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PFAS TREATMENT

SOURCES AND FATE IN WATER, WASTEWATER, AND BIOSOLIDS

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OVERVIEW

- PFAS of increased environmental profile
- Human population exposure
- Common in commerce (water/wastewater)
- Characterization/remediation not easy
- Hazardous designation pending
- Federal and state regulations on the rise

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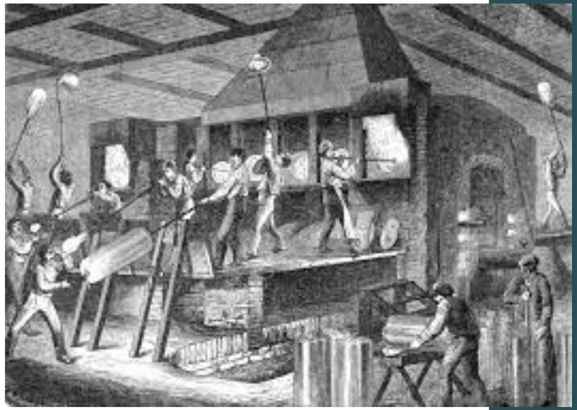
ANCIENT TIMES

FLUORINE

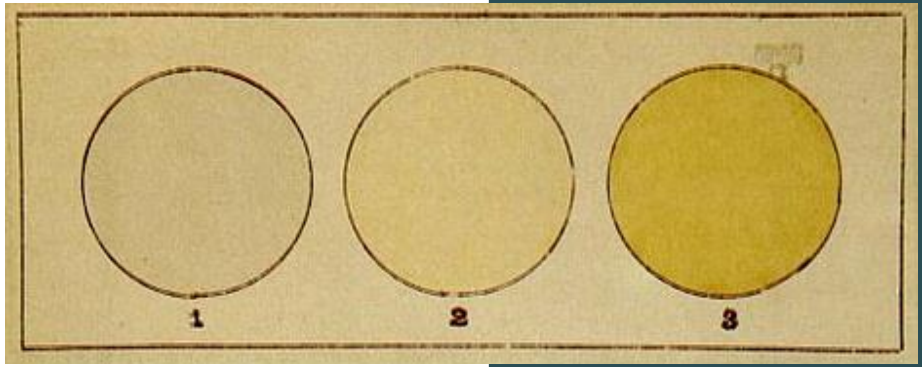
- Ornamental - BC/AD
- Fluorite smelting aid (flux/flow) – 1500s
- Fluoric acid glass etching – 1700s
- Fluorine isolated - 1886

GLASS PRODUCTION



FLUORITE ROMAN CUP

METAL SMELTING



EARLY VISUALIZATION OF AIR (1), FLUORINE (2), CHLORINE (3)

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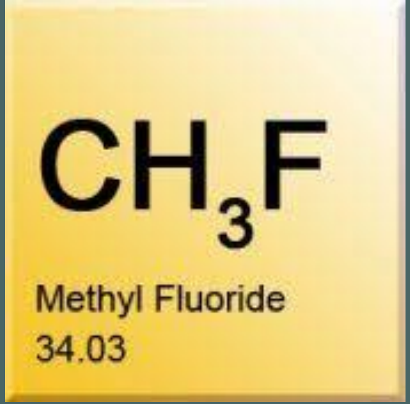
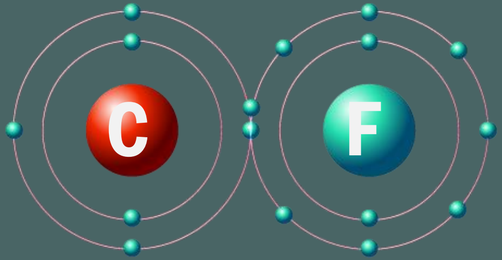
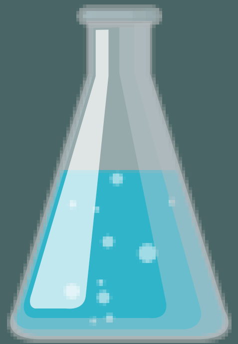
EARLY ORIGINS

HALOCARBONS

- Worked for Emil Erlenmeyer
- Halocarbon work (methyl bromide)
- Paved the way for Jean Dumas to synthesize methyl fluoride in 1835







Alexander Borodin (1833 – 1887)

