"The Truth About Beneficial ReUse"
Developing The Future of Biosolids Management

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Great Lakes Water Authority

Illinois Rural Water Association
43rd Annual Technical Conference

GLWA
Great Lakes Water Authority

IRWA
ILLINOIS RURAL WATER ASSOCIATION

About Dr. John

- *Member,* US EPA Board of Scientific Counselors
- *Director of Research, Innovation, and Transformation*, Great Lakes Water Authority
- *Vice President*, Midwest Biosolids Association
- *Chair*, AWWA Research Committee
- *Vice-Chair*, AWWA Utility Collaboration Subcommittee

- PI, US Department of Energy-funded *Hydrothermal Liquefaction Feasibility Project*
- Co-PI, US EPA-funded *Pollutants in Biosolids* research program
- Co-PI, Water Research Foundation Project 5069 *Managing Prestressed Concrete Cylinder Pipe (PCCP) to Extend Asset Life*

- Chapter lead, AWWA book "M82 Water Utility Innovation"
- Primary author, WEF "Resource Recovery Handbook"
  - (combining "The Nutrient Roadmap", "The Energy Roadmap", and "The Water Reuse Handbook.")

- *Recipient*: Water Research Foundation *2024 Utility Engagement Award*
- *Co-winner*: International Water Association *Project Innovation Award (*Bronze level)
- *Winner: Michigan State University 2025 Distinguished Partnership Award for Community-Engaged Research*

GLWA – System overview

Water System

- Provides over 40% of Michigan's drinking water
- Vast water supply system consisting of:
  - 5 water treatment plants
  - 19 booster pumping stations
  - 32 water storage reservoirs
  - Over 800 miles of > 4ft diameter pipe
- $340 million/year revenue

Sewer System

- Provides sewer services to nearly 30% of Michigan
- 1.7 BGD, single site wastewater treatment plant
  - 5 pump stations
  - 8 CSO facilities, including 5 retention treatment basins and 3 flow-through type facilities
  - 181 miles of trunk sewers and interceptors
- $471 million/year revenue




GLWA current biosolids treatment

¾ goes to Biosolids Drying Facility

¼ goes to incineration

Beneficial reuse is better for the environment

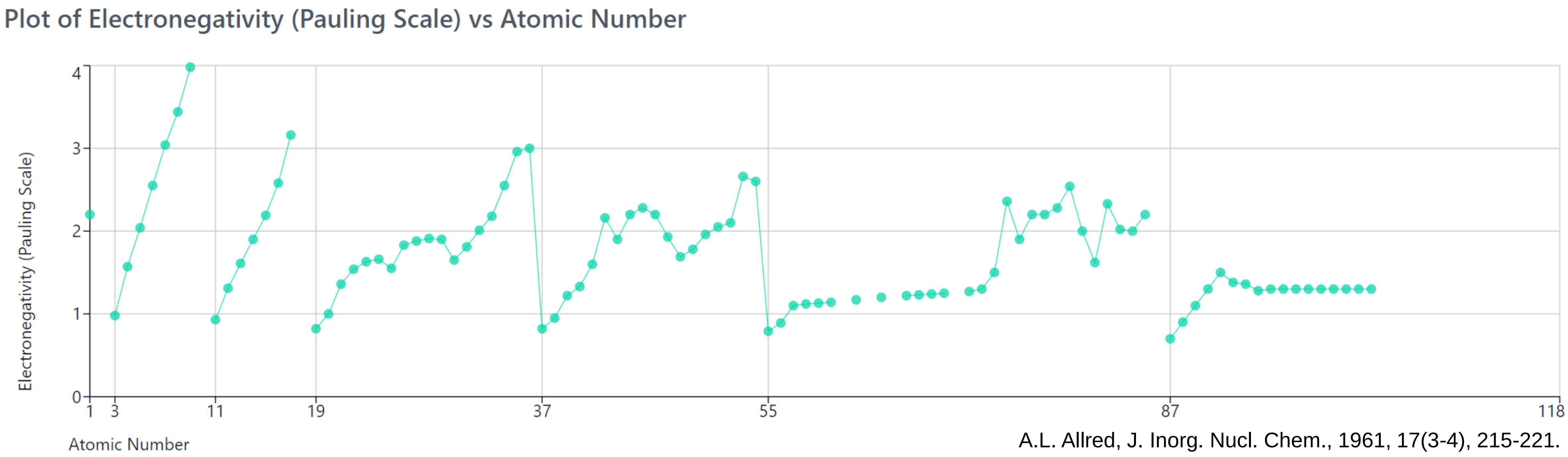
Benefits

- Recovery of nutrients
- Soil organic material
- Reduced greenhouse gas emissions
- Reduced nutrient run-off compared to commercial fertilizers
- PFAS levels are comparable to bagged soils from the “Big Box” stores

Collaborating on papers

- Not presenting these data today
- Focus today is:
  - Background on PFAS
  - Describing current research efforts
  - Addressing risks
  - Longer-term regulatory environment

Electronegativity in the Periodic Table of Elements



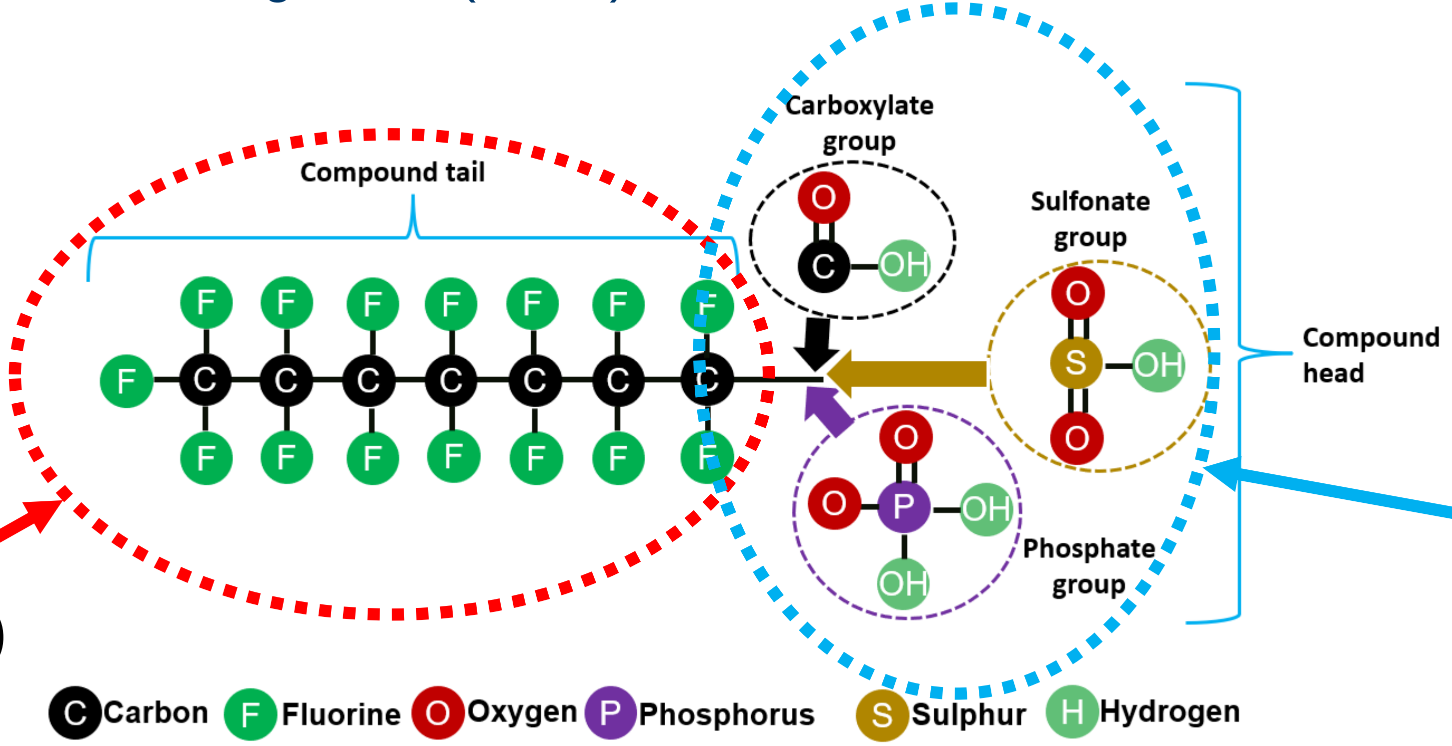
A.L. Allred, J. Inorg. Nucl. Chem., 1961, 17(3-4), 215-221.
DOI:10.1016/0022-1902(61)80142-5

Electronegativity is a measure of the tendency of an atom to attract a bonding pair of electrons. Fluorine is ***the*** most electronegative element that exists!

