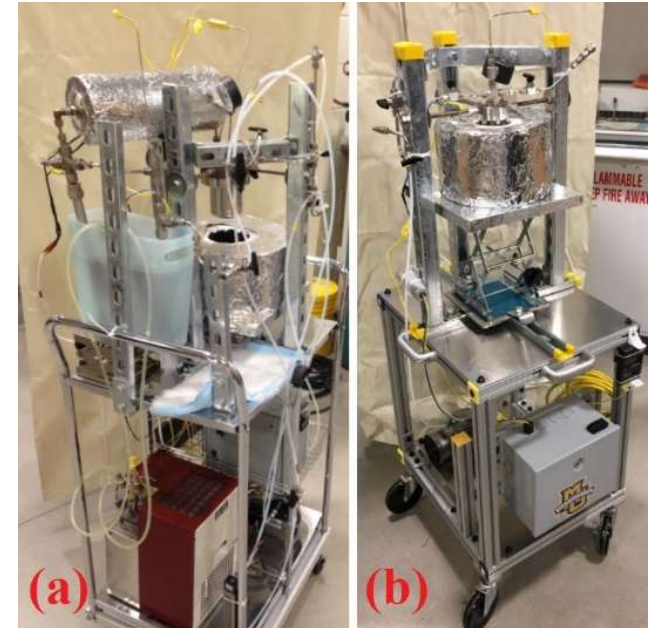


More Research....

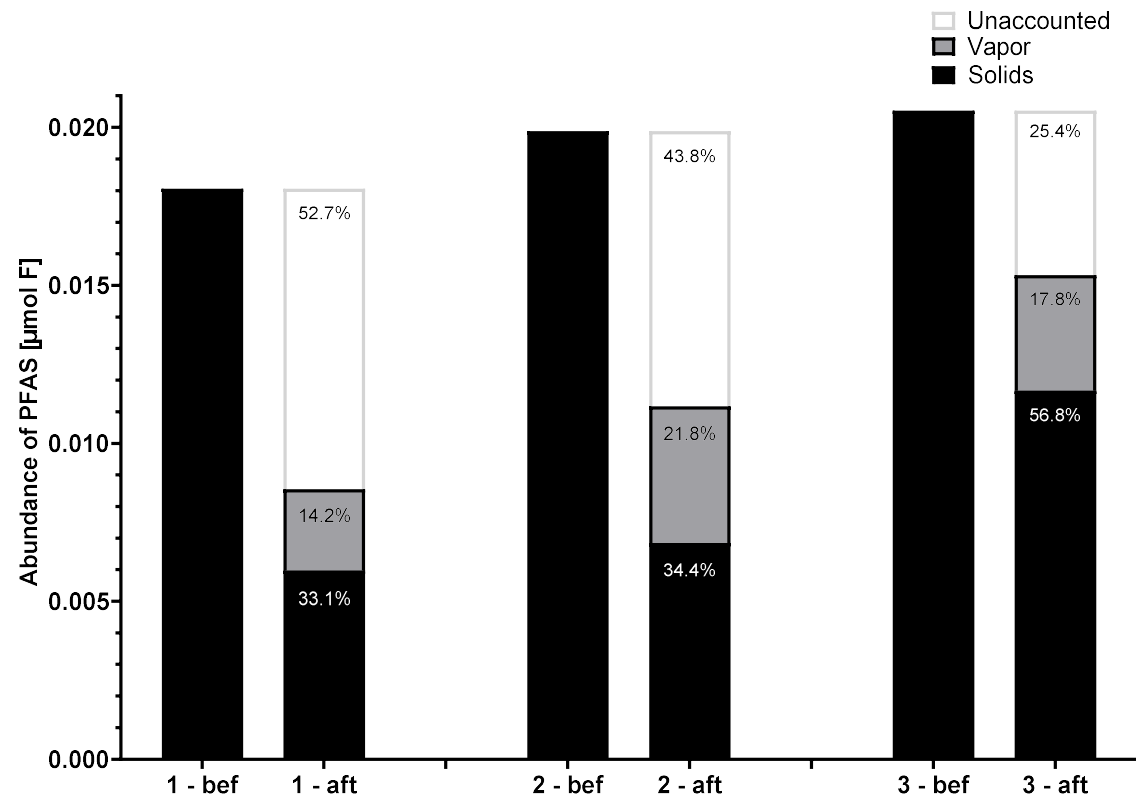
- Dried biosolids from new utility
- Captured gas phase in methanol impingers
- Analyzed methanol for PFAS



Zhongzhe Liu, Ph.D.