1930s/1940s

EMERGENCE OF FERFLUOROCARBONS

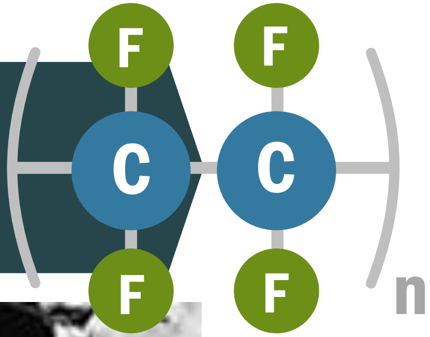
FIRST GENERATION REFRIGERANTS

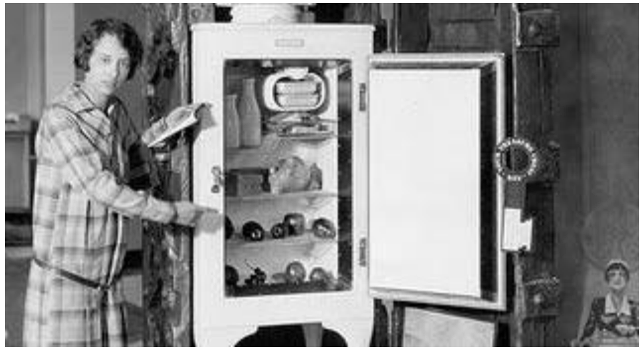
Ammonia, Sulfur Dioxide, Ethers

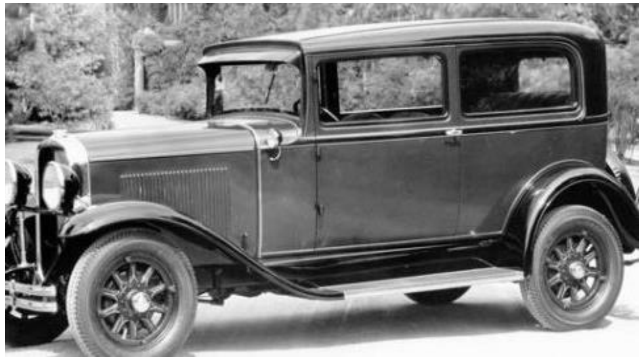
SECOND GENERATION REFRIGERANTS

Chlorofluorochemistry

Polytetrafluoroethylene







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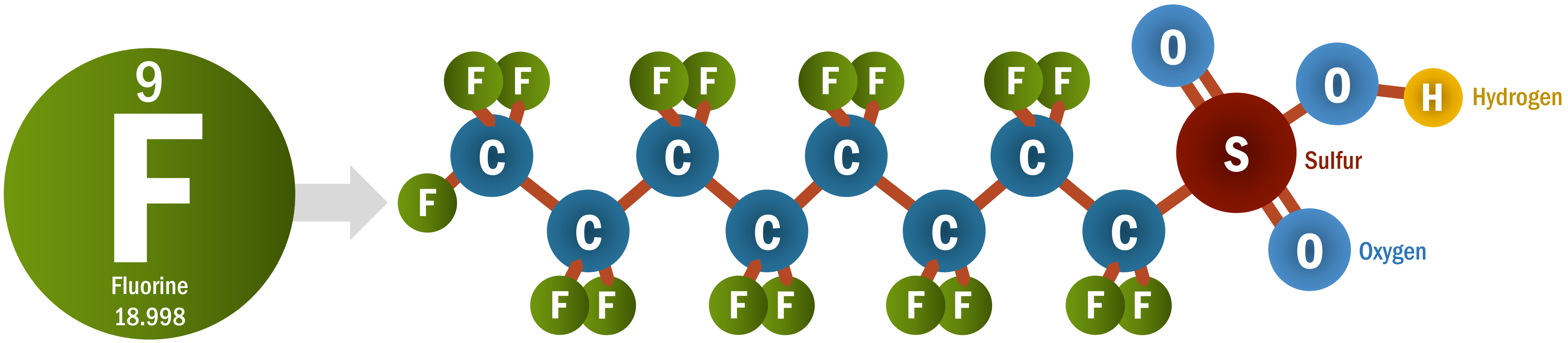
WHAT ARE PFAS?

COMPLEX MIXTURE OF PERFLUOROALKYL AND POLYFLUOROALKYL SUBSTANCES

Family - Fluorocarbons

NEUTRAL TAIL

CHARGED HEAD



Perfluorooctane sulfonic acid (PFOS)

Per = for each
Poly = many
Fluoro = fluorine atom
Alkyl = hydro(gen)-carbon chain with removed hydrogen(s)

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PFAS IS OMNIPRESENT!

https://riversideca.gov/press/understanding-pfas

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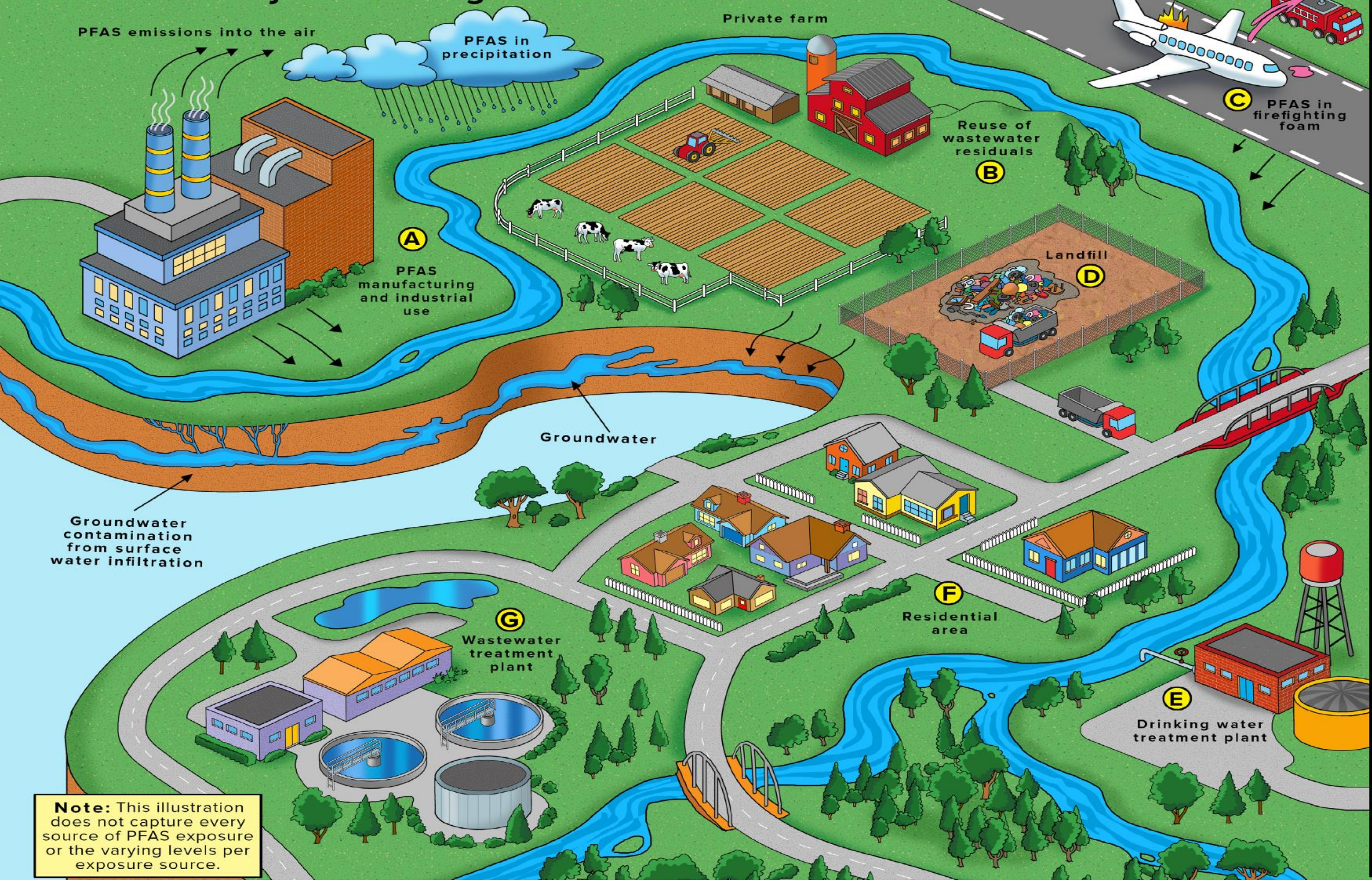
How PFAS Cycle Through the Environment



