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PFAS in biosolids
Recent developments, impacts and treatment

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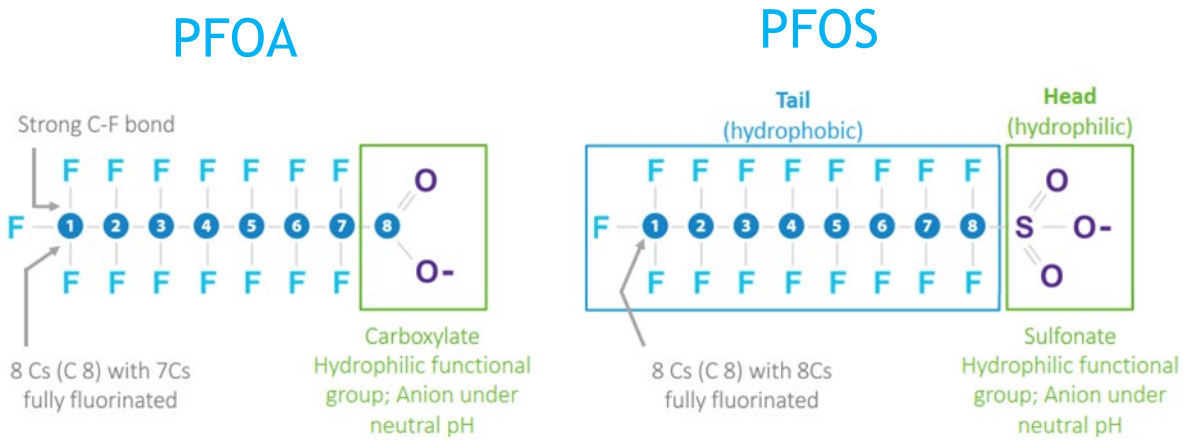
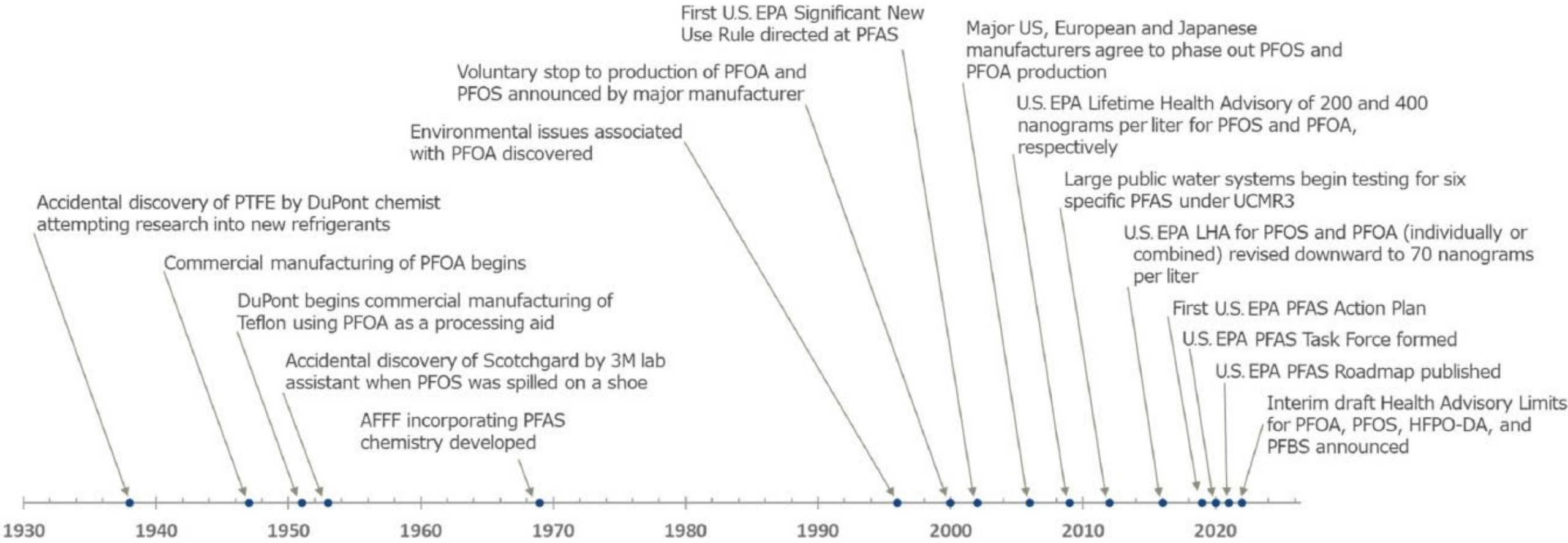
What are PFAS?

- Formerly called “perfluorinated compounds” (“PFCs”)
- Family of anthropogenic chemicals used for decades to make products resistant to heat, oil stains, grease and water
- Also know as “forever chemicals”
- A recent Health Canada biomonitoring study said 98.5 per cent of Canadians have PFAS in their blood