PFAS is so useful because it forms **strong films**

- Aqueous Film Forming Foam (AFFF)

carbon-fluorine bonds are hydrophobic (or water-hating)

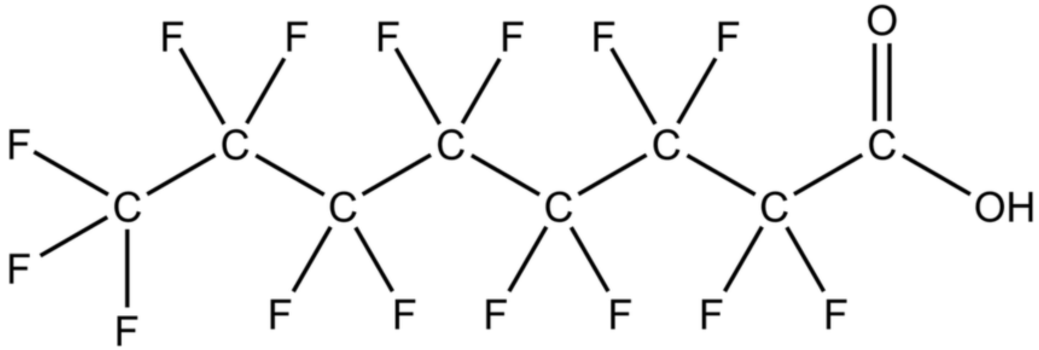


functional groups on the head are hydrophilic (or water-liking)

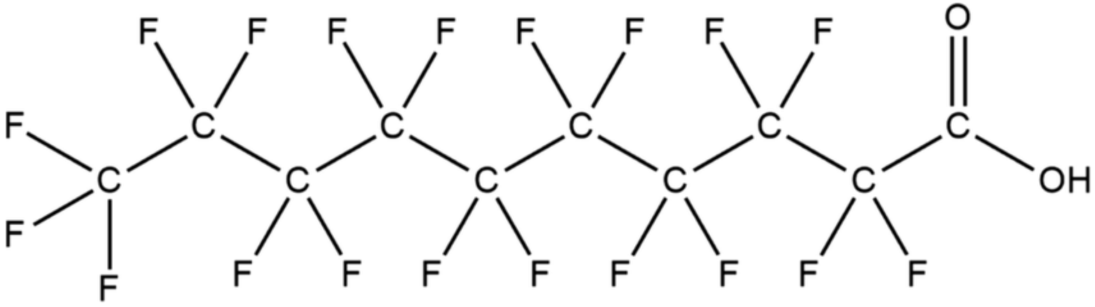
"PFAS compounds are key ingredients in aqueous film-forming foams (AFFF), fireproofing, stain-proofing, surfactants, non-stick cookware, waterproof apparel, packaging, and cosmetics, among many others."

Kibuye, F. 2023. Understanding PFAS - What They Are, Their Impact, and What We Can Do. PennState Extension

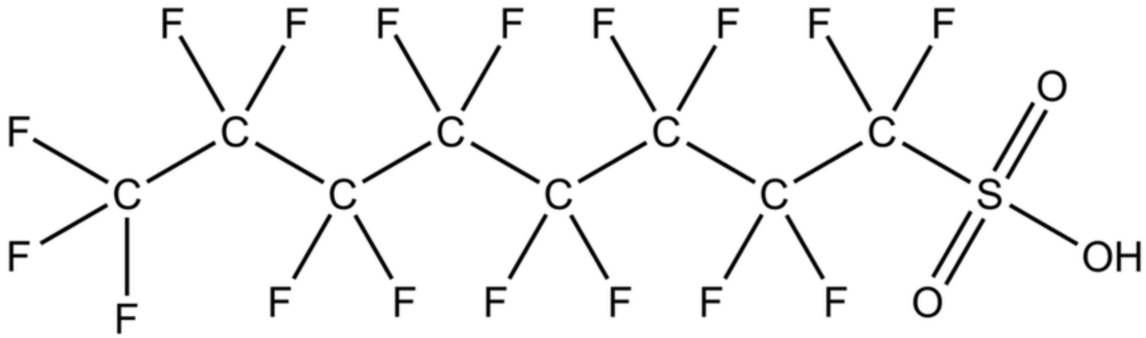
Chemical structure of some cool PFAS compounds



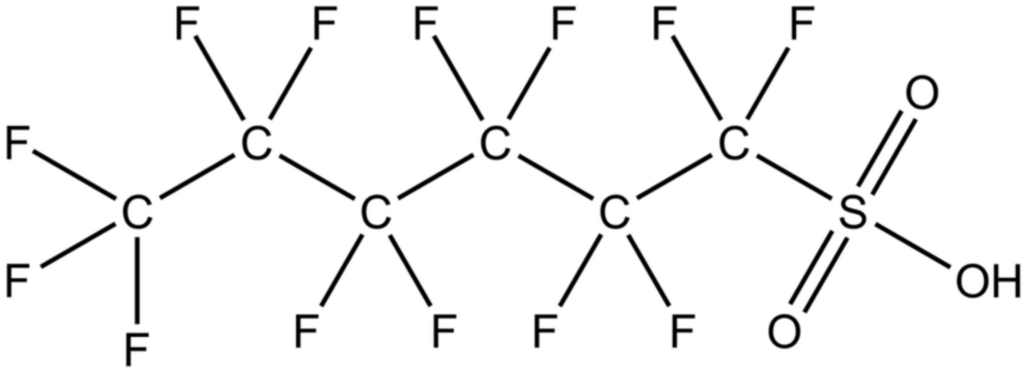
Perfluoro-octanoic acid (PFOA)



Per-fluoro-deca-noic acid (PFDA)



Perfluoro-octane sulphonate (PFOS)



Perfluoro-hexane sulphonic acid (PFHxS)

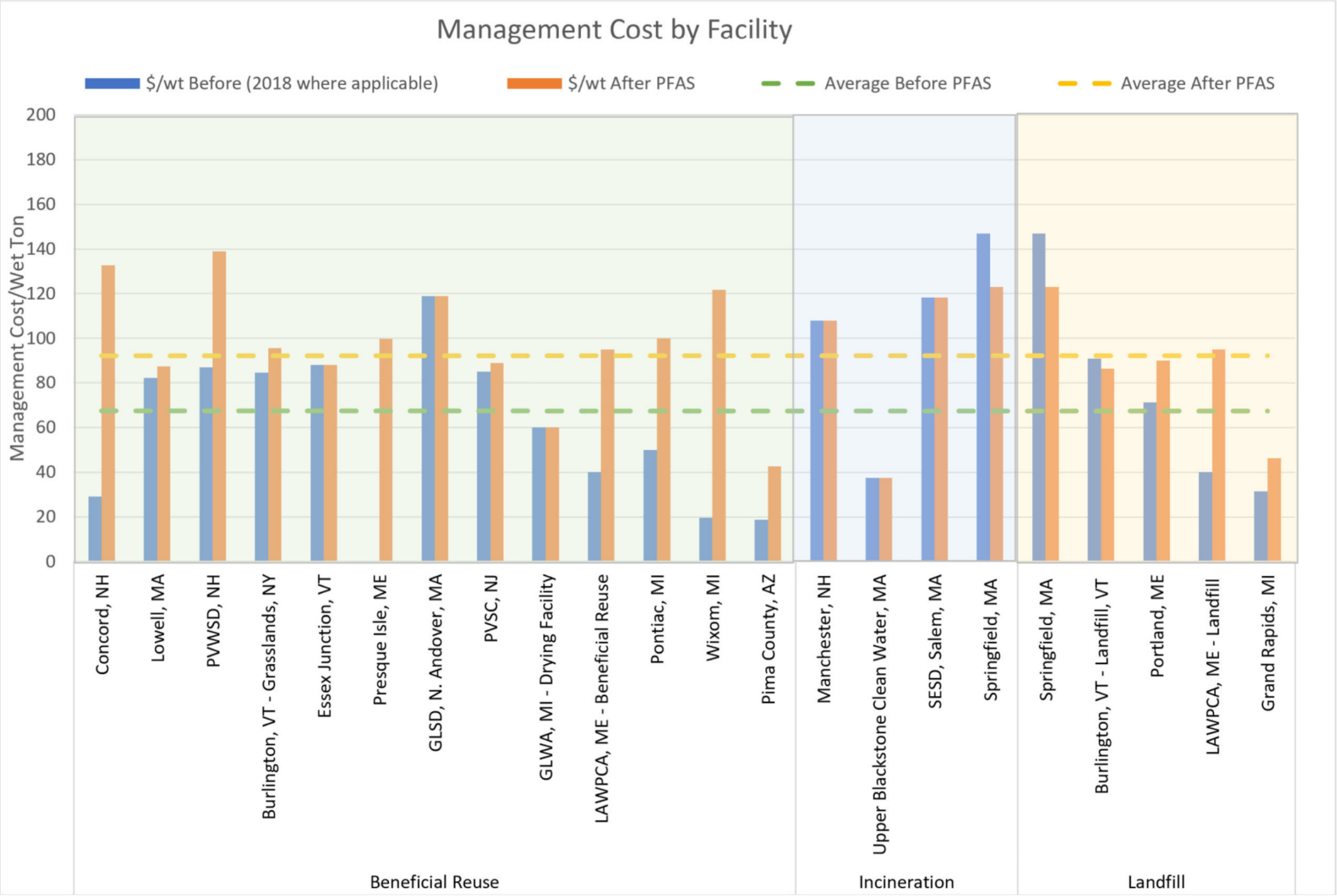
Notice something about the bonds?? C-F covalent bonds are very strong!!

PFAS in regular things….

Media	Concentration	Citation
Dust in your home	523,000 parts per trillion	Wu, Y., K. Romanak, T. Bruton, A. Blum and M. Venier. 2020. *Per- and polyfluoroalkyl substances in paired dust and carpets from childcare centers*. Chemosphere 251:126771.
Lipstick	216,000 to 1,560,000 parts per trillion	Whitehead, H.D., M.Venier, Y. Wu et al. 2021. *Fluorinated Compounds in North American Cosmetics*. Environ. Sci. Tech. Letters 8:7:538-544.
Take-out food packaging	7,000,000 to 876,000,000 parts per trillion	Loria, K. 2022. *Dangerous PFAS Chemicals Are in Your Food Packaging*. Consumer Reports, March 2022.
Dog poop	85,000 +/- 94,500 parts per trillion	Ma, J. H. Zhu, K. Kannan. 2020. *Fecal Excretion of Perfluoroalkyl and Polyfluoroalkyl Substances in Pets from New York State, United States***.** Environ. Sci. Tech. Letters 7:3:135-142.
YOUR poop	86.9 parts per trillion	Moodie, D., T. Coggan, K. Berry, A. Kolobaric et al. 2021. *Legacy and emerging per- and polyfluoroalkyl substances (PFASs) in Australian biosolids.* Chemosphere 270:129143.
Contact lenses	106,000,000 to 20,700,000,000 parts per trillion (that number is correct!)	https://www.mamavation.com/health/pfas-contact-lenses.html
Pacemakers and other medical devices	Widely variable	Glüge J , Scheringer M , Cousins IT , DeWitt JC , Goldenman G , Herzke D, Lohmann R , Ng CA , Trier X , Wang Z . *An overview of the uses of per- and polyfluoroalkyl substances (PFAS).* Environ Sci Process Impacts. 2020 Dec 1;22(12):2345-2373