A

PFAS, which are unregulated in industrial discharges, enter the environment through air, surface water and groundwater.

B

Nutrient-rich materials that remain after wastewater treatment and testing are used on farms as low-cost fertilizers. Significant contributions to wastewater from nearby industrial sites can elevate PFAS levels in residual materials and seep into groundwater if not removed during treatment.

C

Firefighting foams which may contain PFAS are used at airports, military bases and training sites. Runoff containing PFAS migrates through soil into surface and groundwater.

D

At older landfills, wastewater from PFAS-contaminated waste may leach into groundwater or enter surface water.

E

New technologies have enabled recent detection of PFAS in drinking water supplies. Water treatment facilities that hadn't previously known of PFAS in their water supplies are determining the most effective treatments for removal.

F

PFAS continue to be used in common household products such as stain repellants and non-stick cookware. Their use contributes to PFAS exposure in humans and drinking water, source water and groundwater.

G

Liquid waste that seeps from landfills and wastewater is treated at wastewater plants, but PFAS may remain in the water after treatment and contaminate ground water.

American Water Works Association

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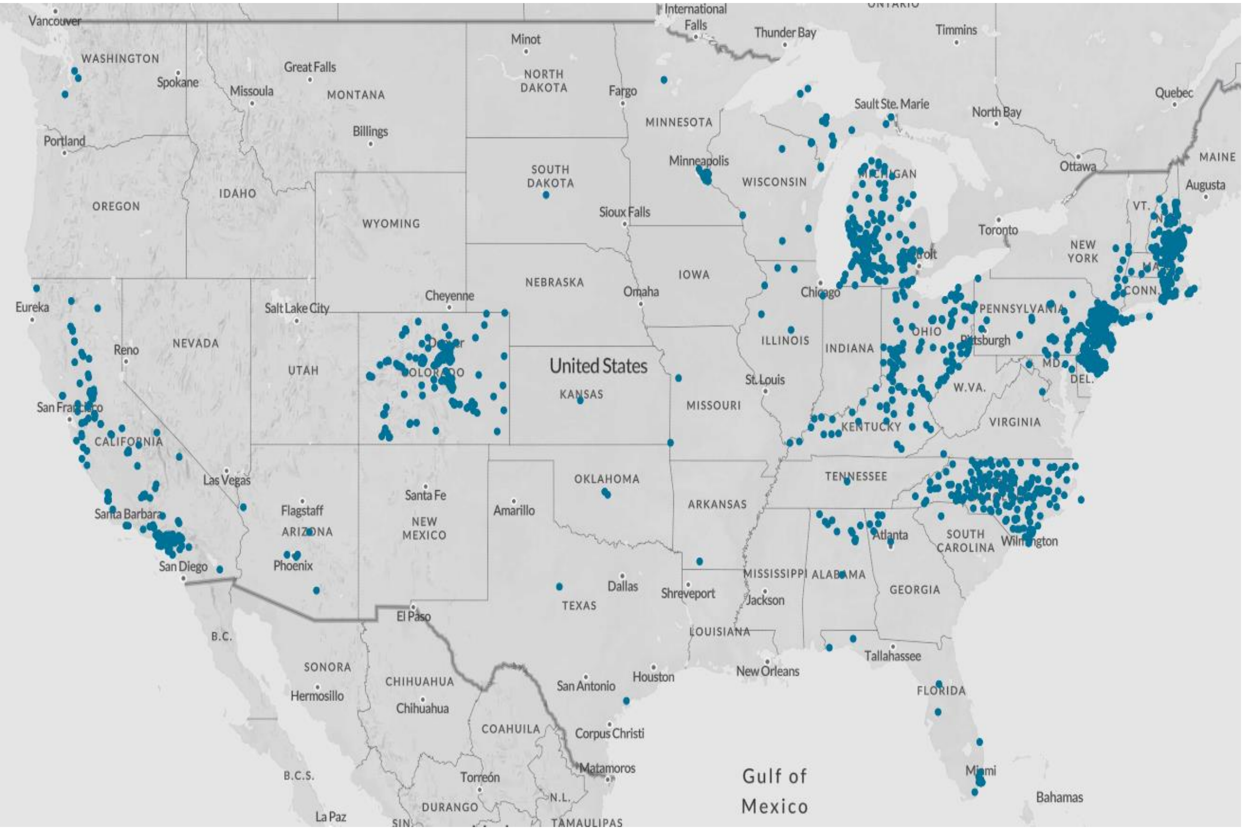
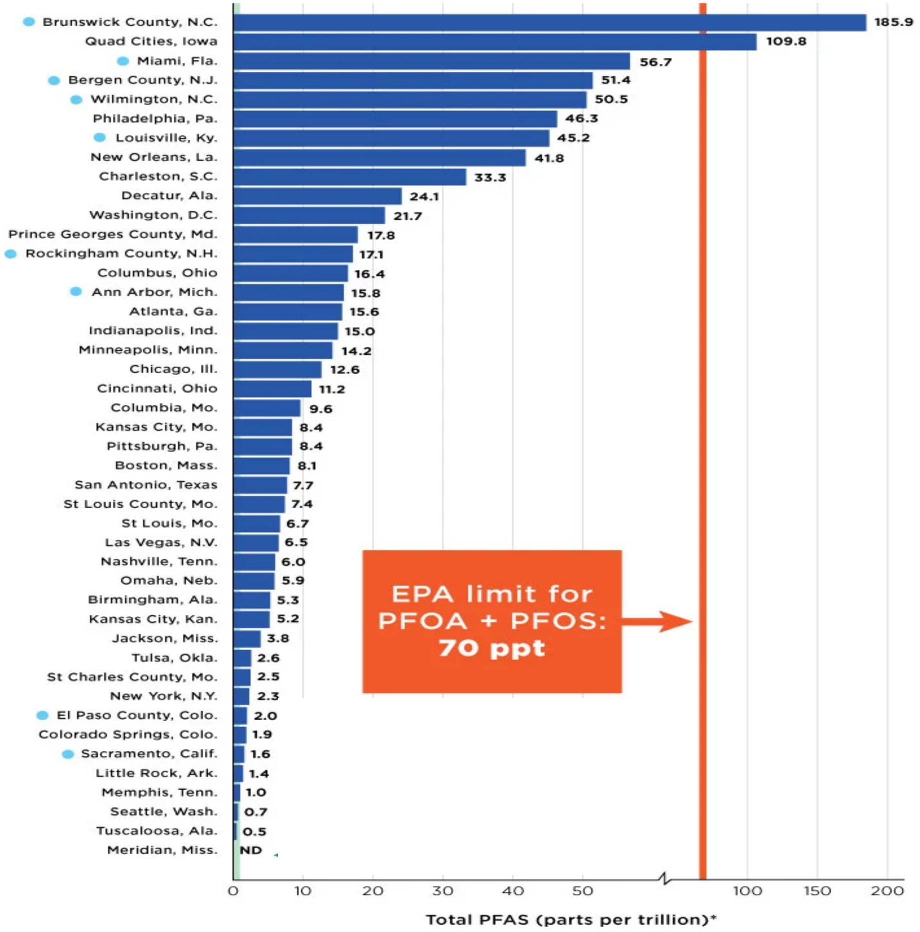
PFAS DETECTED IN DRINKING WATER

~10% of PWS with measurable PFAS
UCMR 3 (2013-2015), UCMR 5 (2023-2025)



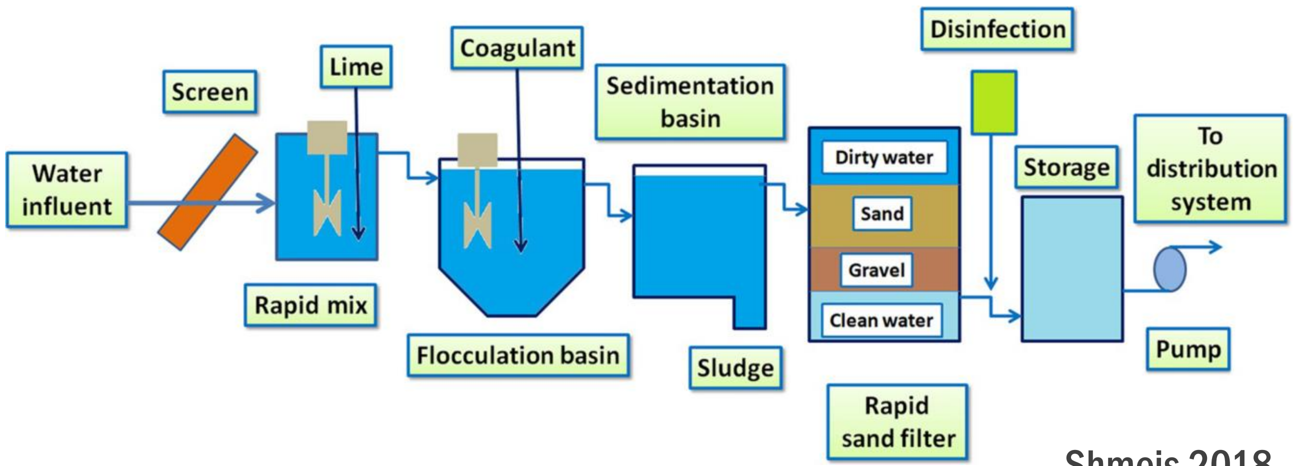
https://www.ewg.org/interactive-maps/pfas_contamination/map/ (January 2021)

EWG TESTS FOUND TOXIC PFAS CHEMICALS IN TAP WATER IN 31 STATES AND D.C.