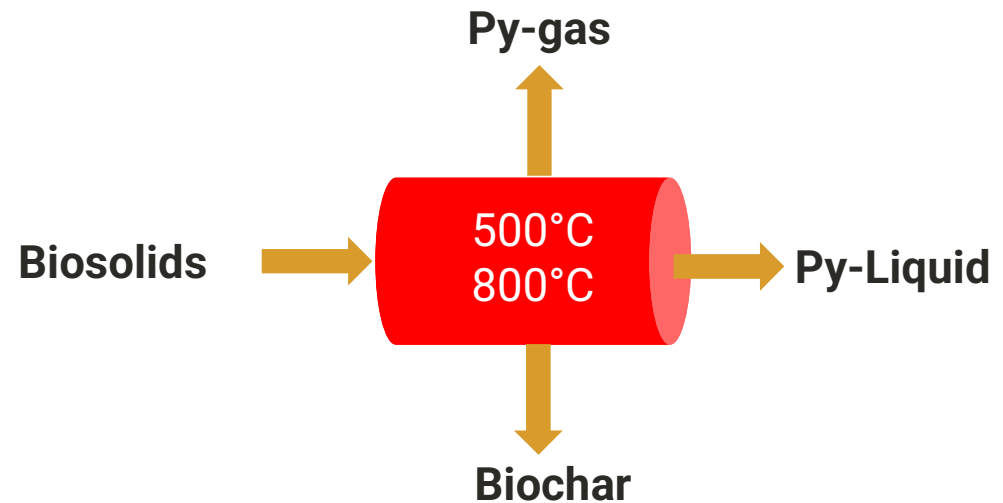
Some PFAS were captured,
more was not



What does pyrolysis do to PFAS?

Experimental Approach:

- Triplicate Batch Experiments
- Feed 1 (Low PFAS)
- Feed 2 (High PFAS)