Adapted from: Brown, S. ***Connections: Facts Versus Fear Mongering***, BioCycle, Sept 3, 2024

Addressing PFAS is adding 36% to biosolids costs



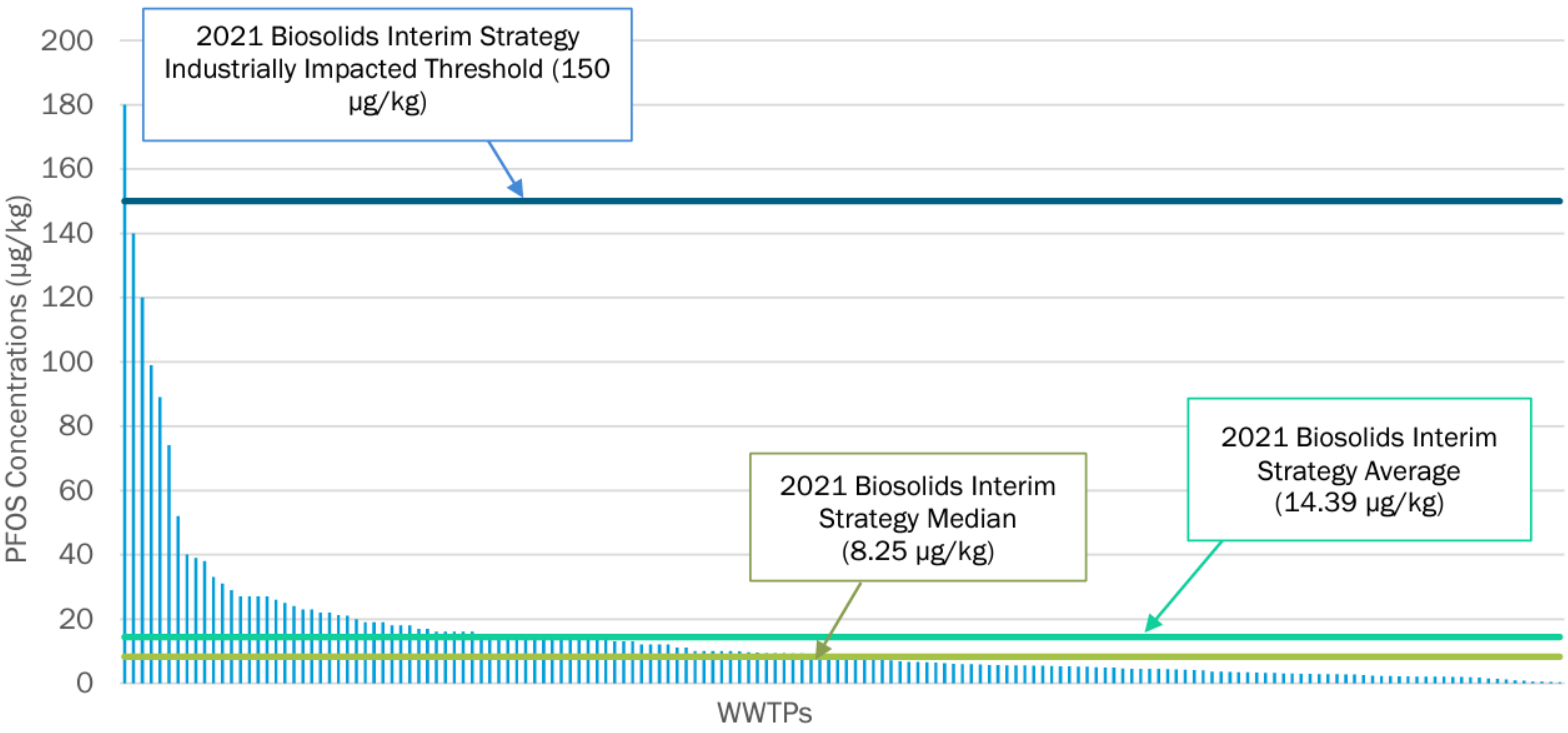
2020. Cost Analysis of the Impacts on Municipal Utilities and Biosolids Management to Address PFAS Contamination. WEF.

GLWA

PFAS is NOT evenly spread across the United States

MICHIGAN STRATEGY FOR LAND APPLICATION OF BIOSOLIDS CONTAINING PFAS (UPDATED 2022)

Figure 3. 2021 Interim Strategy PFOS Concentrations



2022. Land Application of Biosolids Containing PFAS Interim Strategy (Michigan.gov)

GLWA - Source identification by industry

SIU Sampling Source Identification					
Industry	# of SIUs	# Significant Source	PFAS Range for Significant Sources (ngms/l)		# Not Significant Source
			PFOA	PFOS	
Airfields	2	2	21-140	220-240	--
Aluminum	1	--	ND	ND	1
Centralized Waste Treatment	7	6	10-1790	30-350	1
Chemical	3	2	28-120	310-840	1
Electroplating & Metal Finishing	83	18	ND-30	20-9,750	65
Groundwater	2	2		14-96	--
Hospital	1	--	ND	ND	1
Iron & Steel	3	--	ND	ND	3
Landfills	13	13	ND-840	15-700	--
Laundry	3	2	ND-20	40-50	1
Leather Processing	2	1	43	14	1
Paint Formulating	1	1	20	60	--
Petroleum Refining	1	1	3.5-620	18-800	--
Plastics	2	--	ND	ND	2
Tank Cleaning	1	1	280	140	--
Other	13	3	ND-5	ND	10
Total w/Data	**138**	**52**			**86**

GLWA – Industrial pretreatment program success

	PFOS Comparisons 2019 - 2023				
	PFOS Contributions from identified sources - Estimated				
	Centralized Waste Treaters	MacDermid	Landfill Discharge	All other Point Sources	Totals
	mg/day	mg/day	mg/day	mg/day	mg/day
CY 2019	3,589.5	**42,682.7**	ND	2,196.7	48,468.9
		(one off event)			
CY 2020	684.46	25.59	ND	2,703.0	3,413.59 7
CY 2021	335.06	4.33	ND	2,361.75	2,701.14
CY 2022	277.72	13.52	461.75	3,472.57	4,225.55
CY 2023	367.65	4.45	200.9	5,247.6	5,820.6
Percent of Total-2023	6.3%	0.076%	3.45%	90.146%	

Source and acknowledgement: Stephen J Kuplicki, Manager - Industrial Waste Control Group, GLWA

PFAS in the State of Michigan

	(Potable) Treated Water[1]	(Wastewater) Treated Final Effluent[2]	(Wastewater) Beneficial Reuse Biosolids[3]
Michigan EGLE (Environment, Great Lakes, and Energy)	Specific PFAS Drinking Water MCL Parts per Trillion (ppt) PFNA 6 ppt PFOA 8 ppt PFHxA 400,000 ppt PFOS 16 ppt PFHxS 51 ppt PFBS 420 ppt HFPO-DA 370 ppt	NPDES Water Quality Standard PFOA 66 ppt (changed from 420 ppt in 2022) PFOS 11 ppt	PFOS or PFOA ≥ 100 (µg/kg, ppb) CANNOT be land applied. 100 > PFOS or PFOA ≥ 20 µg/kg (ppb) Application rate > 1.5 (dt/acre), sampling of the biosolids source effluent (within 30 days), implement a source reduction plan PFOS and PFOA < 20 µg/kg (ppb) May be land applied with no additional requirements
GLWA	Non-detects	PFOS: 13.8 ppt PFOA: 8.5 ppt	PFOS: 3.5 µg/kg (ppb) PFOA: 0.47 µg/kg (ppb)

[1]EGLE GENERAL PFAS SAMPLING GUIDANCE, January 2024
[2]EGLE The Rule 57 Water Quality Values for Select PFAS, 2022
[3]https://www.michigan.gov/egle/about/organization/water-resources/biosolids/pfas-related

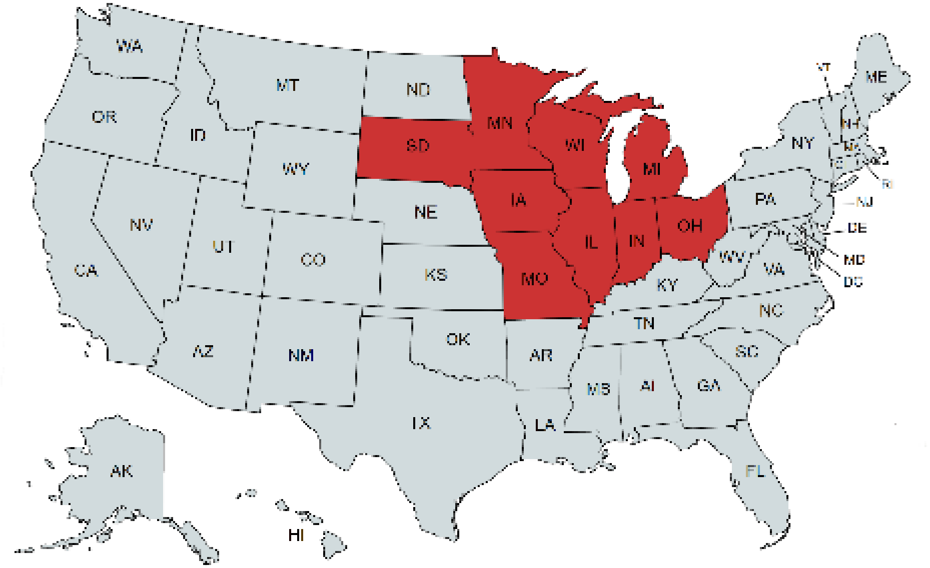
Rationale for exploring biosolids treatment processes

- INCINERATION
  - Incinerator complex nearing end of operational life.
  - Significant level of required renewal/rehabilitation investment.
  - KEY: Level of renewal investment kicks us into new air pollution control requirements → and significant (~$250 million) additional investment requirements
- LAND APPLICATION
  - Increasing environmental concern regarding emerging contaminants (e.g., PFAS, pharmaceuticals)
  - Increasing utility concern regarding shifting REGULATORY environment
- KNOWLEDGE
  - Improve understanding/science of micropollutant fate and transport