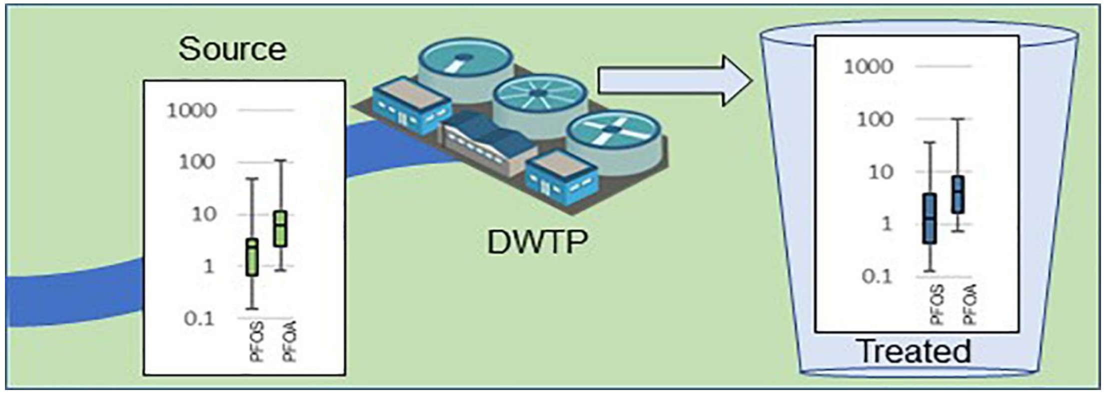


PFAS FATE IN
DRINKING WATER TREATMENT PLANTS

- Little to no removal or transformation
- Relative species composition unchanged
- Systems with activated carbon polishing likely to retain some long chain PFAS if properly maintained