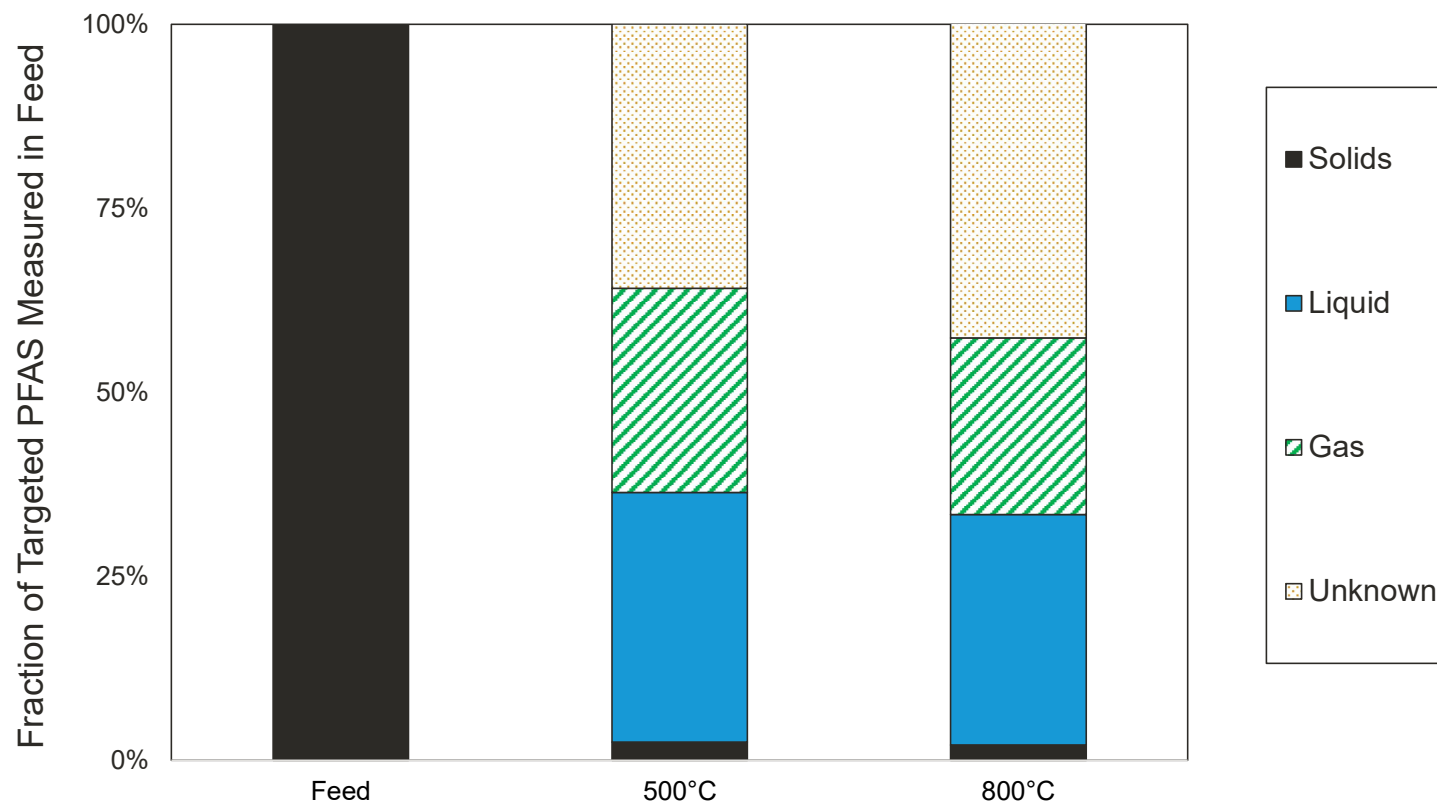


- 30 minutes
- 100 g dried biosolids

Feed 1: Low PFAS (µg/kg)

Species	Rep 1	Rep 2	Rep 3
PFBA	0.41	0.31	0.23
PFPeA	1.7	1.7	1.6
PFHxA	0.67	0.80	0.86
PFOA	0.61	0.74	0.74
PFNA	0.36	0.42	0.42
PFDA	1.3	1.6	1.5
PFUnA	0.28	0.29	0.29
PFDoA	0.43	0.46	0.47
PFHxS	BRL	0.28 ¹	0.21 ¹
PFHpS	BRL	BRL	BRL
PFOS	4.1	4.6	4.5
FOSA	BRL	BRL	BRL
NMeFOSAA	1.7	2.0	1.9
NEtFOSAA	0.76	0.83	0.78
NMeFOSE	0.98	0.93	0.96
NEtFOSE	0.32	0.62	0.46
3:3 FTCA	BRL	BRL	BRL
5:3 FTCA	7.1	7.7	7.5
7:3 FTCA	1.6	2.0	2.0
6:2 FTS	BRL	BRL	BRL
8:2 FTS	0.33	BRL	BRL
10:2 FTS	0.25	0.25	0.27
Sum	22.9	25.5	24.7