Formation of the Midwest Biosolids Association

- New effort to found a Midwest-based association to inform and grow understanding of municipal biosolids
- Over 90 utilities and growing!
- Currently in the formation stage…

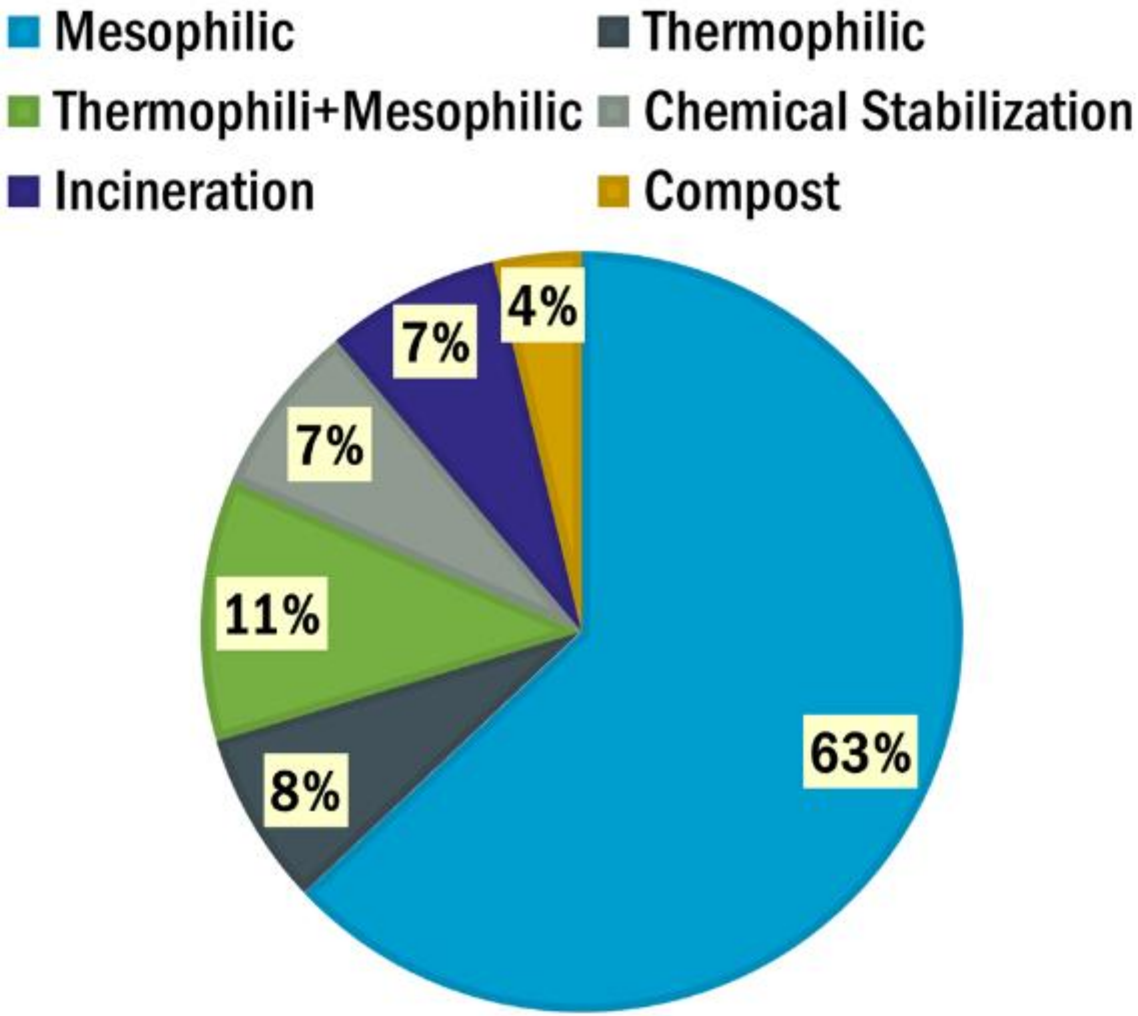
- Goals and focus:
  - Research – Identify needs and coordinate resources such funding and expertise for research
  - Education – Serve as a primary repository for data and be a trustworthy resource for information
  - Networking - Collaborative network for the biosolids community to share, learn, and bridge the gap
  - Advocate for environmentally sound and cost-effective management of biosolids in the region.



MWRD Chicago; Columbus, Ohio; Mankato, Minnesota; California Association of Sanitary Agencies; Ohio State University; Purdue University, Michigan State University; Metropolitan Council Environmental Services, Minneapolis, MN; Urbana-Champaign Sanitary District; Michigan EGLE; Merrell Brothers; Lystek International; Marion, Indiana; Green Bay, Wisconsin, and many others!

GLWA

Sludge Stabilization Method



- Type of Biosolids generated:
  - Class A EQ(7%),
  - Class A (19%)
  - Class B (52%),
  - SRT not met (7%)
  - Landfill (7%)
  - Other (7%)

Research into three “new to us" technologies

- Anaerobic digestion (“AD”)
  - Use of bacteria to convert carbon-based feedstock into methane
- Hydrothermal liquefaction (“HTL”)
  - Physical/chemical process using high temperatures and extremely high pressures to convert carbon-based feedstock into “biocrude”, ash, and liquid waste stream
- Pyrolysis (“PITA”)
  - Physical/chemical process using moderate temperatures and pressures to convert carbon-based feedstock into tar, clogged equipment, and crushed hopes and dreams.

Biosolids disposal options?

GLWA’s PFAS-related research efforts

- Review of PFAS within water treatment facilities
  - Lloyd J. Winchell; Martha J. M. Wells; John J. Ross; Xavier Fonoll; John W. Norton, Jr.; Stephen Kuplicki; Majid Khan; Katherine Y. Bell. 2022. ***Per- and Polyfluoroalkyl Substances Presence, Pathways, and Cycling through Drinking Water and Wastewater Treatment***. Journal of Environmental Engineering. 2022-01
  - Lloyd Winchell, Martha Wells, John Ross, Xavier Fonoll, John Norton, Stephen Kuplicki, Majid Khan, Katherine Bell. 2021. ***Analyses of per- and polyfluoroalkyl substances (PFAS) through the urban water cycle: Toward achieving an integrated analytical workflow across aqueous, solid, and gaseous matrices in water and wastewater treatment***. Science of The Total Environment. Volume 774, 20 June 2021.
- Sanitary Sludge Incineration, (WRF 5111: Studying the Fate of PFAS through Sewage Sludge Incinerators)
  - Winchell, L. J., Ross, J. J., Brose, D. A., Pluth, T. B., Fonoll, X., Norton, Jr., J. W., and Bell, K. Y. (2022a). ***High-temperature Technology Survey and Comparison Among Incineration, Pyrolysis, and Gasification Systems for Water Resource Recovery Facilities***. *Water Environment Research*, 94. https://onlinelibrary.wiley.com/doi/10.1002/wer.10715
  - Lloyd J. Winchell; John J. Ross; Dominic A. Brose; Thaís B. Pluth; Xavier Fonoll; John W. Norton, Jr; Katherine Y. Bell. 2022. ***Pyrolysis and gasification at water resource recovery facilities: Status of the industry***. Water Environment Research. 2022-03
  - Lloyd J. Winchell; John J. Ross; Martha J. M. Wells; Xavier Fonoll; John W. Norton, Jr; Katherine Y. Bell. 2021. ***Per- and polyfluoroalkyl substances thermal destruction at water resource recovery facilities: A state of the science review.*** Water Environment Research. 2021-06-31
- Pollutants in Biosolids (US EPA and GLWA-funded effort, $1.8 million)
  - Oza S, Bell KY, Xu Z, Wang Y, Wells MJM, Norton JW Jr, Winchell LJ, Huang Q, Li H. ***Surveillance of PFAS in sludge and biosolids at 12 water resource recovery facilities***. J Environ Qual. 2024
  - Under review: ***Per-and polyfluoroalkyl substances in untreated and treated sludge/biosolids from 27 water resource recovery facilities across USA and Canada***, Water Research
- PFAS fate and transport through GLWA’s WRRF
  - Project with Wayne State University (results forthcoming)
- Hydrothermal Liquefaction Feasibility Study (US Department of Energy and GLWA-funded effort, $1.5 million)
  - Pilot to initiate Fall 2024, Comprehensive mass balance of PFAS-spiked biosolids through the system
- Analysis of US EPA POTW PFAS influent study results (GLWA and Cincinnati MSD-led effort)
  - Development of base data underway, subject to US EPA schedule and timing of data gathering effort

Pollutants in biosolids research - $1.5 million US EPA win!

(in collaboration with Michigan State University, Colorado State University, University of Georgia, Howard University)

Assessing Biosolid Treatment Processes on Pollutant Environmental Fate and Plant Uptake following Land Application

EPA Grant R840252, Project Period: September 1, 2021, to August 31, 2024, Project amount: $1,499,999

Project Investigators

Hui Li, Courtney Carignan and Wei Zhang

Michigan State University

James Ippolito

Colorado State University

Qingguo Huang

University of Georgia

John Norton, Jr.