Shmeis 2018

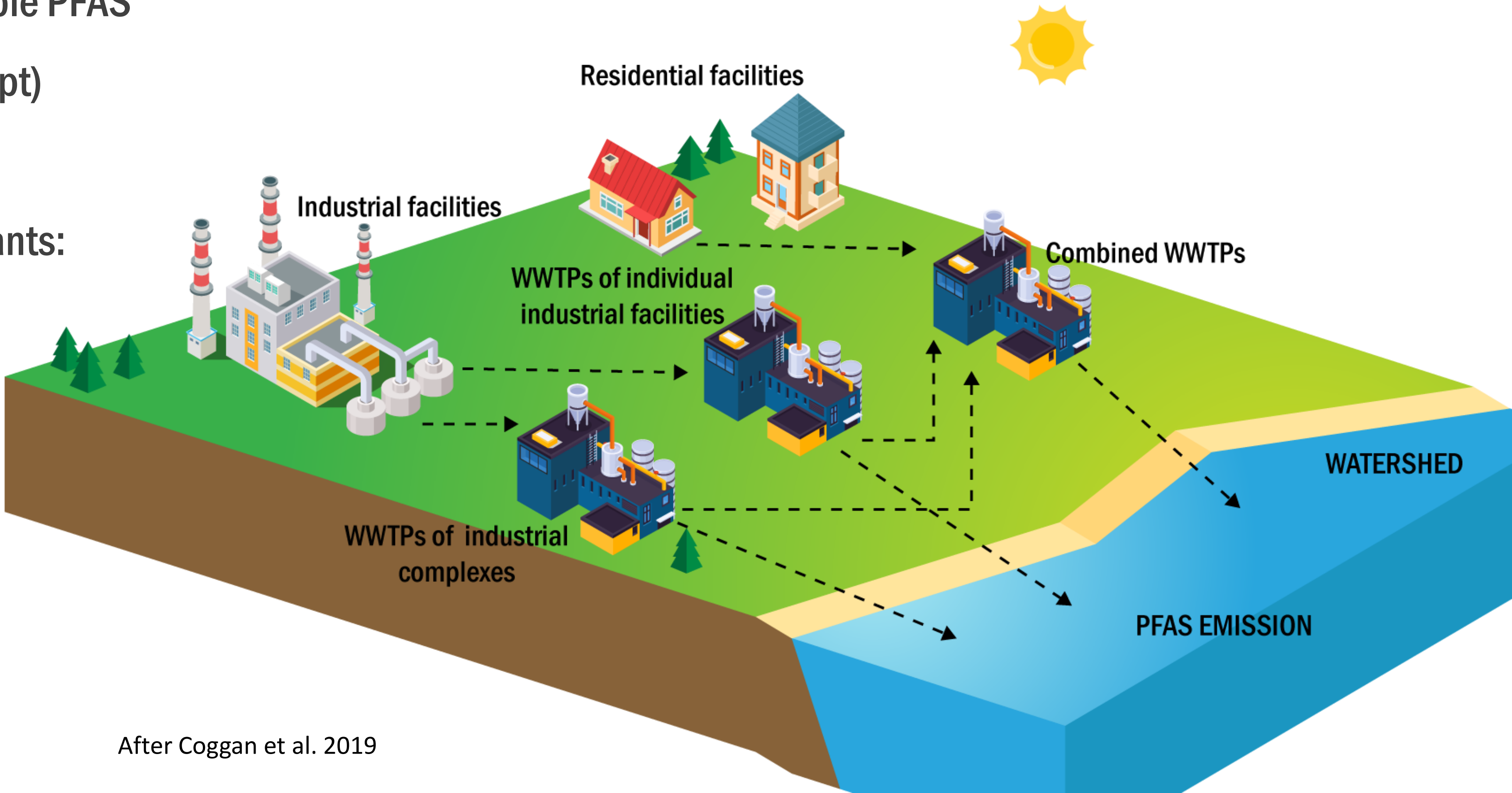


Boone 2019

PFAS DETECTION IN WASTEWATER

USEPA ORD NATIONAL EFFLUENT SURVEY

- >80% WWTPs with measurable PFAS
- Median levels 10-30 ng/L (ppt)
- Predominantly C6&C8 PFAS
- Data based on 50 largest plants:
- 20% of population
- 17% of discharge



After Coggan et al. 2019

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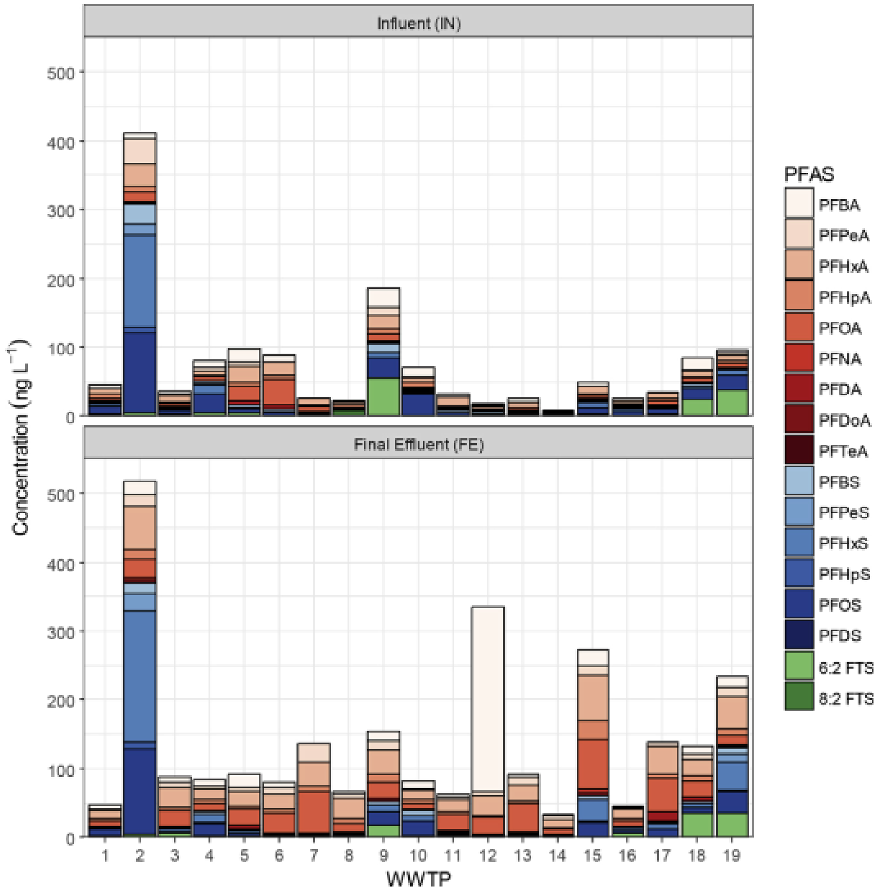
PFAS FATE IN
