

Per and Polyfluoroalkyl Substances (PFAS) Release from Carpet in Landfills

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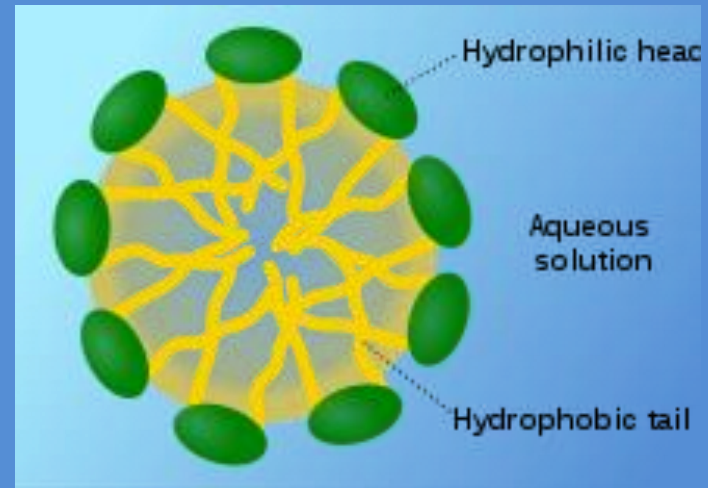
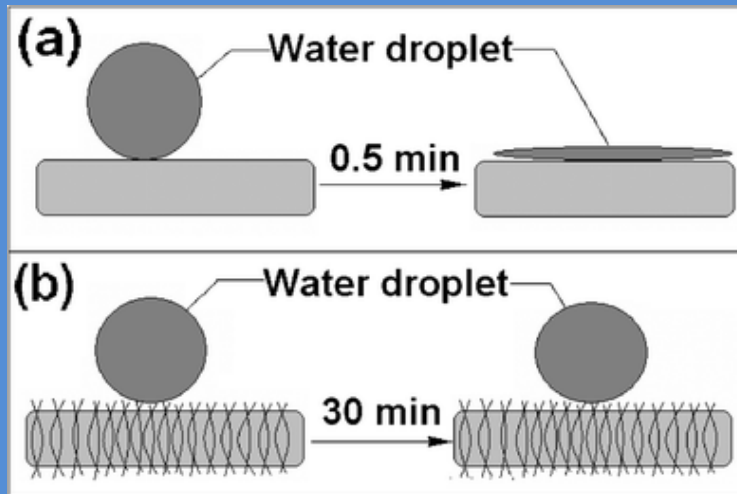
EPA Research Triangle Park, NC

Disclaimer

- This research was completed as my PhD. Dissertation from North Carolina State University (NCSU)
- The information presented here does not represent the official views and policy of the USEPA.
- No part of this presentation should be considered an endorsement or recommendation by the USEPA.

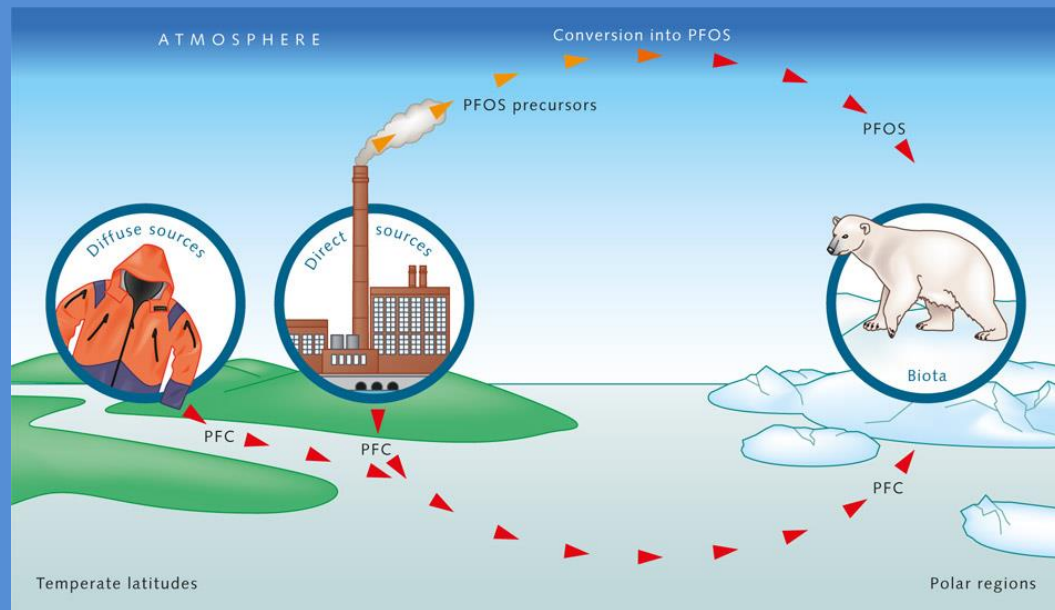
PFASs: Compounds with Carbon Fluorine Bonds