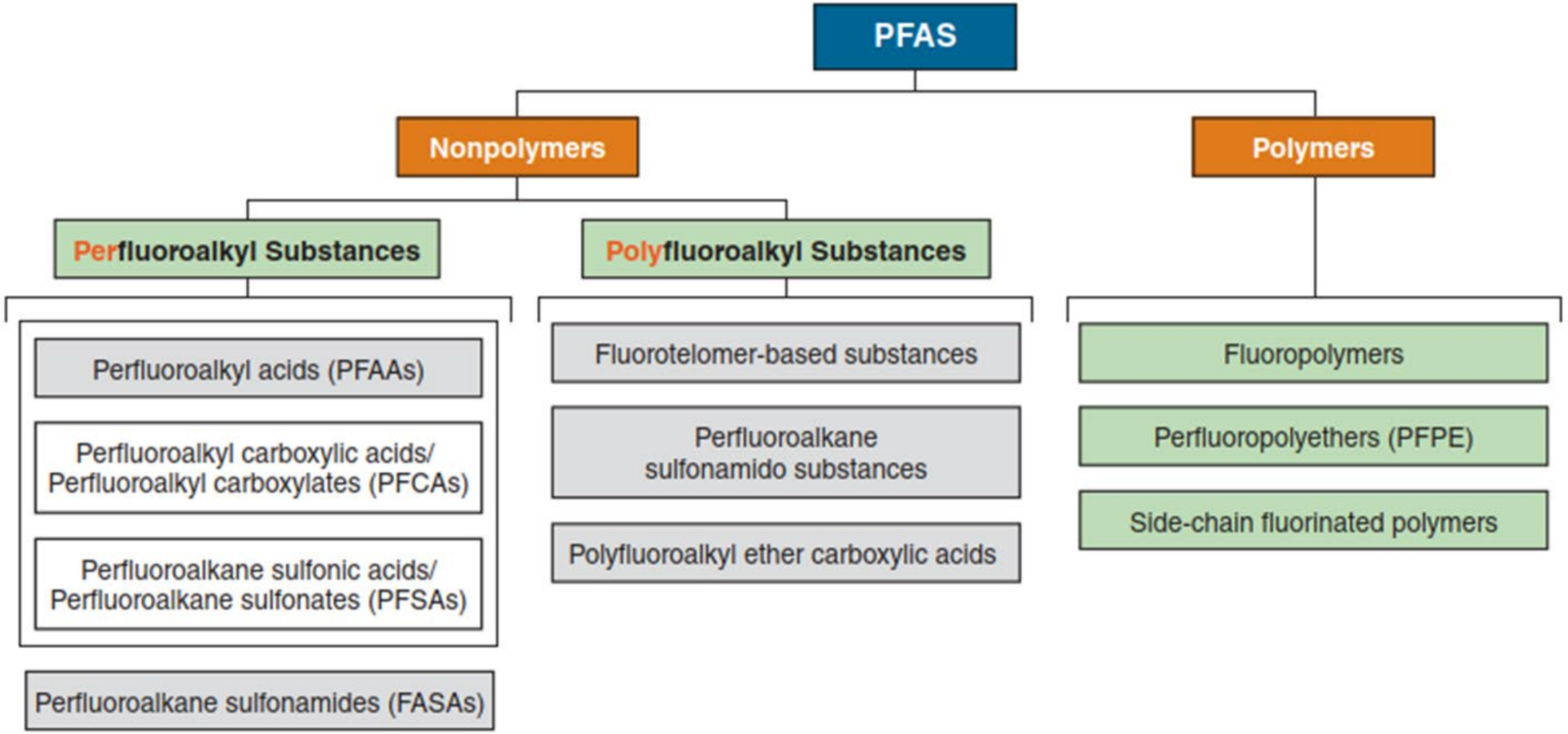
Source: Chiang and LeBlanc, 2019

PFAS Milestones

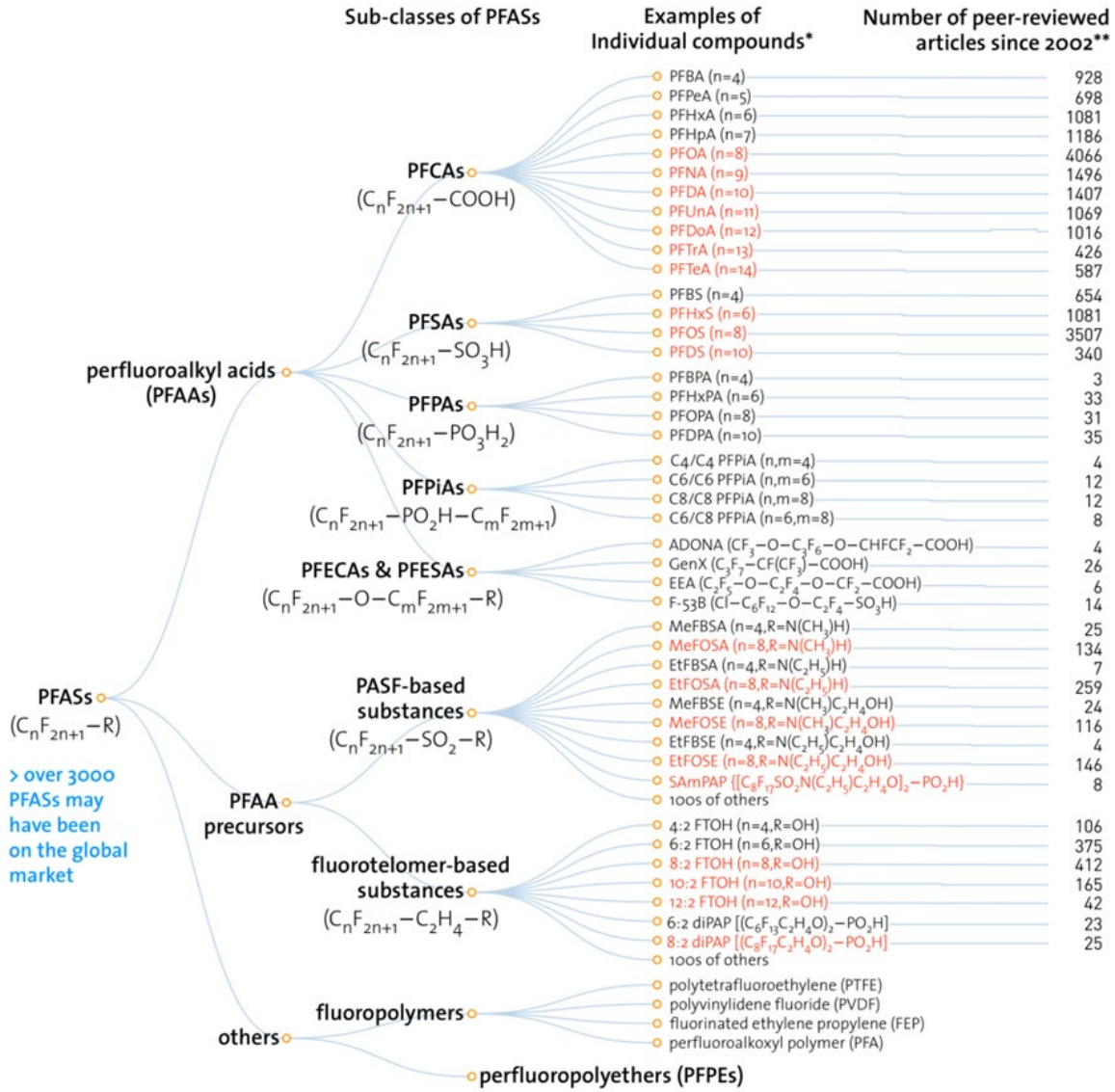


Source: WEF (2023)

PFAS Families



More PFAS Compounds



Recent reports - inventory of more than 7,000 compounds

Source: Wang et al. 2017

Exposure

Drinking contaminated municipal water or private well water

Eating fish caught from water contaminated by PFAS (PFOS, in particular)

Accidentally swallowing contaminated soil or dust

Eating food that was packaged in material that contains PFAS

Using some consumer products such as stain resistant carpeting and water repellant clothing

PFOA and PFOS Guidelines

Agricultural soil quality guideline for human and environmental health:

- PFOS = 0.01 µg/g (ppb) or 10 ng/g (ppt)

Groundwater guideline for human health:

- PFOS = 0.6 µg/L (ppb) = 600 ng/L (ppt)

Drinking water guideline in Canada:

- PFOA = 200 ppt
- PFOS = 600 ppt
- Proposed total PFAS objective = 30 ppt

Drinking water guideline in the US:

- PFOA = 8 – 35 ppt
- PFOS = 10 – 40 ppt

Biosolids:

- Quebec temporary moratorium on biosolids from the US
- CFIA interim standard of 50 ppb of PFOS before biosolids/fertilizers can be imported or sold in Canada

Water Quality Standards (in Michigan)

	PFOS (ppt)	PFOA (ppt)
Receiving water not used for drinking water	12	12,000
Receiving water used as drinking water source	11	420

Source: WEF (2023), Michigan EGLE (2021)

Putting into perspective

PFAS Product Concentrations

DUST IN DAYCARE CENTER
142 parts per billion (1)

MICROWAVE POPCORN BAG
68-167 parts per billion (2)

BIOSOLIDS
35-200 parts per billion (3)

FIRE TRAINING CENTER
695 parts per billion (4)

MAKEUP FOUNDATION
2,370 parts per billion (5)

Measurement

1 ppt = 1 sec. in 31,700 yrs.