Pyrolysis Removes PFAS from Solid Phase

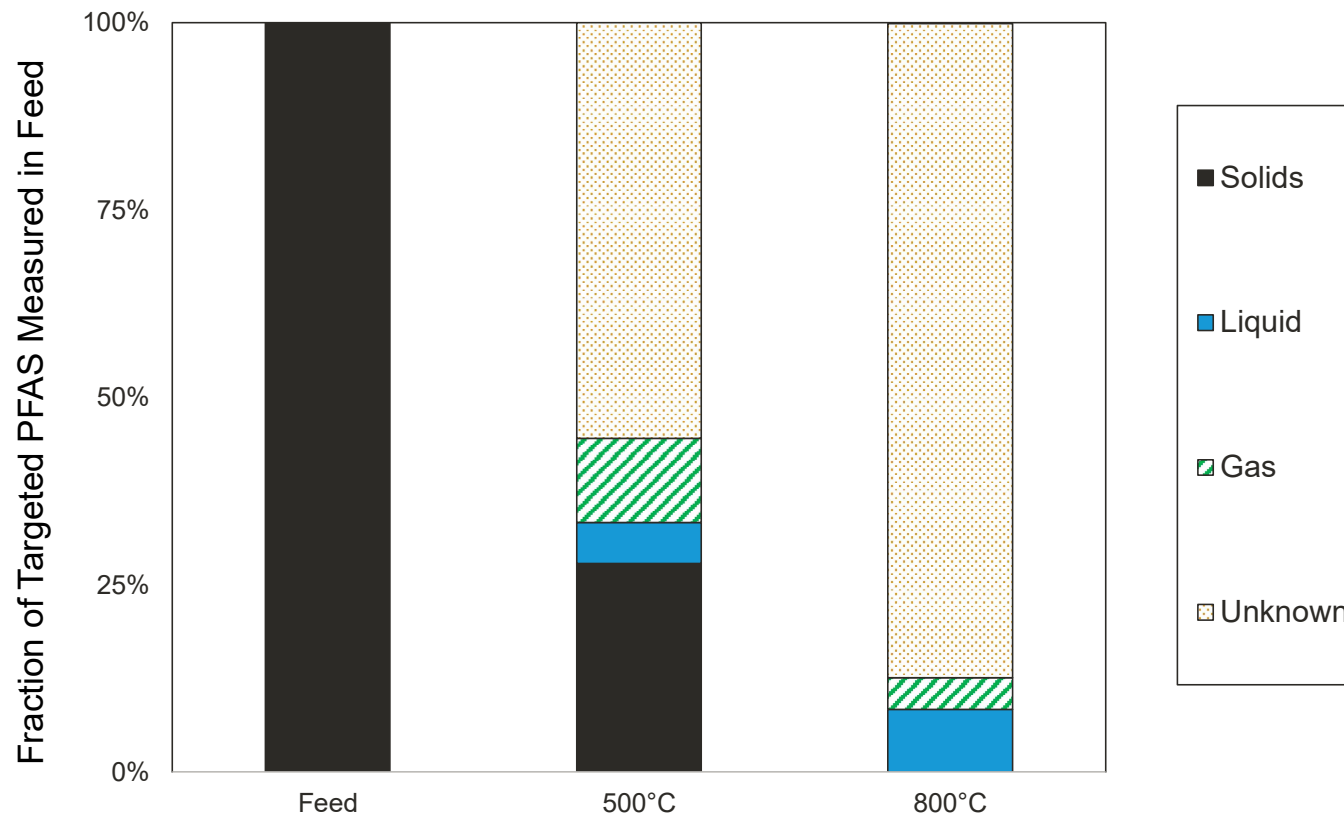


These Findings Corroborate Earlier Findings:
Pyrolysis Removes PFAS from Solids (Biochar)