WASTEWATER TREATMENT PLANTS

- Generally, **increased total concentrations in final effluent** vs. influent
- Shift in relative and absolute species composition
- Emergence of shorter-chain PFAS in effluent (PFAS breakdown?)
- Retention of longer-chain PFAS in sludge?



Coggan et al. 2019

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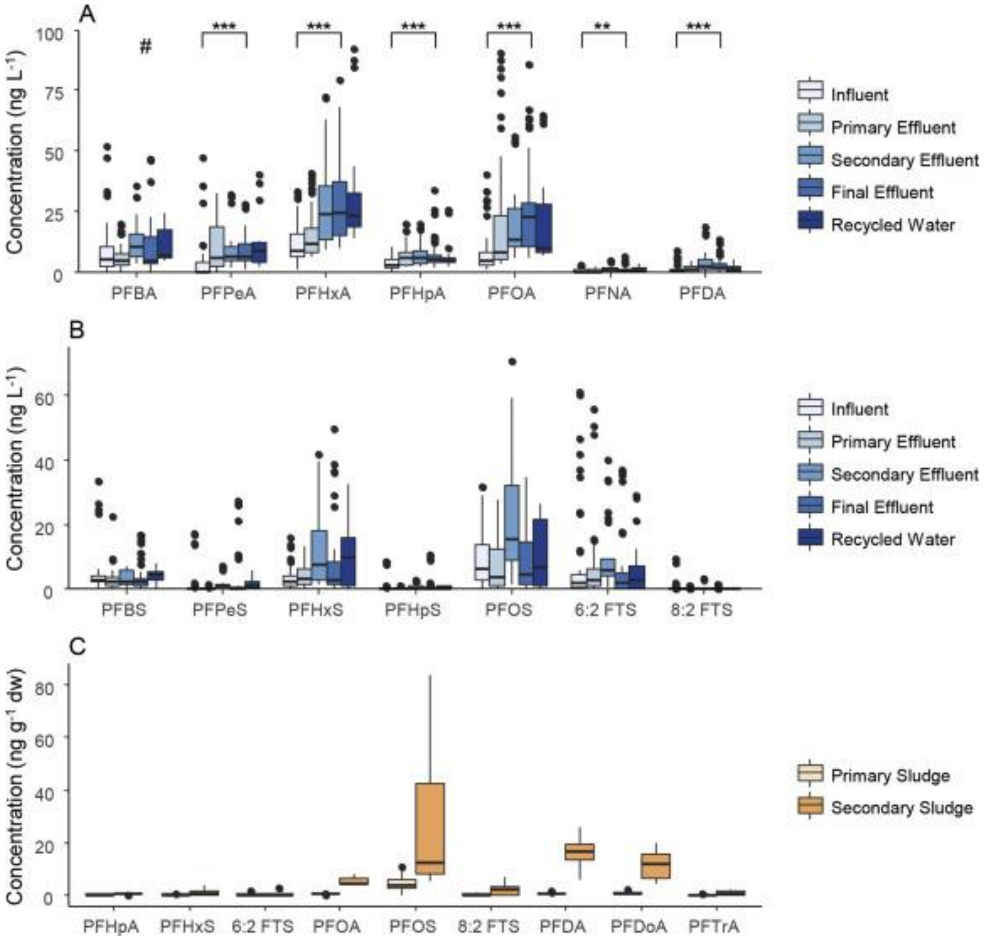
PFAS FATE IN
WASTEWATER TREATMENT PLANTS