1 ppb = 1,000X more than ppt or 1 sec. in 31.7 yrs.

References

(1) Strynar M.J., Lindstrom A.B. Perfluorinated compounds in house dust from Ohio and North Carolina, USA. Env. Sci. & Tech 42:3751-3756. 2008.

(2) Yuan G, Peng H, Huang C, Hu J. Ubiquitous occurrence of fluorotelomer alcohols in eco-friendly paper-made food-contact materials and their implication for human exposure. Environ Sci Technol 50(2):942-950. 2016.

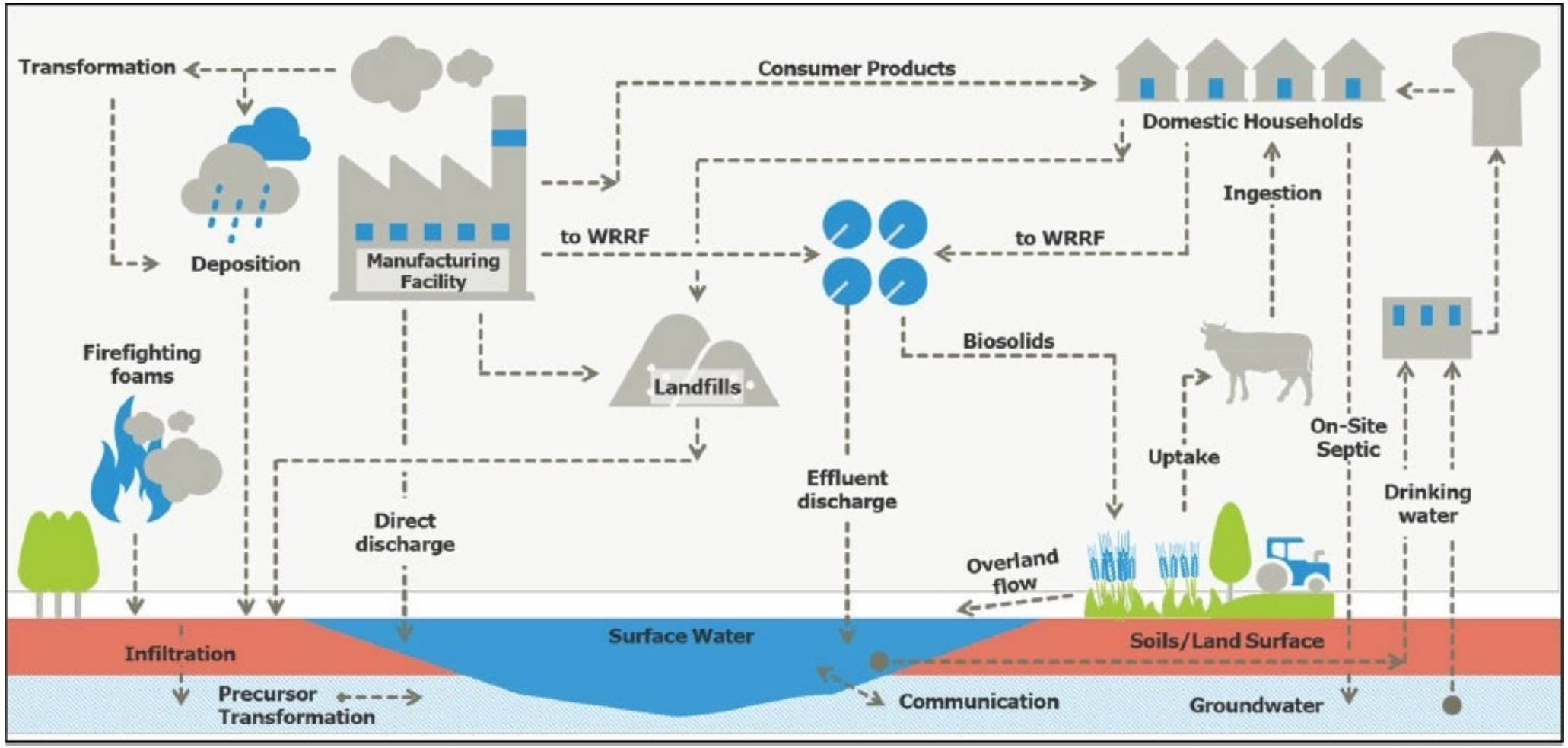
(3) Venkatesan, K, and Halden, R., National inventory of perfluoroalkyl substances in archived U.S. biosolids from the 2001 EPA National Sewage Sludge Survey. Journal of Hazardous Materials, 252- 253, (2013), 413- 418. 2013.

(4) Environmental Working Group. PFAS Contamination in the U.S. 2021.

(5) The Danish Environmental Protection Agency. Risk assessment of fluorinated substances in cosmetic products. 2018.

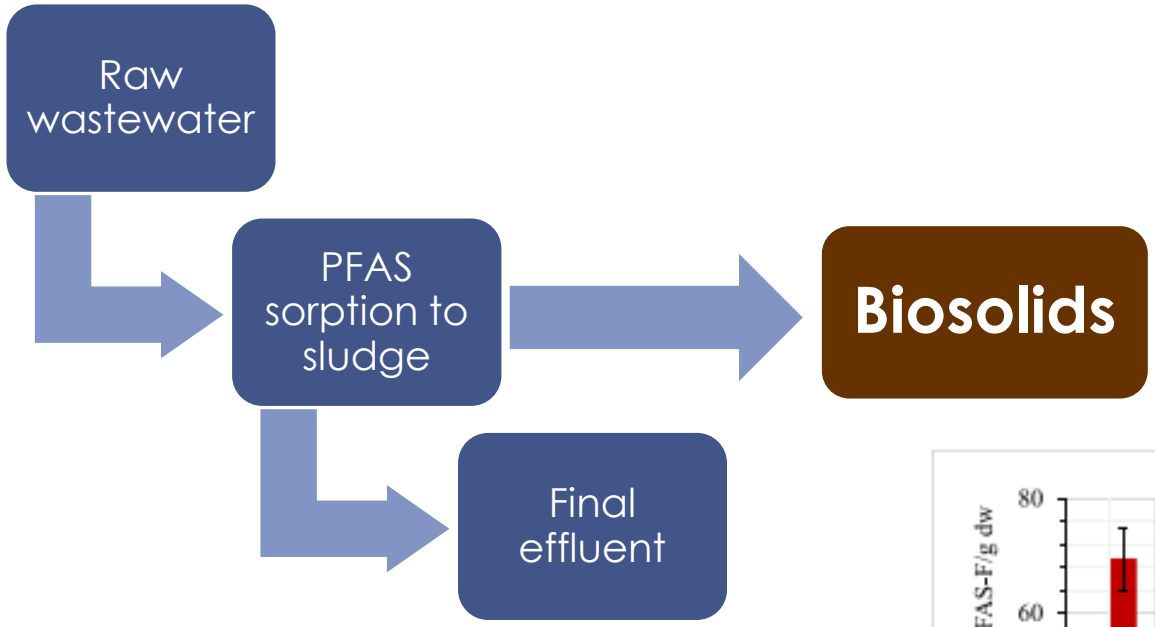
Source: WEF, (2021)