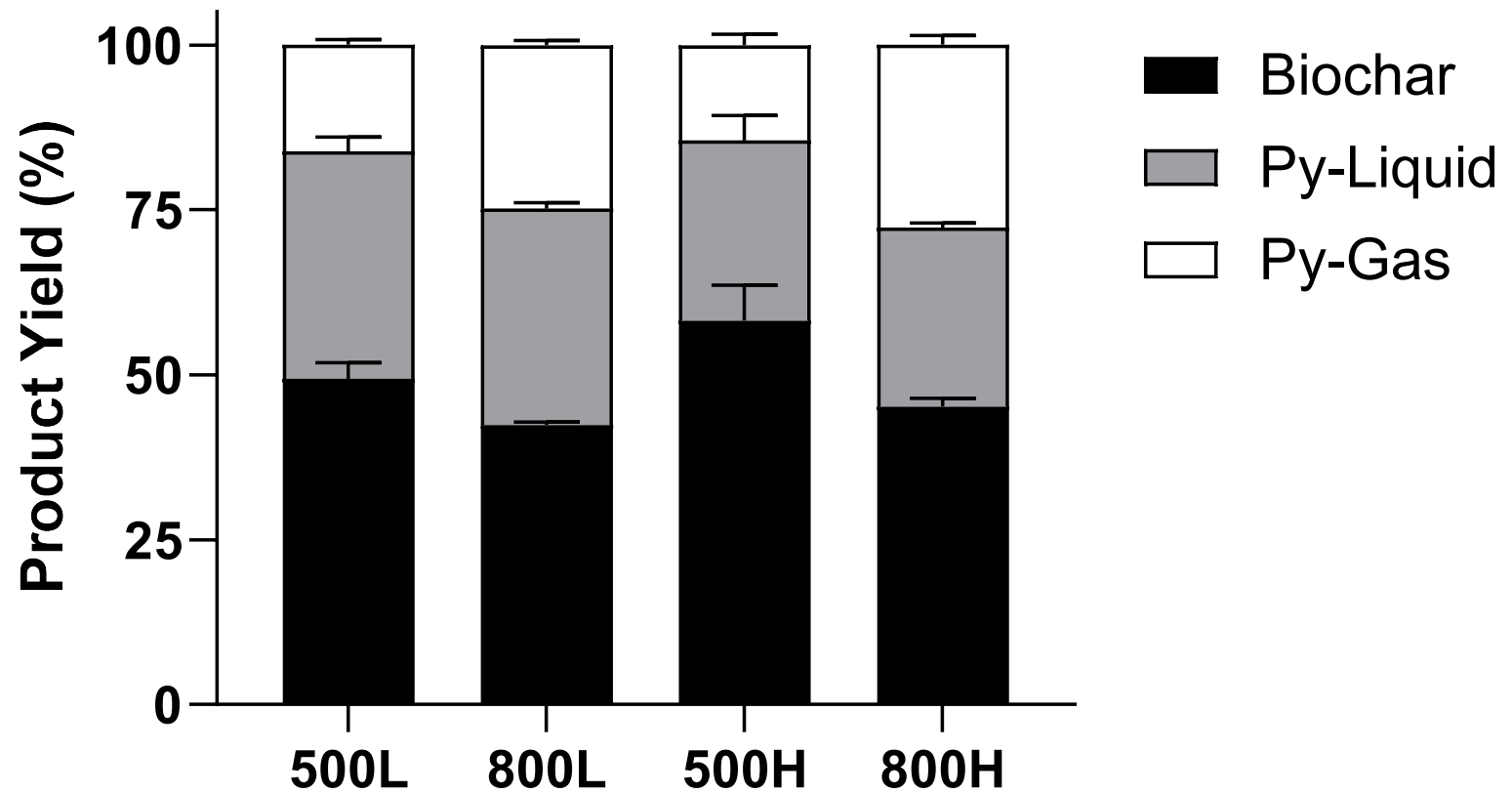
Feed 2: High PFAS

Species	Rep 1	Rep 2	Rep 3	Avg
PFBA	1.1	1.0	1.3	1.1
PFPeA	11	9.5	10	10.2
PFHxA	1.2	1.1	1.2	1.2
PFOA	1.0	1.0	1.0	1.0
PFNA	0.6	0.5	0.5	0.5
PFDA	1.7	1.8	1.7	1.7
PFUnA	0.3	0.4	0.3	0.3
PFDoA	0.0	1.4	0.0	0.5
PFHxS	1.4	0.3	1.2	1.0
PFHpS	0.3	0.0	0.2	0.2
PFOS	66	70	65	67
FOSA	0.3	0.0	0.3	0.2
NMeFOSAA	2.3	0.3	2.3	1.6
NEtFOSAA	0.7	2.6	0.8	1.4
5:3 FTCA	9.2	11	9.1	9.8
7:3 FTCA	1.1	1.3	1.2	1.2
6:2 FTS	0.4	0.0	0.4	0.2
8:2 FTS	1.2	0.0	1.1	0.8
Sum	99.7	102.1	97.6	99.8

PFOS Remains in Biochar at 500°C



Biochar Yield Varied Across Experiments

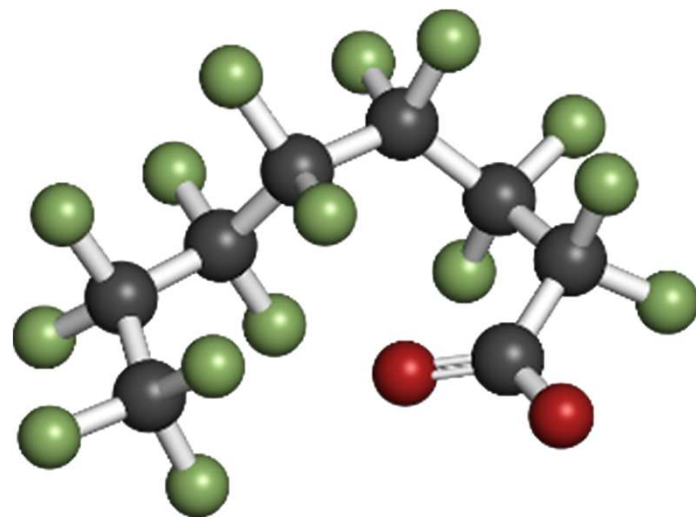


These Findings Indicate that Initial PFAS Concentration, Time, and Temperature Affect Removal