Great Lakes Water Authority, Detroit

EPA Cooperators

Mark Strynar (ORD-CEMM)

Kirk Scheckel (ORD-CESER)

Elizabeth Resek (OW)

Consulting Support

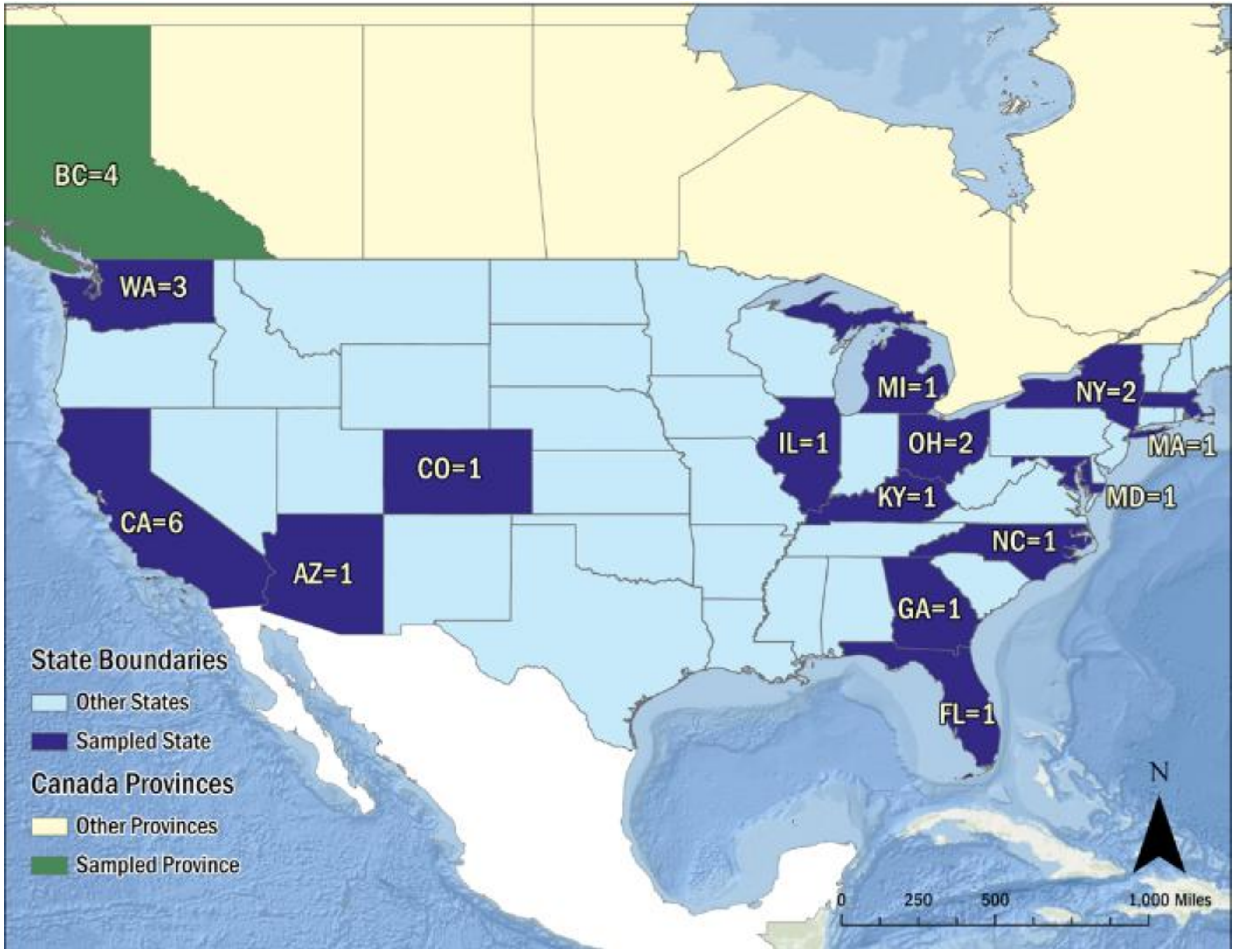
Shubhashini Oza, Kati Bell, and Shirin Estahbanati

Brown and Caldwell

Awesome set of utility collaborators:

California Association of Sanitation Agencies; Clay County Water Authority, GA; Chicago Metropolitan Water Reclamation District; Denmark VSC; Denver Metro Wastewater Reclamation District; Englewood South Platte Renew, CO; Hillsborough County Water Resources Department; King County Wastewater Treatment Division, WA; Lake County Utilities, OH; Louisville MSD, KY; Massachusetts Water Resources Authority; New York City Department of Environmental Protection; South Australian Water Corporation; Vancouver Metro Liquid Waste Services, BC, Canada

Sample Collection

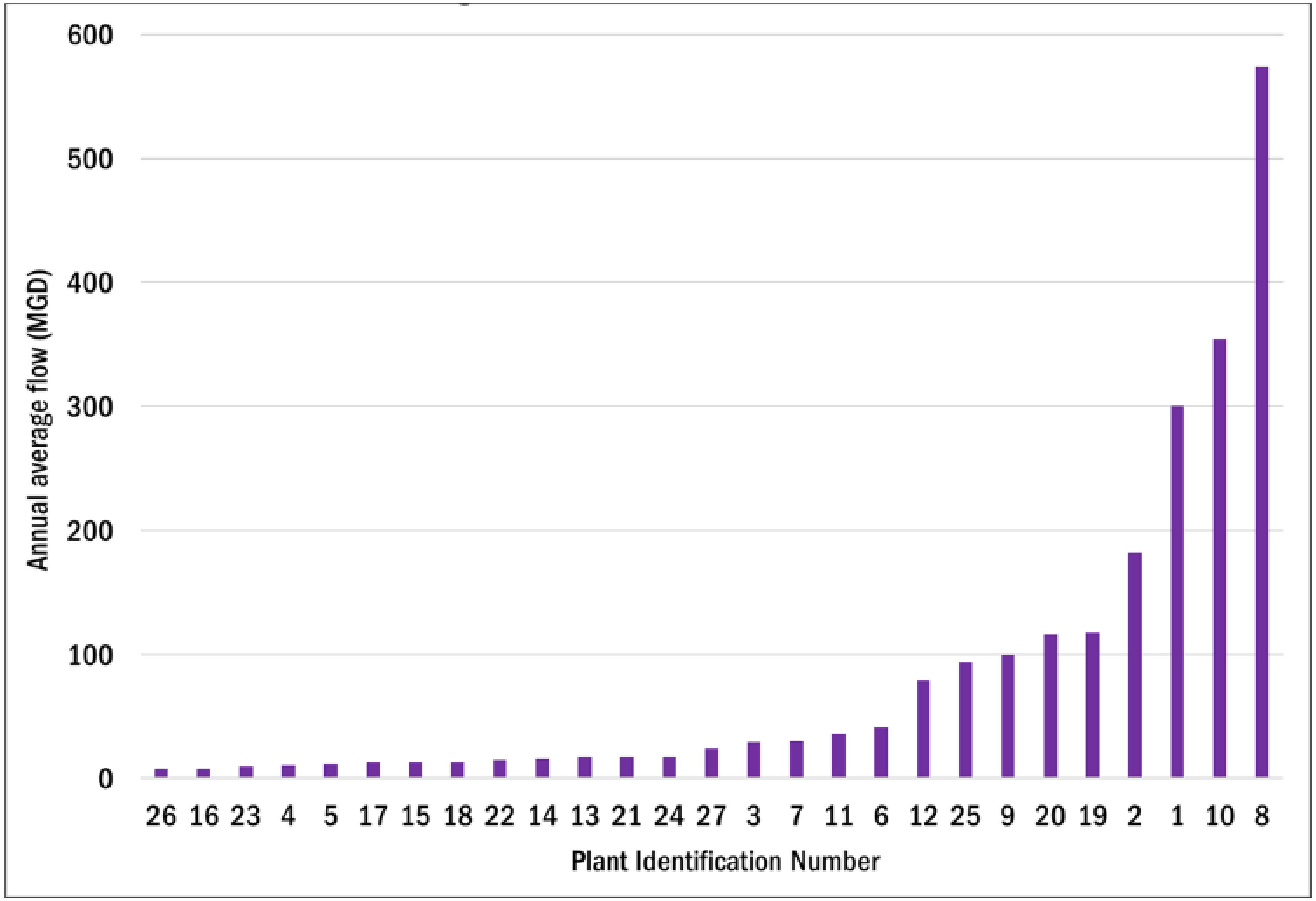


SAMPLE COLLECTION

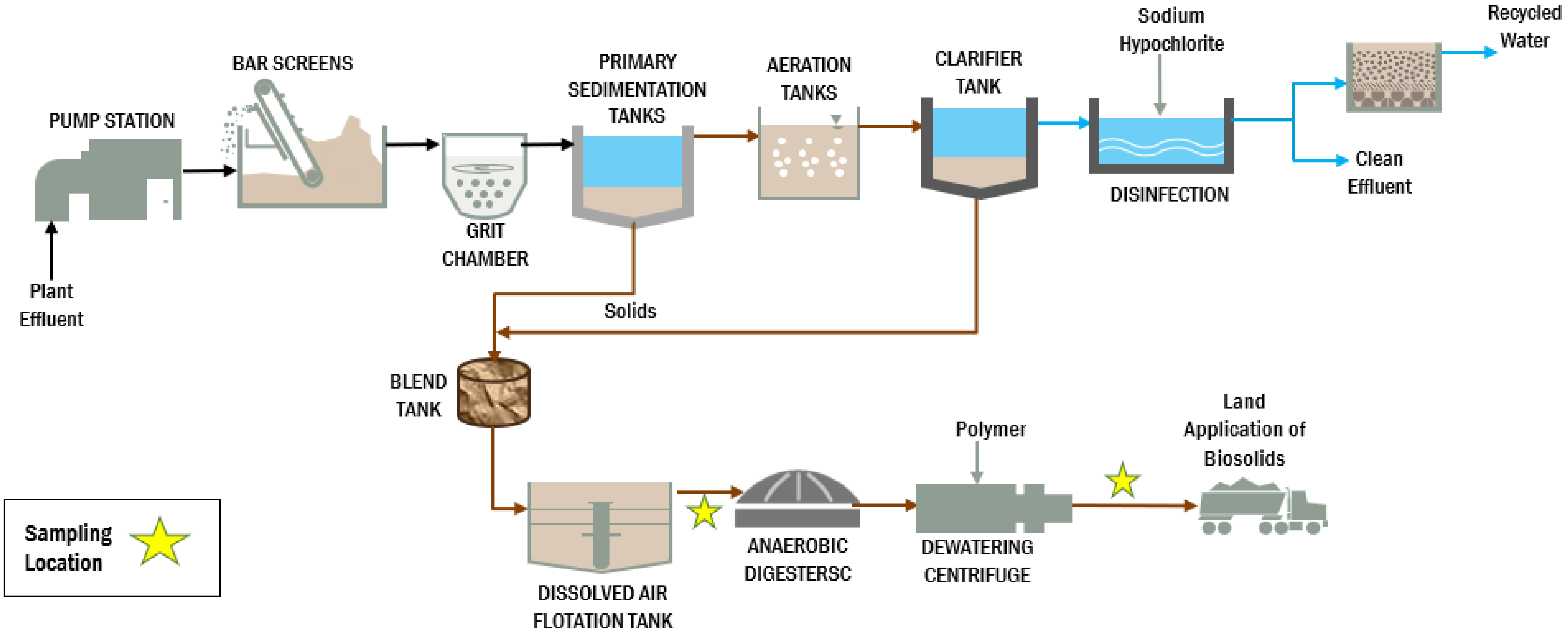
(i) 27 WWTPs
(ii) Minimum 2 locations per WWTP
(iii) A total of **<u>59 samples</u>** (pre, and post-stabilization)