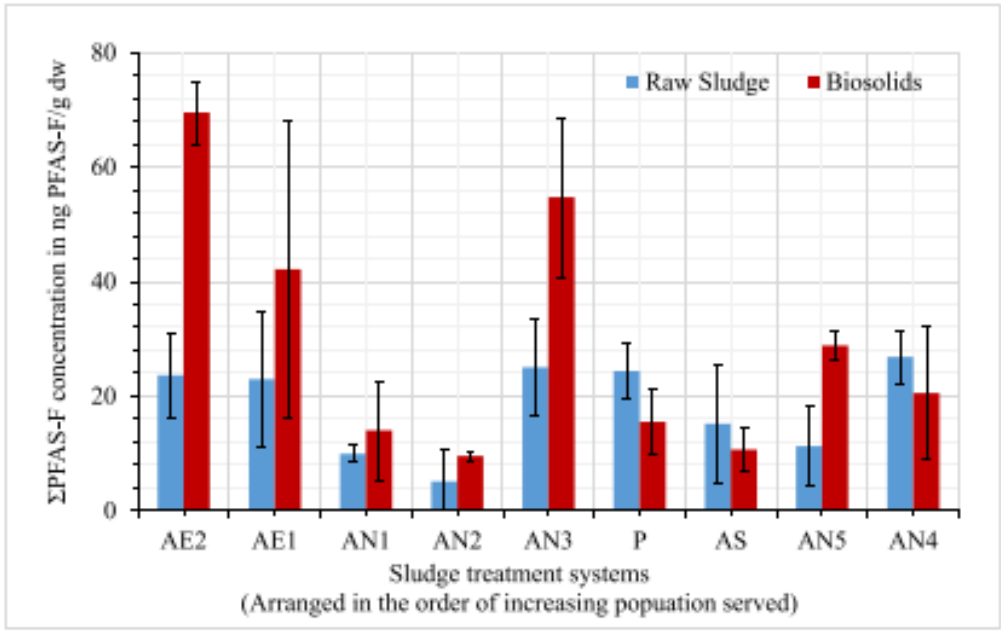
PFAS cycle in the environment



Source: WEF (2023)

WWTP – Where PFAS lead to more PFAS

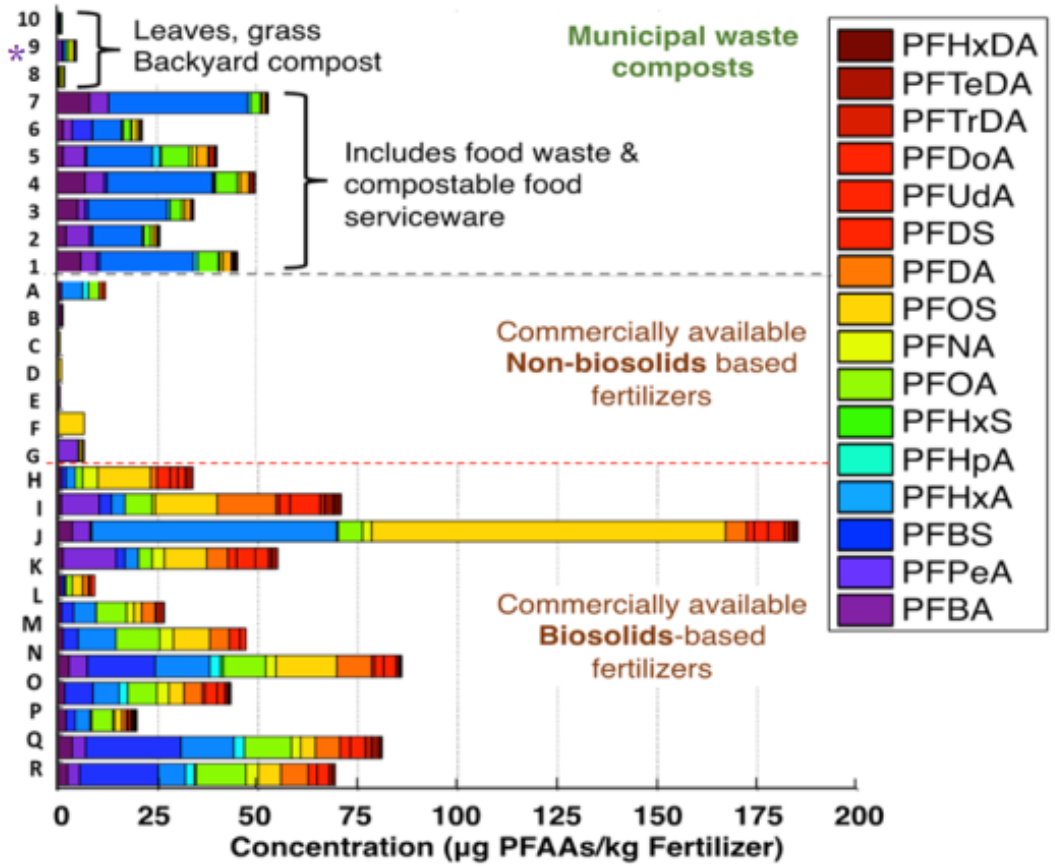




Source: Lakshminarasimman et al. (2021)