- Shift in concentrations take place in primary & secondary effluents
- Precursor transformation, supported by TOP assay on effluents (Tavasoli 2021)
- PFAS reductions unlikely
- C6, C8 highest detections (100 ppt)
- Secondary sludge repository of >C8s



Coggan et al. 2019

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PFAS DETECTION IN BIOSOLIDS

Year Sampled	PFOA (ng/g dry wt)	PFOS (ng/g dry wt)	Reference
2001	12 - 70	308 - 618	Venkatesan, 2013
2004-2007	8 - 68	80 - 219	Sepulvado, 2011
2005	16 - 219	8.2 - 110	Loganathan 2007
2005	18 - 241	<10 - 65	Sinclair, 2006
2006		81 - 160	Schultz, 2006
2006-2007	18 - 69	31 - 702	Yu, 2009
2007	20 -128	32 - 418	Yoo, 2009
2011	1 - 14	4 - 84	Navarro, 2016
2014	10 - 60	30 - 102	Mills, Dasu (in prep)
2018	1-11	2 – 1,100	EGLE, 2020

USEPA 2020

NOW WHAT?

- PFAS in PWSs
- PFAS in WWTPs
- PFAS in Biosolids

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WATER

TREATMENT TECHNOLOGIES

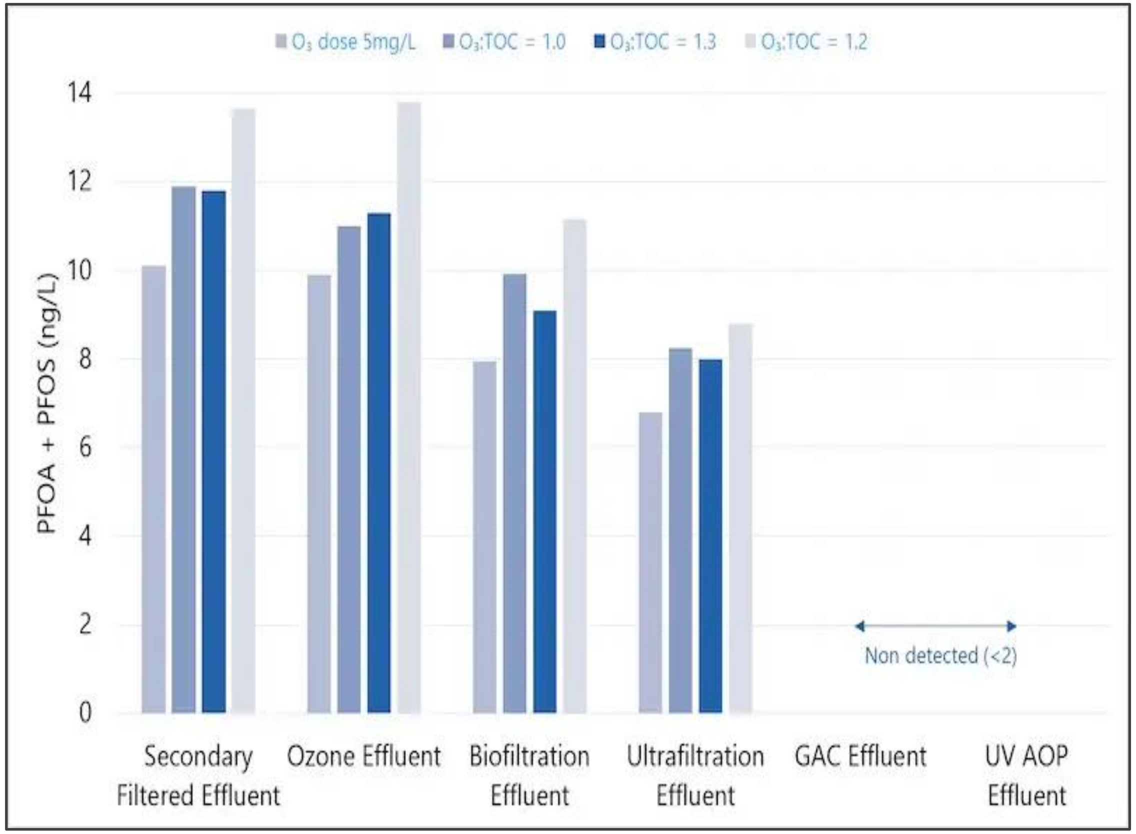
TREATMENT SYSTEM	EFFECTIVE? (MAX. % REMOVAL)
Sand Filtration	No
Biological Treatment	No
Disinfection	No
Oxidation	No
Membranes (filtration): • Low pressure • High pressure	 No Yes
Activated Carbon* (adsorption): • Granular • Powdered	 Yes (>98%) Yes (>97%)
Ion Exchange Resins (adsorption)	Yes (>99%)
In Development (destruction): • Electrochemical oxidation • Plasma reactor • Catalytic transformation	NA