WRRF Influent Flow

Plot represents the average dry weather influent flow to the treatment plant (million gallons per day)



EPA study - Sample Locations

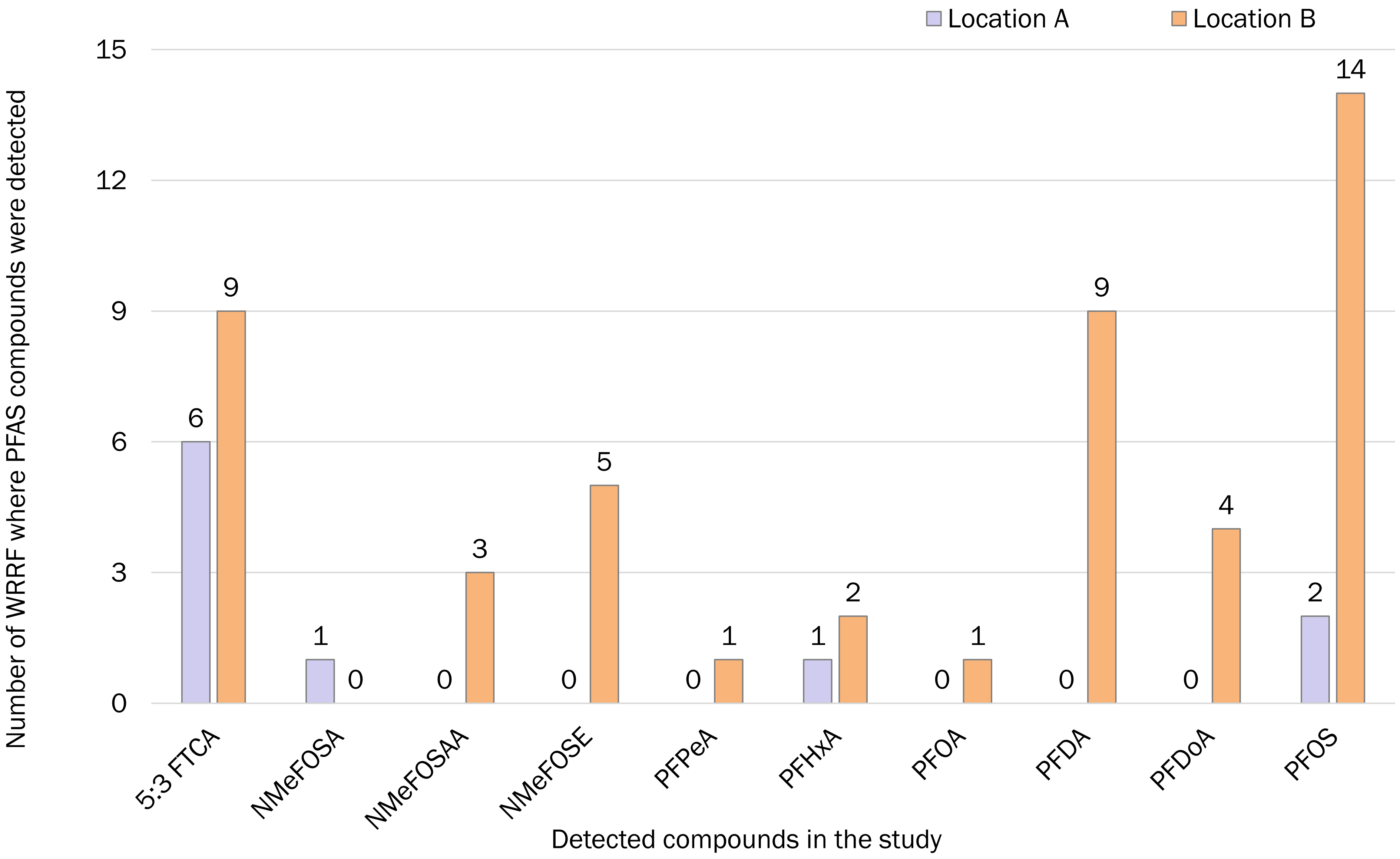


SAMPLE LOCATIONS

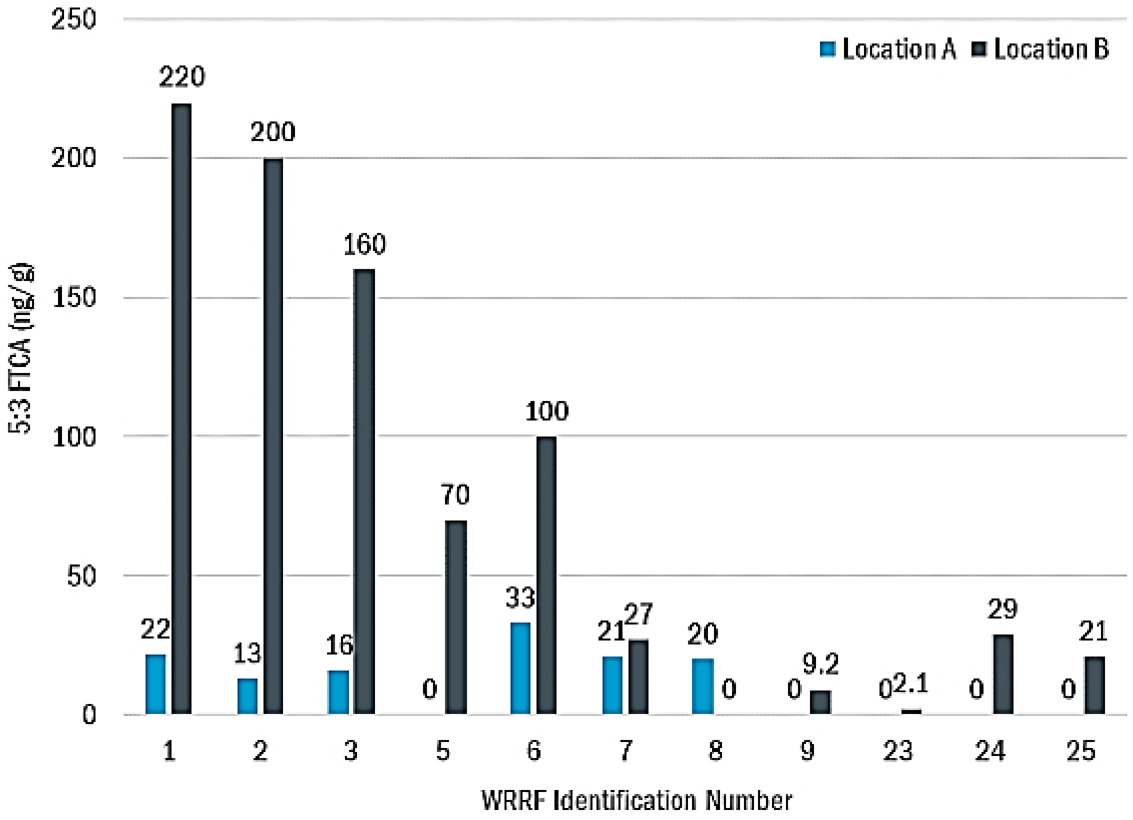
(i) Just before solids stabilization, and

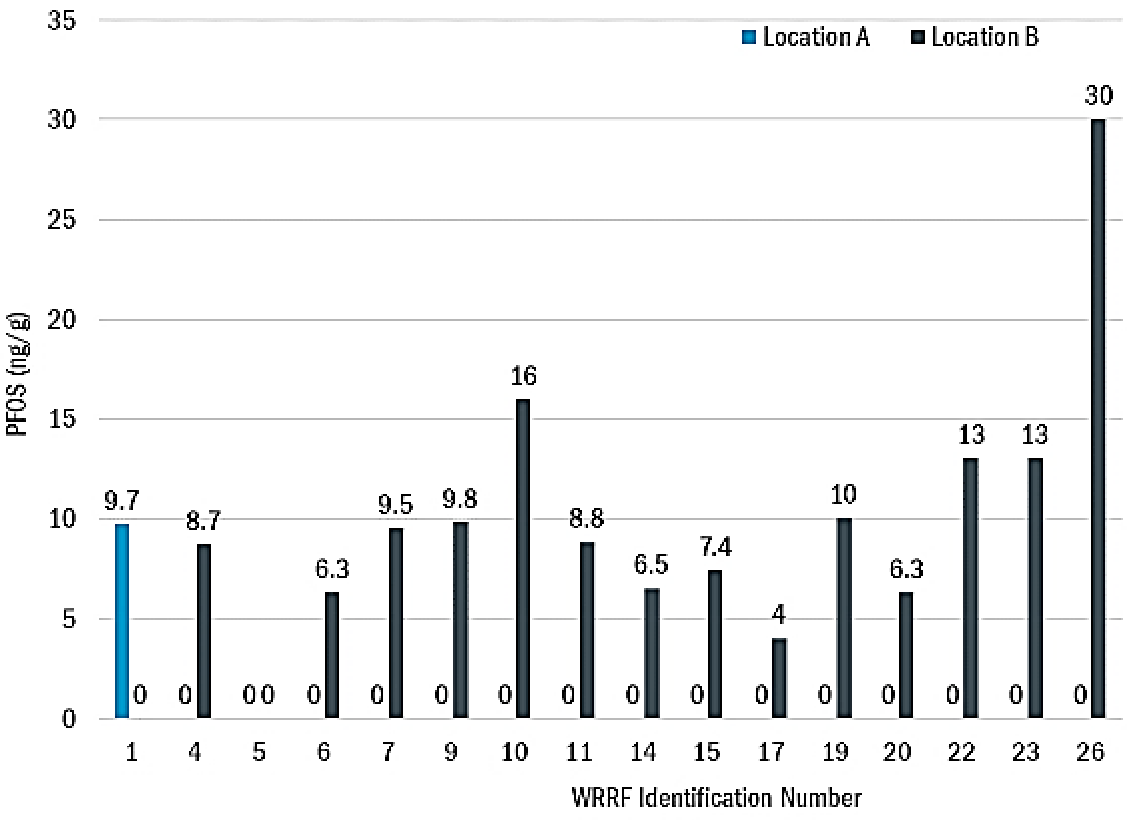
(ii) Stabilized solids leaving the WWTP

EPA study - Results



PFOS & 5:3 FTCA Trend





- PFOS was predominantly observed in Location B, concentration in the range of 4 to 30 ng/g
- 5:3 FTCA, observed in both location, but higher concentration for Location B