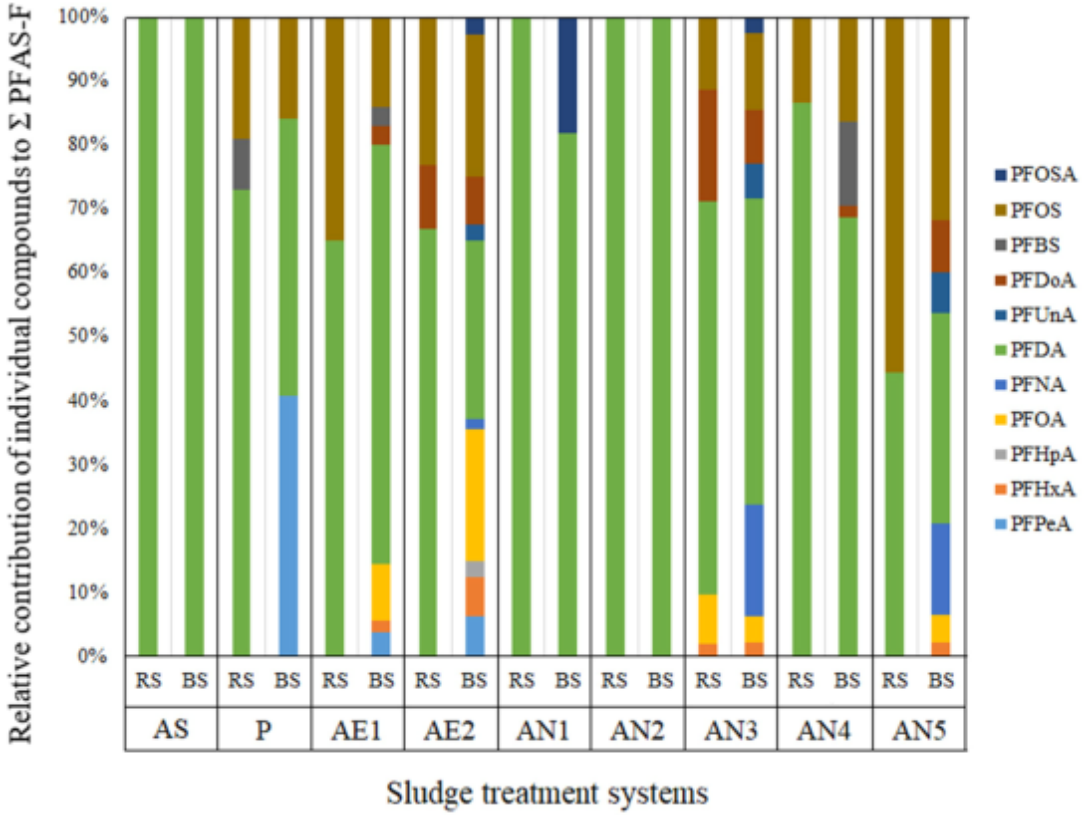
Contribution of individual PFAS compounds

United States



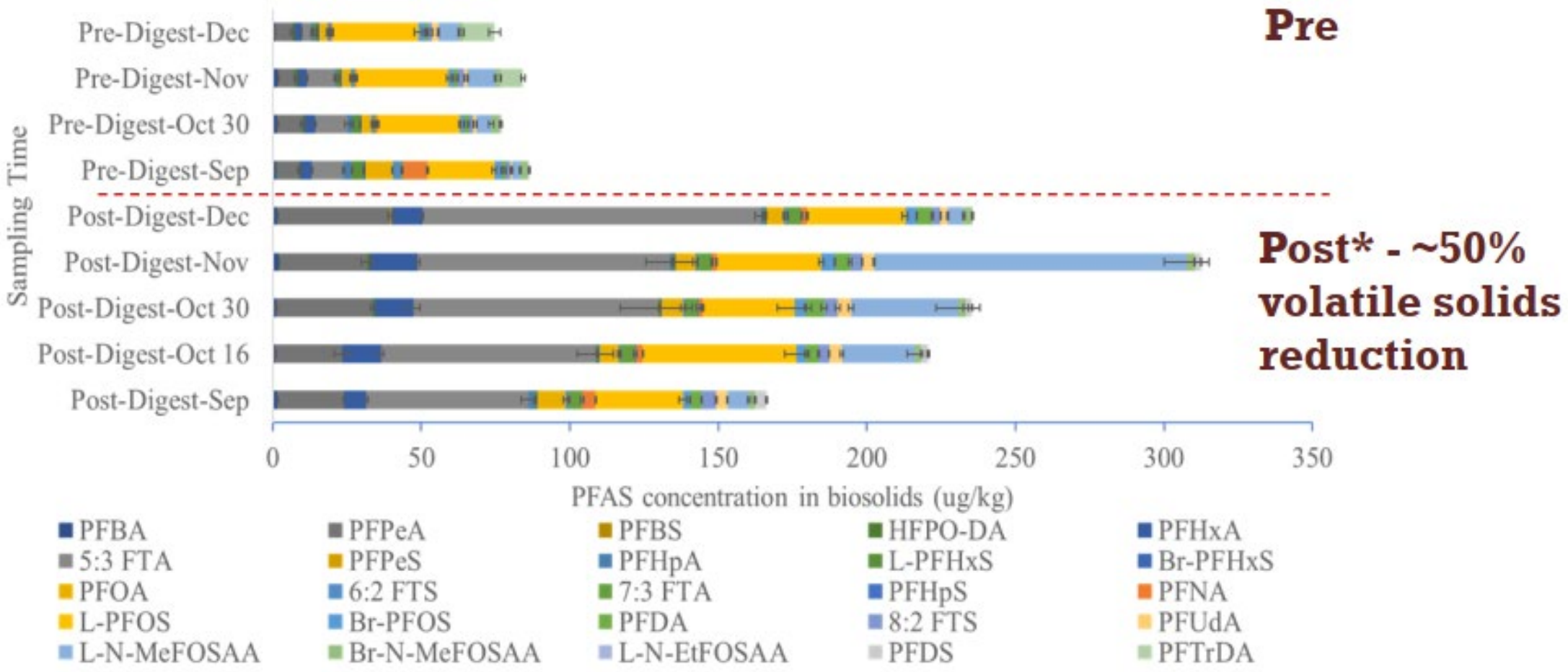
Source: Choi et al. (2019), Lazcano et al. (2020)

Canada



Source: Lakshminarasimman et al. (2021)