Final Thoughts



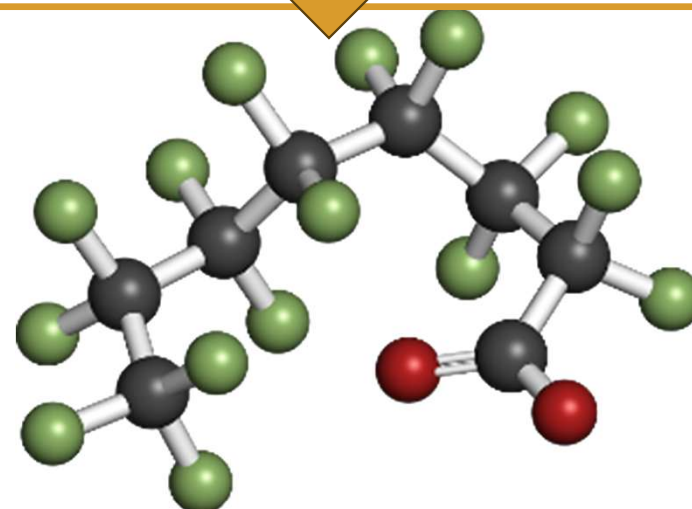
Biosolids





Biosolids

Drying



Acknowledgements



Lynne Moss
Communications Lead WRF 5211
Residuals and Odor Control
Practice Leader – Black & Veatch



Zhongzhe Liu, Co-PI
Thermochemical Process
Lead WRF 5211
Associate Professor
Dept. Chair
CSU-Bakersfield



Jessie Calteux
Ph.D. Student
Marquette University



Taryn McKnight, Co-PI
PFAS Practice Leader
Eurofins Environment
Testing (USA)



Eric Redman
VP of Technical Services
Eurofins Environment
Testing (USA)

The Next Layers

What about emissions and recycle streams of the existing system?

Is pyrolysis economical, reliable, and scalable?

Can we market biochar with the same success as biosolids?

Should we do this alone, or is a regionalized approach warranted?



Thank you! Questions or Comments?

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mmagruder@mmsd.com



A Milorganite Poem – Allegedly Taught in School

Milwaukee is a land of cheer,
German cooking, ale and beer;
They eat and drink from morn' 'til night,
And then they make [Milorganite \(opens in new tab\)](#)!

Their ball team is quite their pride,
It's fame has traveled far and wide.
The grandstand has a place in sight
Where they can go and make Milorganite!

After the game they go to dinner,
It does not matter whose the winner;
And after sleeping through the night,
Start making more Milorganite!

I state without equivocation,
This chore has keen cooperation;
It's manufacture is an art,
Where everybody does his part.

Old men, young men, perfumed ladies,
Boys and girls and even babies;
Grunt and strain and do what's right,
To pile up more Milorganite!
-Author unknown



D&D Overview

High Level Look

- 200 DT/day
- 24/7/365 Operation
- Feed: DSD + WAS (70:30) 2-3% DS
- Dewatered using BFP + Polymer to >16% DS (can add ferric for Fe content, and H2O₂ for odor control)
- Mixed w/Recycle Dry Product to obtain 20-30% DS as dryer feed
- Dried in Rotary Drum Dryers (Davenport) to 95% DS