*Works better for longer-chained PFAS

USEPA 2020

WASTEWATER
TREATMENT TECHNOLOGIES

- PFAS in wastewater - **lower focus than drinking water treatment**
- Removal research ongoing
- Conceivably, water removal methods would apply, but **complexity and cost**
- Direct water reuse, advanced water treatment (AWT) as a potential model



Steinle-Darling 2020

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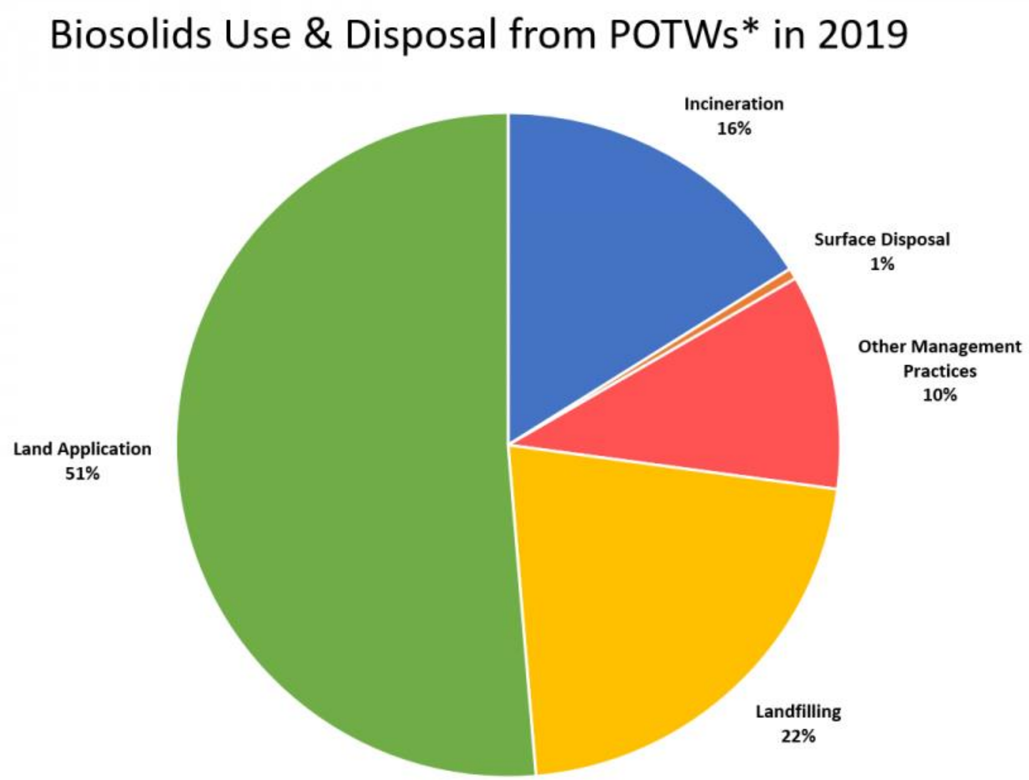
BIOSOLIDS

TREATMENT TECHNOLOGIES

- Research needed on reducing PFAS in WWTP sludges
- Biosolids disposal options:
  - Hazardous waste landfilling (if accepted)
  - Incineration (ensuring complete destruction)
  - Land application/fertilizer/soil augmentation not recommended without a prior risk assessment



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PENDING FEDERAL REGULATIONS WATCHLIST

- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)/Resource Conservation and Recovery Act (RCRA)
  - Hazardous designation under CERCLA/RCRA* – pending (2023?)
- Safe Water Drinking Act (SDWA) – PFAS MCL (proposed rule in 2023?)
- Clear Water Act (CWA):
  - NPDES – wastewater discharge limits (WV, PA)
  - Industrial pretreatment programs (manufacturer consent decrees)
  - Biosolids limits/regulations/risk assessment (in progress)

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*January 14, 2021 ANPRM: PFOS/PFOA and their salts (ammonium, sodium, potassium, etc. and structural isomers
https://www.epa.gov/pfas/epa-actions-address-pfas

SNAPSHOT OF CURRENT LIMITS

	LOWEST		HIGHEST
	CALIFORNIA PHGs[1] 0.007 ppt (PFOA)	DRINKING WATER	NEVADA BCLs 667 ppt (PFOA)
	MINNESOTA HBV-RIVER 6 ppt (PFOS)	DISCHARGE WATER[2]	OREGON IL 300,000 ppt (PFOS)
	MAINE - SLUDGE 2,500 ppt (PFOA)	BIOSOLIDS	NEW YORK - SCREENING 72,000 ppt (PFOA)

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[1]Draft
[2]Entering US waters

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