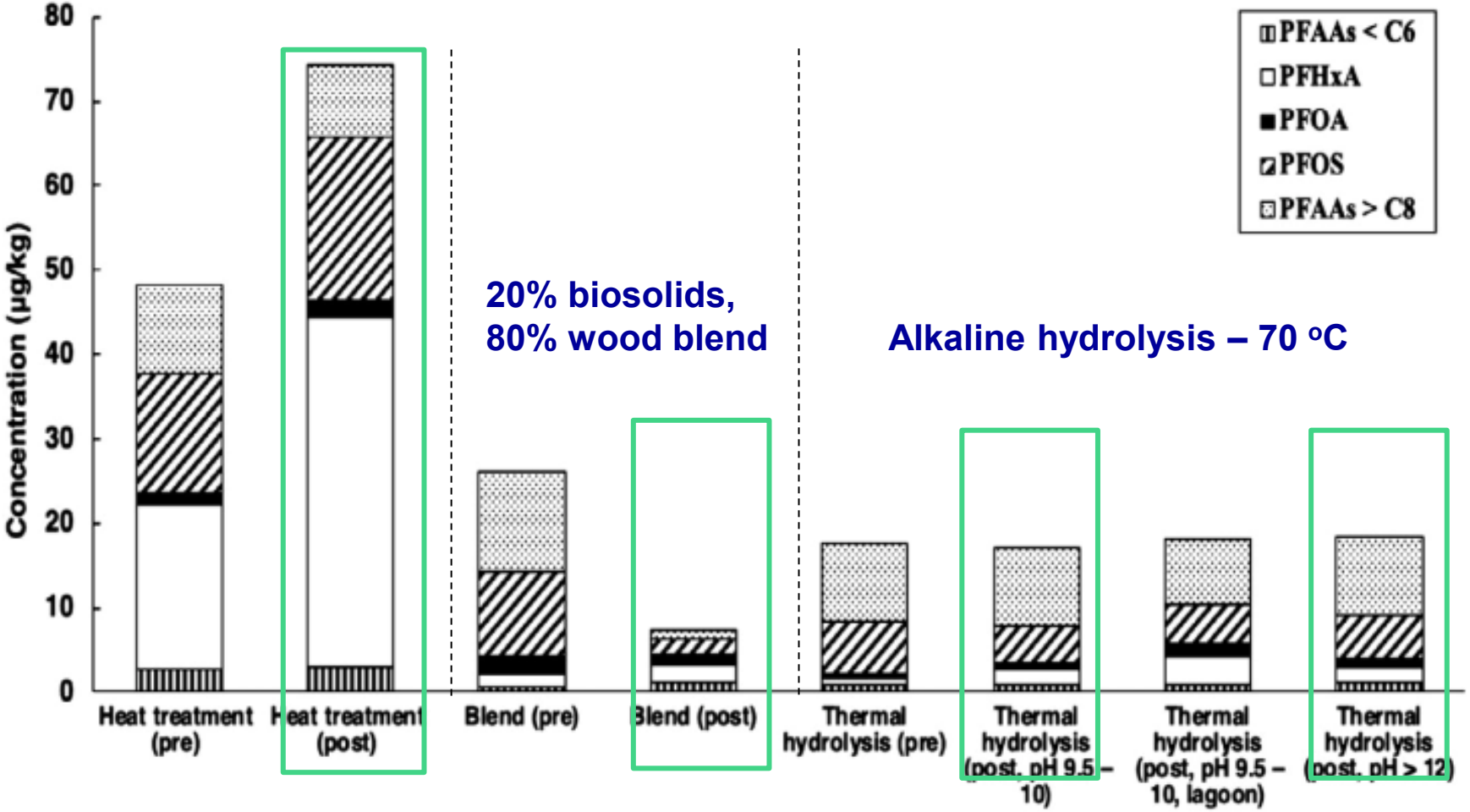
Anaerobic digestion



Source: WEF, Linda Lee (2021)

Drying, blending and thermal hydrolysis

Rotary Drum Dryer – 480 to 650 °C



Source: Lazcano et al. (2019)

Composting and lime stabilization

Composting

- PFOS was the most commonly detected PFAS in all materials (wastewater solids, bulking agents, and composts)
- PFAS in fresh bulking agent materials were lower than in other bulking agent mixtures
- Aerobically and anaerobically digested solids appear to result in less precursor transformation during composting, and concentrations of terminal PFAS are similar before and after composting.

Lime stabilization

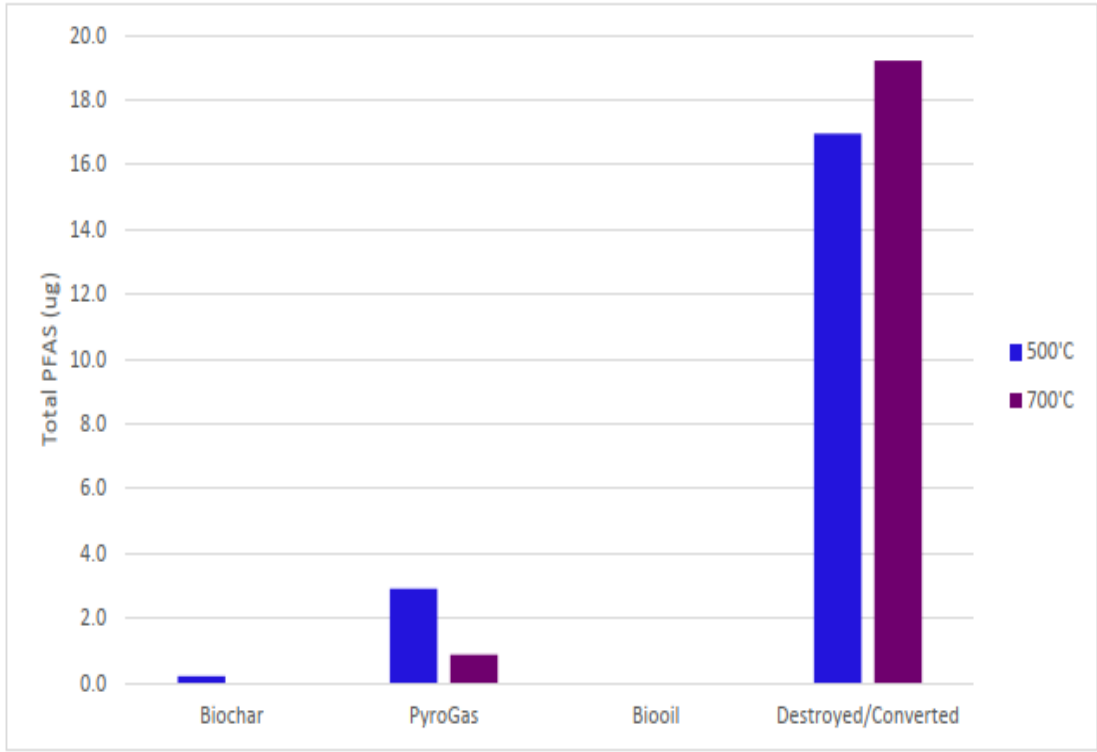
- PFAS concentration increases in an alkaline stabilized biosolids, suggesting under high pH conditions PFAS precursors transformation can be enhanced.

Incineration

- Only a few full-scale studies are available
- Operating temperatures: 700 – 1,200 °C
- At least some PFAS destruction will occur with incineration of biosolids
- An array of by-products is possible during thermal treatment, creating more PFAS
- Need to evaluate impacts of temperature, residence time and mixing (or turbulence)

Pyrolysis

- A recent study completed by Bioforcetech showed PFAS removal to non-detect levels in biochar and bio-oil in a system operating at 850 °C. No PFAS were detected in biochar and in the water scrubber that followed the pyrolysis chamber.
- One other study has also found removal of more than 91% of PFOS and PFOA from sewage sludge during pyrolysis at 500 °C.
- Pyrolysis gas can still contain a large portion of PFAS after pyrolysis.