D&D Overview Continued

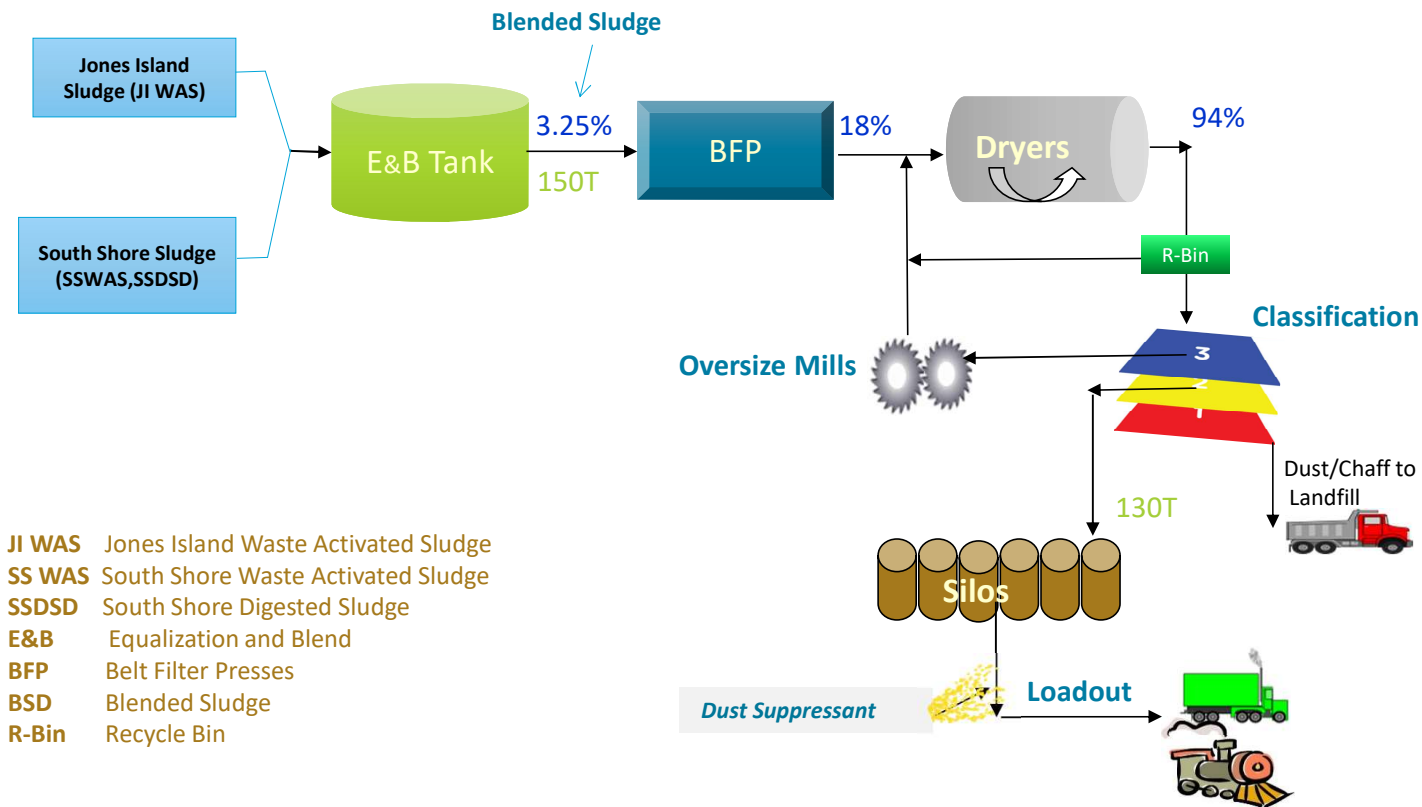
High Level Look

- Dried product sieved through 10-mesh Tyler sieve and retained on a 65-mesh Tyler sieve (milling to reduce size of large product and can recycle back to dryer)
- Product is cooled then conveyed to storage.
- Cyclone Waste (Chaff/Fines) separated from the drying air stream and sent to landfill (~13% of total dry mass)