Analytical results vary among laboratories/methods

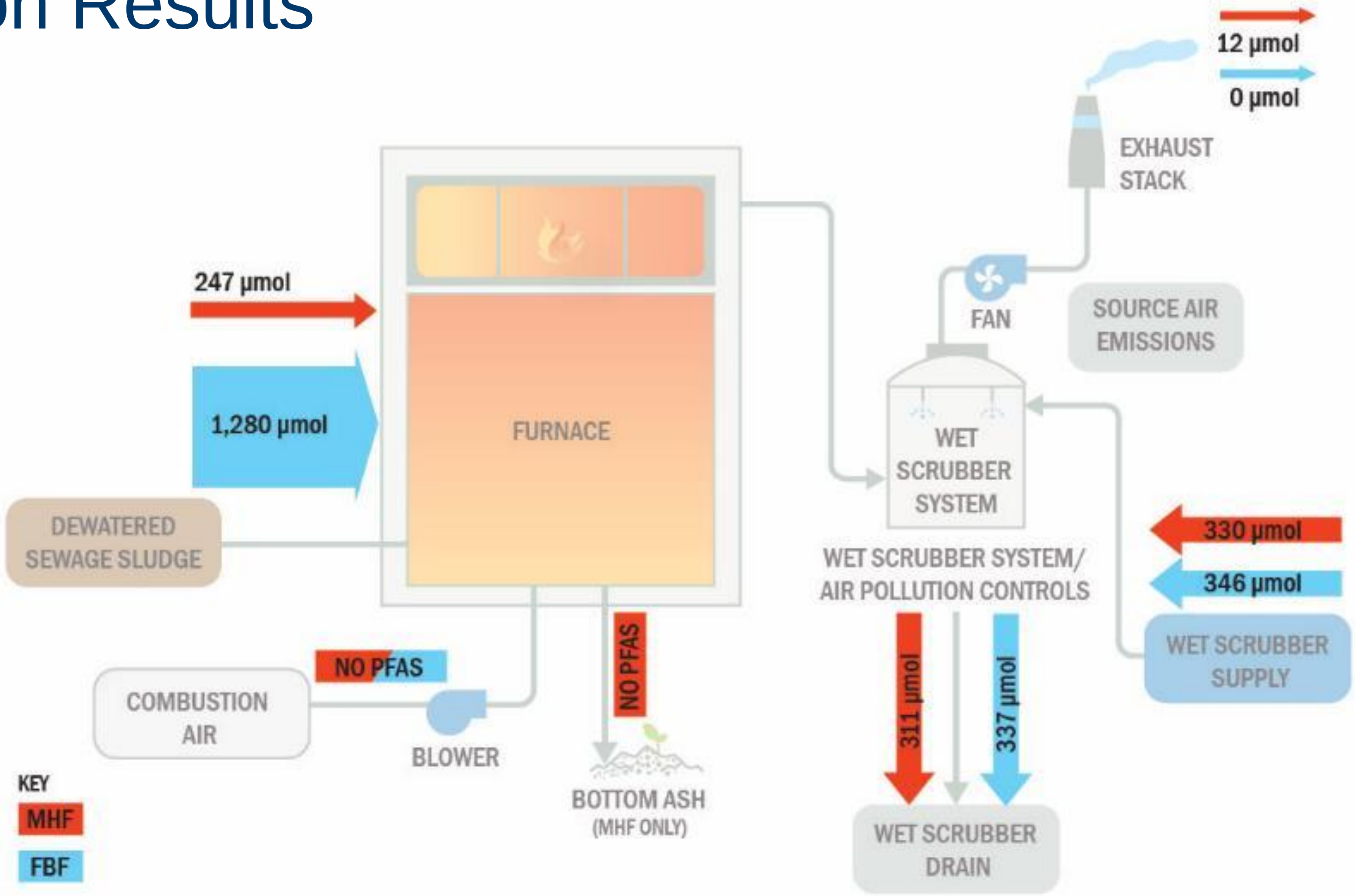
WRRF Site Number	5:3 FTCA					
	Pre-stabilized Solids (ng/g)			Post-stabilized (ng/g)		
	Lab 1	Lab 2	Lab 3	Lab 1	Lab 2	Lab 3
1	22	<34	146	220	<76	616
2	13	<57	104	200	<103	523
3	16	<68	177	160	<103	304
4	*- cn	<6	187	*- cn	19	235
5	U *- cn	<37	117	70	24	193
6	33	<41	164	100	28	508
7	21	<35	86	27	<8	161
8	20	<68	362	<0.6	<2	<1.6
9	*- cn	<27	156	*- cn	<6	82
10	*- cn	<26	137	*- cn	<8	141
11	*- cn	<206	635	*- cn	164	658
12	*- cn	<32	134	*- cn	20	219

Next steps

- Correlate {wastewater parameters} with {PFAS compounds}
  - Process type, HRT, chemical use (P removal, pH adjustment, supplementary carbon), etc
  - Microbiome (classified using genomics…., sadly, not microbial methods ☹… I'm old school)
- Laboratory column leaching studies
- Greenhouse plant uptake studies
- Field application fate and transport.

WRF study - Incineration Results

- WRF 5111 – “Existing” Incinerators
- Sampled two sites, represented furnace technologies used in US
- Key Results
  - Air emissions meet state air health guidelines
  - Ash is PFAS “free”
  - Degradation supported, destruction requires further investigation

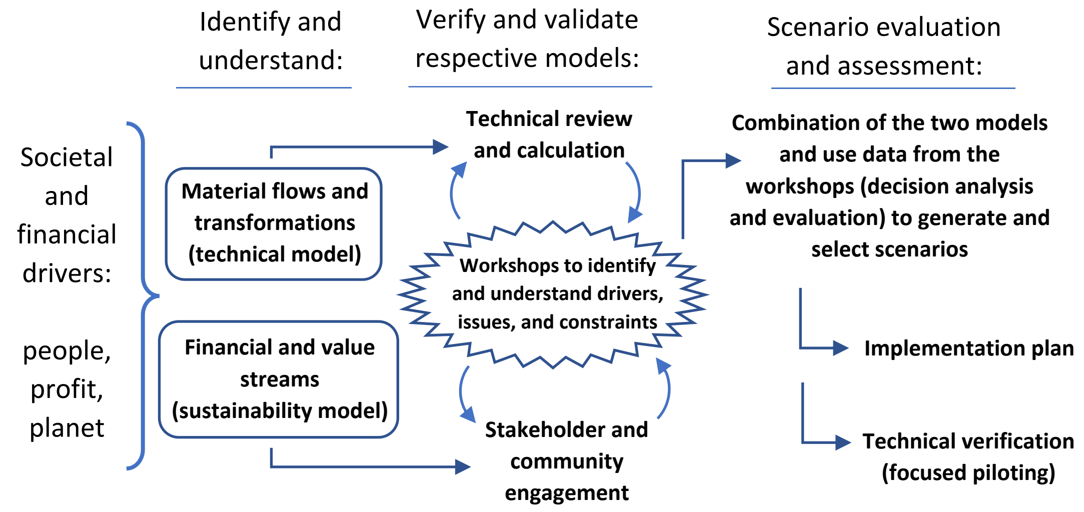


Winchell, L. J., Wells, M. J.M., Ross, J. J., Kakar, F., Teymouri, A., Gonzalez, D. J., Dangtran, K., Bessler, S. M., Carlson, S., Fonoll, X., Norton Jr., and Bell, K. Y. (2024) Fate of PFAS Through Two Full-Scale Sewage Sludge Incinerators. Water Environment Research. https://onlinelibrary.wiley.com/doi/10.1002/wer.11009

Hydrothermal liquefaction – NEW WIN!
$1,500,000 Department of Energy-funded project

- **Federal Funding Requested: $1,500,000/Cost Share: $375,000**
- **Project Duration: 3 years**

GLWA (Prime): Dr. Xavier Fonoll Almansa (PI), Dr. John Norton
PNNL: Dr. Michael Thorson, Dr. Lesley Snowden Swan, Dr. Uriah Kilgore
Genifuel: James Oyler
Wayne State University: Dr. Carol J. Miller



A community based HTL waste conversion project which:

- Enables wastewater utilities to properly evaluate HTL in biosolids treatment and conversion to biofuel
- Provides a real world HTL demonstration for GLWA and other utilities
- Develops business case evaluation of HTL in biosolids/waste conversion
- Examines social and environmental impacts of wet waste conversion
- Studies social, environmental, equitable, economic and sustainability impacts of the HTL for disposal of wet wastes.
- Evaluate expanded organic wet waste feeds in the greater Detroit area
  - Food waste, yard waste, wastepaper, etc.
  - Evaluate the potential for jobs creation