Source: Williams et al. (2021)

Innovative biosolids processing technologies

Hydrothermal liquefaction

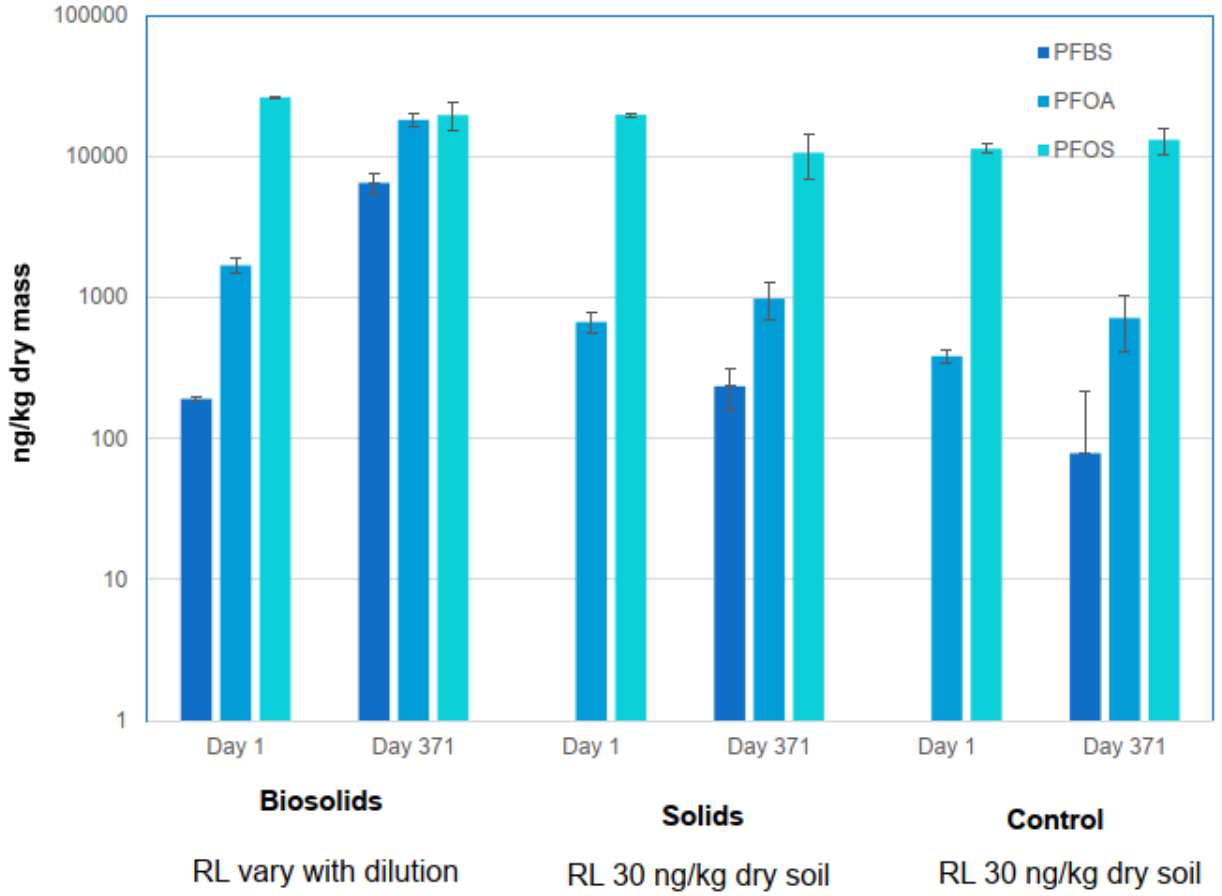
- Generates a liquid biocrude oil from dewatered sludge
- Bench-scale tests suggest some PFAS removal
- PFAS found in the bio-oil fraction suggesting PFAS precursor transformation

Supercritical water oxidation

- Water is heated above 374 °C and pressure of 221 bar, which corresponds to the supercritical stage
- Bench-scale tests found 99% destruction of 12 PFAS from a landfill leachate
- Pilot scale tests conducted in Maine showed 99% removal of PFOS and PFOA from lime-stabilized sludge.