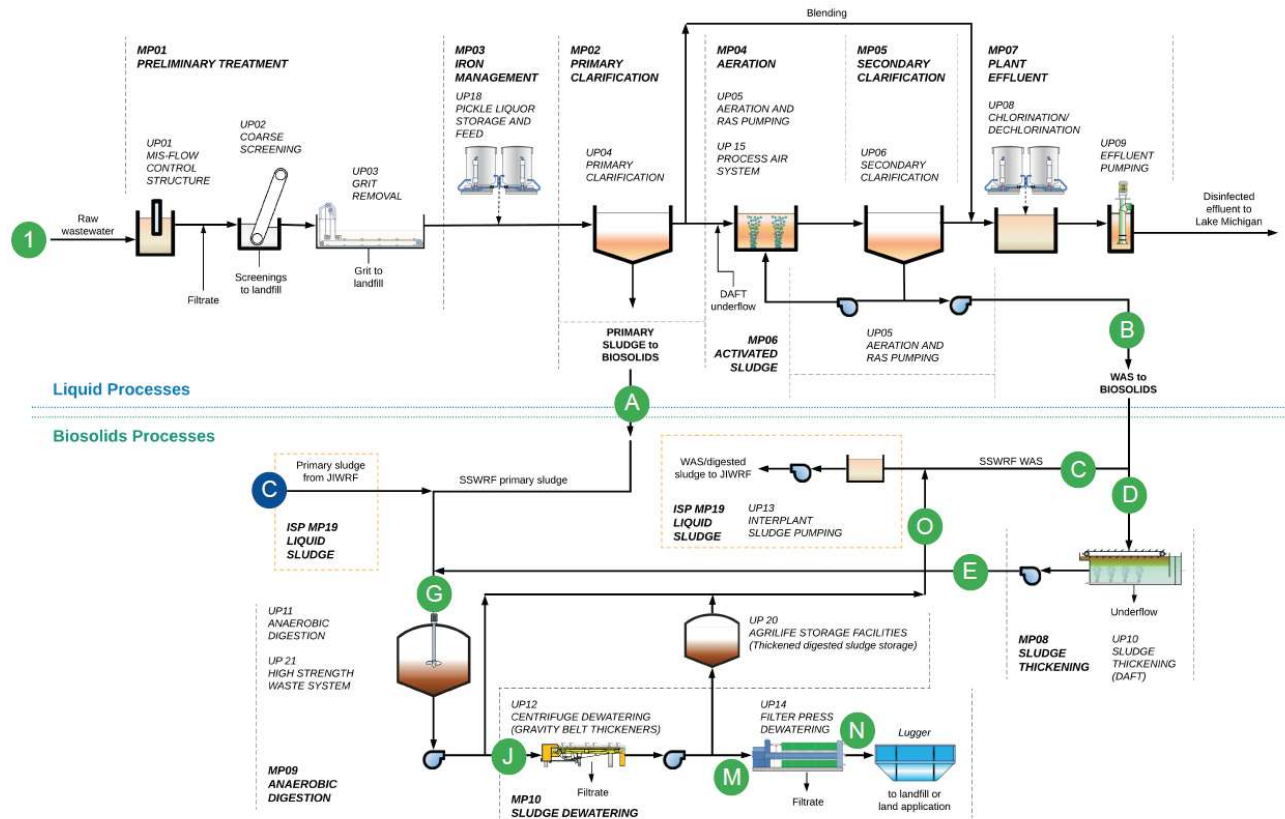


Typical Biosolids Process Day

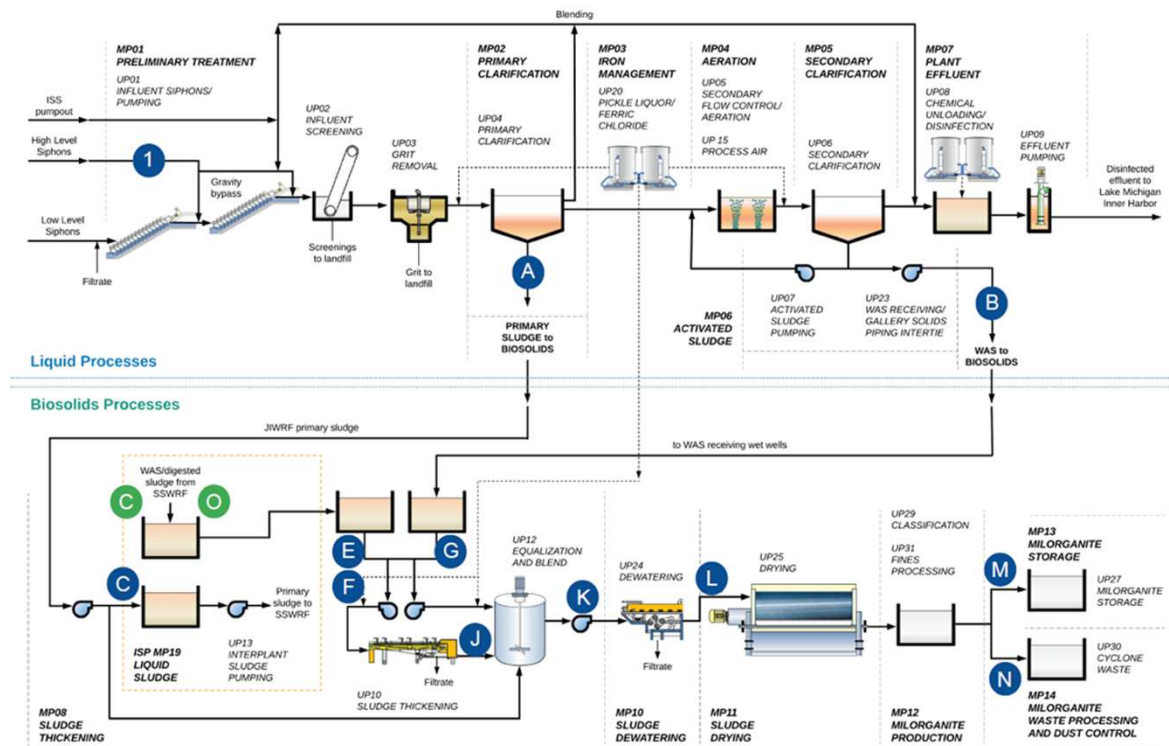
% TS and Mass (Dry tons per day)



South Shore Process



Jones Island Process



WHERE DOES THE WATER GO?

MMSD Service Area

- 300 miles of MMSD Sewers
- Over 3000 miles of municipally owned sewers
- Over 3000 miles of private laterals