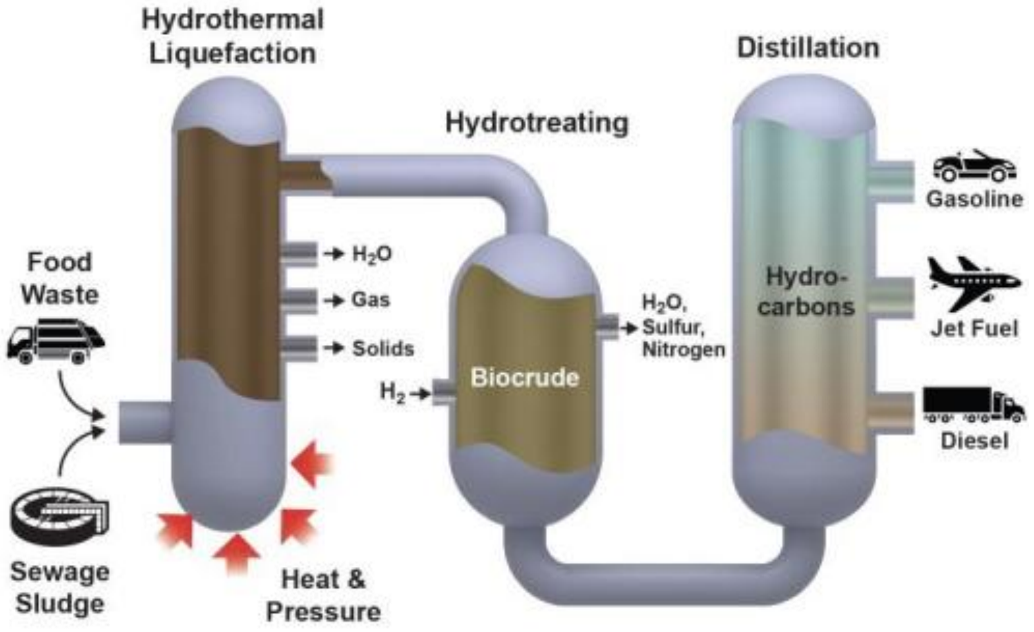
Project Outcomes

- Demonstration of HTL process for energy recovery in real-world setting
  - Conversion of local wet-wastes blends to fuels
- Development of comprehensive technical and sustainability models
  - HTL municipal waste to energy scenarios
- Validation of the technical and sustainability models
  - Achieved through community outreach and stakeholder engagement
- Application of the technical and sustainability models to determine "most optimal" waste-to-energy scenarios
- Developed business/implementation plan for HTL waste to energy scenario
- Dissemination of results and methods to large WRRF's across the US.
  - Encourages and accelerates adoption of HTL technology

Hydrothermal liquefaction research focus

Feed carbon

- WWTP biosolids
- Other waste streams
  - Food waste
  - Yard waste
  - Wastepaper
  - Small plastic fractions
- Impact
  - Volume of biocrude
  - Value of biocrude
  - Capital/O&M costs
  - Tipping fees
  - Local job creation



Liquid waste stream

- 90% of the original volume
- Nitrogen → hard to treat aromatics
- Recycle to front end headworks?
  - MetroVC-1:300 GLWA 1:700
- Exploring advanced AD treatment

Waste ash

- Currently landfilled
- Nutrient rich
- Beneficial recovery??

Hydrothermal liquefaction research
(in collaboration with Pacific Northwest National Lab)

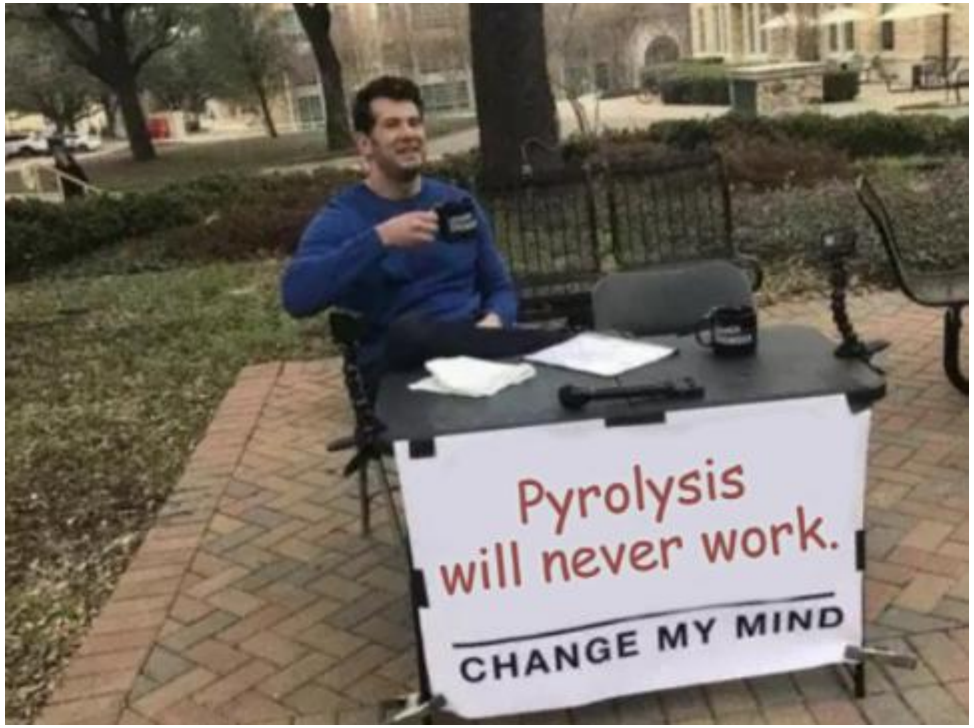
- Cronin, D.; Schmidt, A.J.; Billing, J.; Hart, T.R.; Fox, S.P.; Fonoll, X.; Norton, J.; Thorson, M.R. 2022. ***Comparative Study on the Continuous Flow Hydrothermal Liquefaction of Various Wet-Waste Feedstock Types***. ACS Sustainable Chemistry and Engineering.

- Snowden-Swan, Lesley J., Li, Shuyun, Jiang, Yuan, Thorson, Michael R., Schmidt, Andrew J., Seiple, Timothy E., Billing, Justin M., Santosa, Daniel M., Hart, Todd R., Fox, Samuel P., Cronin, Dylan, Kallupalayam Ramasamy, Karthikeyan, Anderson, Daniel B., Hallen, Richard T., Fonoll-Almansa, Xavier, and Norton, John. 2022. ***Wet Waste Hydrothermal Liquefaction and Biocrude Upgrading to Hydrocarbon Fuels: 2021 State of Technology***. United States: 2022. doi:10.2172/1863608

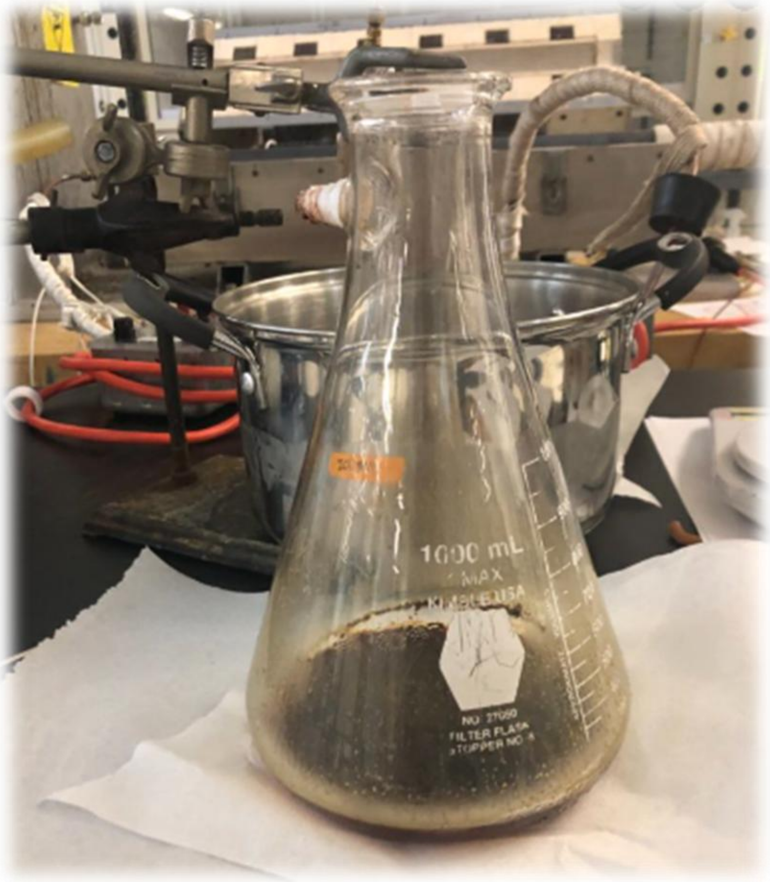
PNNL HTL system

Pyrolysis research focus

- Idea: heat up the carbon and you will get oil
- Reality: generally, you get tar



TAR. (TAR BAD).



Junsung Ra, Amanda Tatem, Alexis Vaccarella, University of Rochester, Senior Design Day, 2022
https://www.hajim.rochester.edu/senior-design-day/acorn-biochar-by-product-removal-from-pyrolysis-gas/

Dr. John's recommendations

- Aggressively target the "bad apples"
  - 1,000's of pp**m** ← bad
  - 20 pp**b** ← not bad
- Understand the tradeoffs
  - HUGE energy demand and carbon emissions from treating "de minimis" levels of PFAS
  - PFAS makes life better – the best pacemaker has PFAS in it
- Beneficial reuse of biosolids (land application)
  - Is critical for returning nutrients to soils
  - Is MUCH more effective than chemical fertilizer application

Utilities!! ***PLEASE*** collaborate in research efforts!!

The "distance" of understanding between these sectors is often so extreme as to be unpassable. Reasons? Ego, boundaries of experience, "relevance paradox", simple limit on ability to learn multiple disciplines, trust, ….

Players cannot make good decisions outside of their knowledge space because they are unaware of the drivers and constraints existing in those spaces.

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… and many others.

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