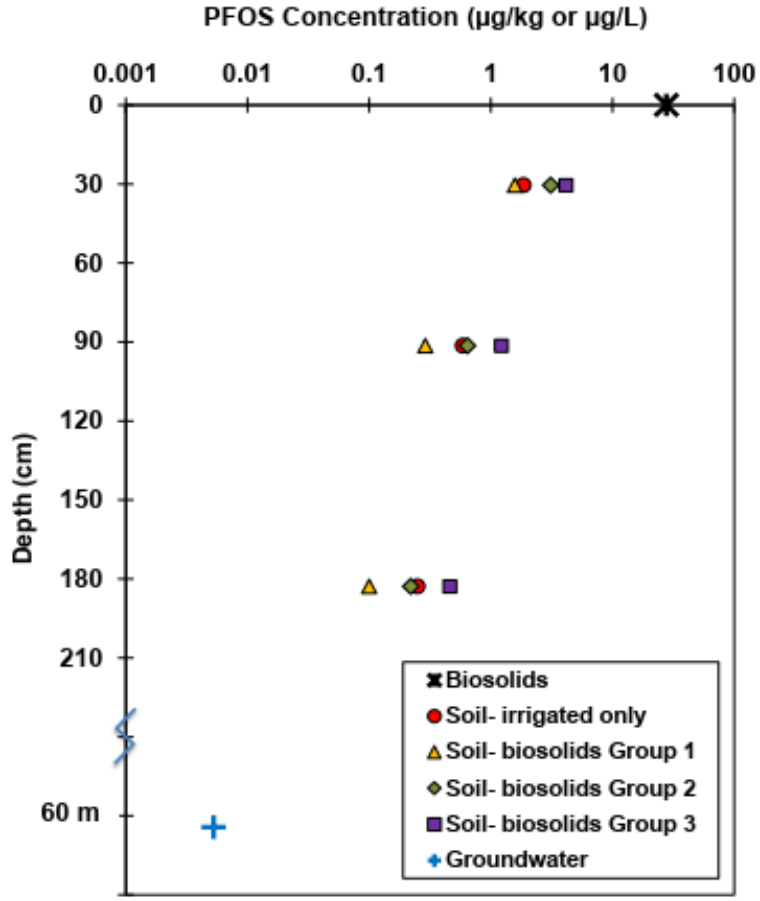
Land application of biosolids

US EPA Control Plot Study



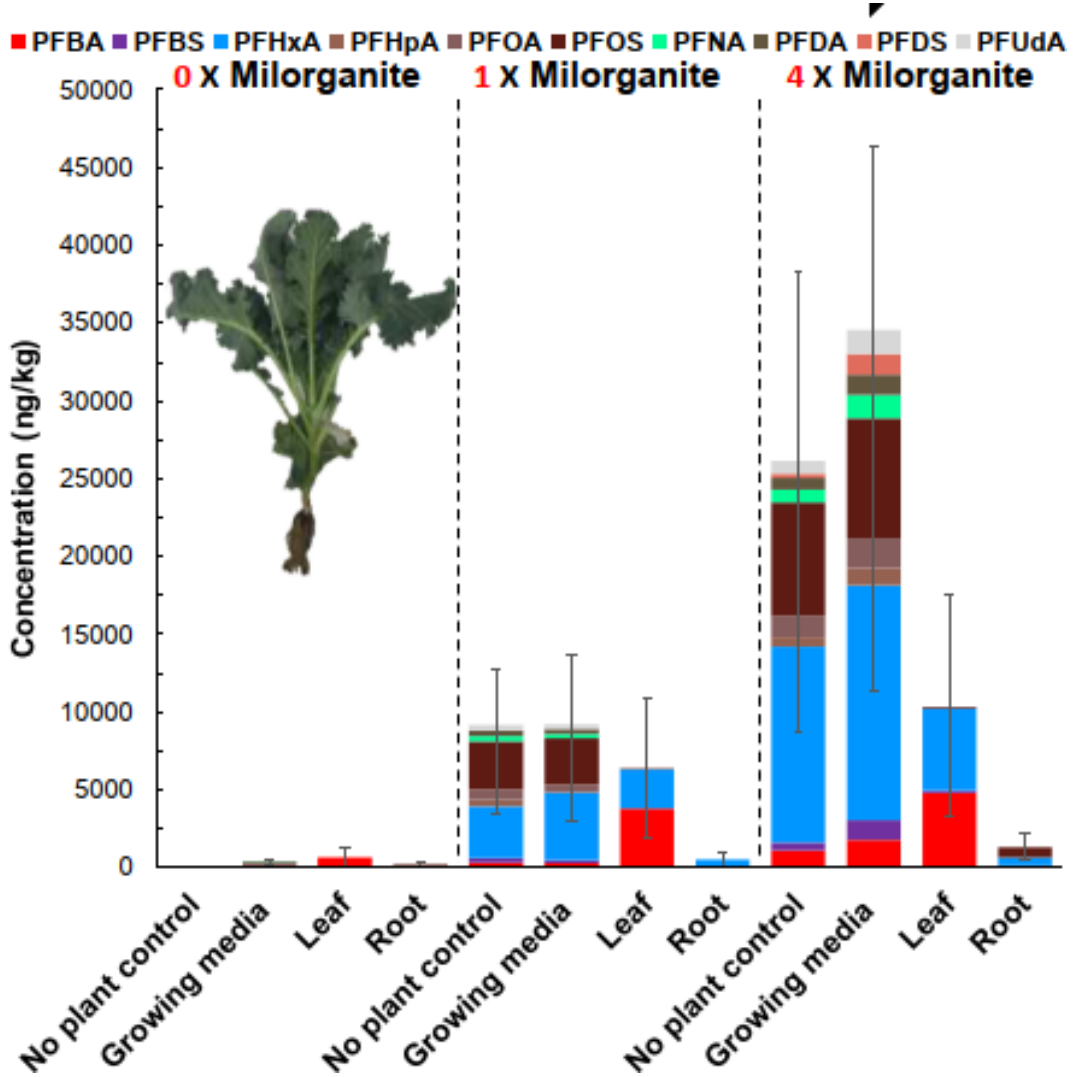
Source: US EPA (2020)

Arizona Field Study



Source: Ian Pepper (2022)

Plant uptake



- Short-chain PFAA (C4-C6) tend to accumulate or have greater uptake by plants
- Longer chains remain in growing media or are sorbed to roots
- Higher application rates lead to more accumulation and increased concentration in plants

Source: Lazcano (2019)

Why do we care?

- PFAS are forever chemicals, meaning… they are here forever
- Continued exposure above specific levels to certain PFAS may lead to adverse health effects
- WWTP are passive receivers of PFAS
- PFAS tend to concentrate during treatment and some compounds end-up in biosolids
- Biosolids can be land applied and there is a risk of both soil and water contamination

- Limit human exposure to potentially harmful levels of PFAS in the environment

What are the options?

- Do Nothing or…"Don't Look Up"!
- Banning biosolids will not work and could lead to unintended consequences:
  - Incineration – potential for by-products to be emitted to the atmosphere and be later deposited on soils and water
  - Landfilling – PFAS in leachate will return to the WWTPs
- Focus on mitigating risks and use source reduction to continue drive PFAS concentrations down
- Ban PFAS from use in food packaging, furniture, carpets, etc.
- Fund research efforts:
  - Mitigation and treatment options
  - Incidence in soil, assess mobility and crop uptake

Questions?

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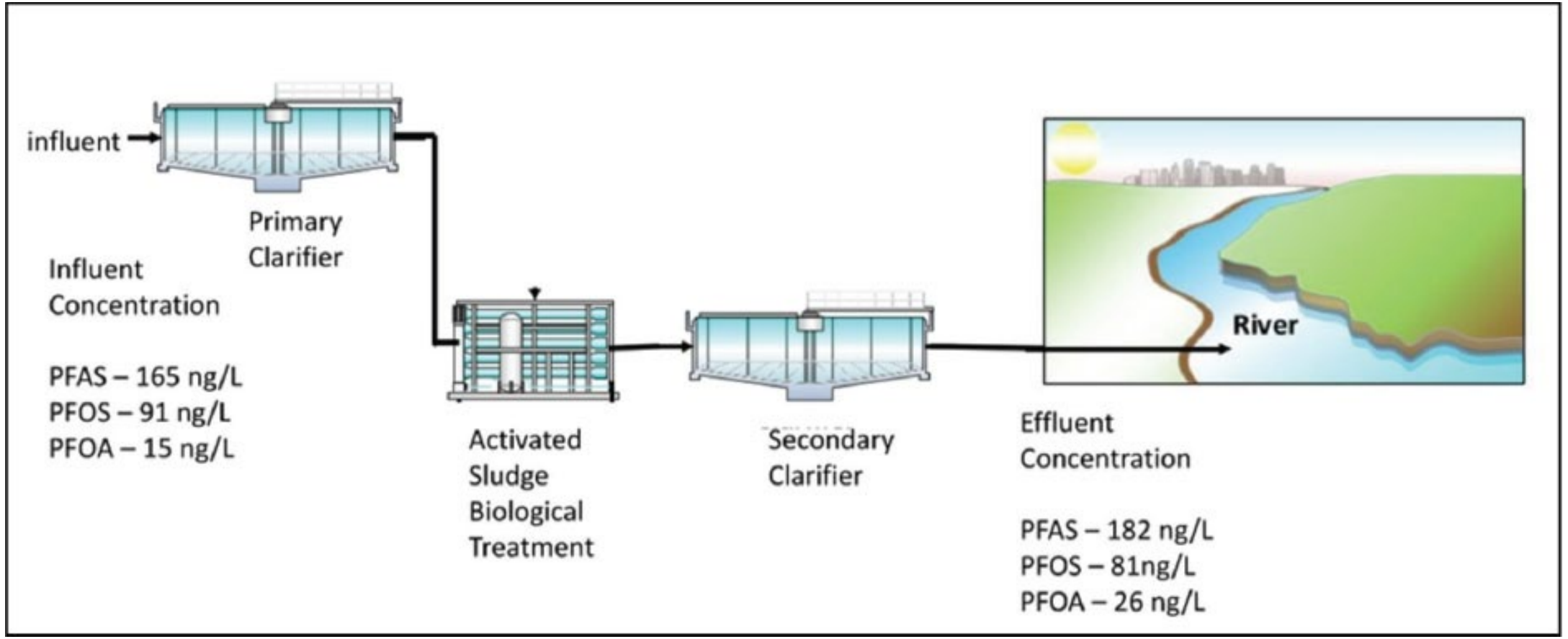
Typical PFAS "removal" at CAS plants



Source: WEF (2023), Michigan EGLE (2021)