- Surfactants: Surface active compound that repels oil and water



PFASs: Compounds with Carbon Fluorine Bonds

- Nondegradable: The carbon fluorine (C-F) bond is extremely stable¹
- Bioaccumulative: Perfluorooctanoic acid (PFOA) $\frac{1}{2}$ life ~2.3 years in humans²
- Found in 98% of the US population's blood

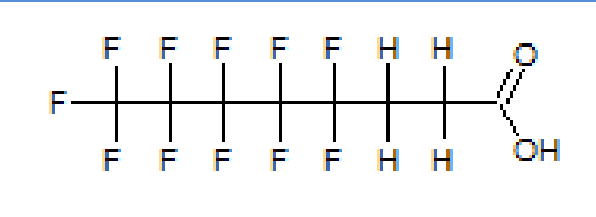
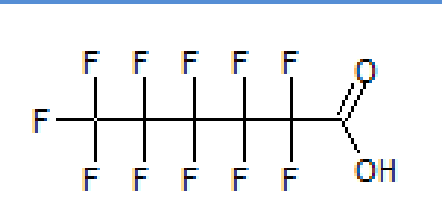
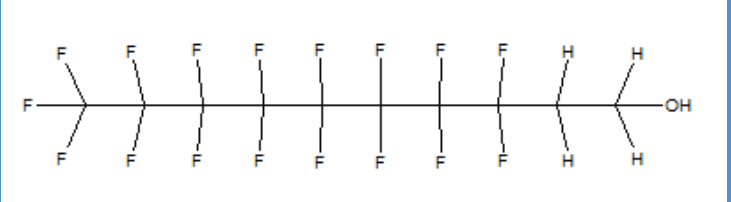
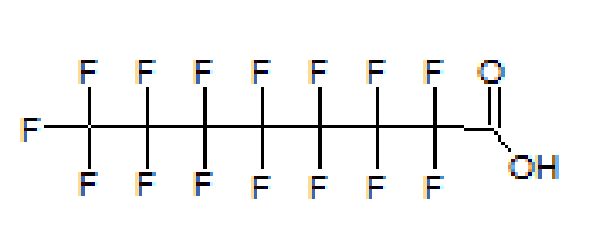


1 Smart, 1994

2 Health Effects Support Document for Perfluorooctanoic Acid (PFOA). EPA. May 2016

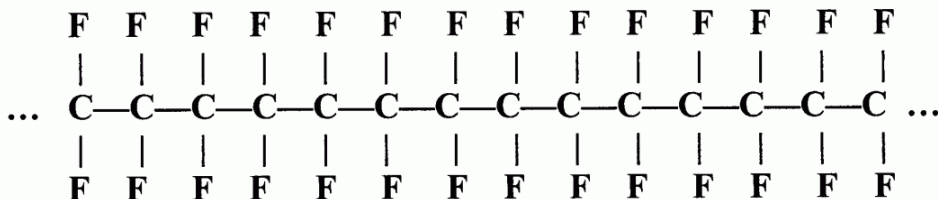
Chemistry and Acronyms of Monomers

- Monomers: a single fluorinated carbon tail
- Fluorinated tail: Hydrophobic
- Head group: Hydrophilic

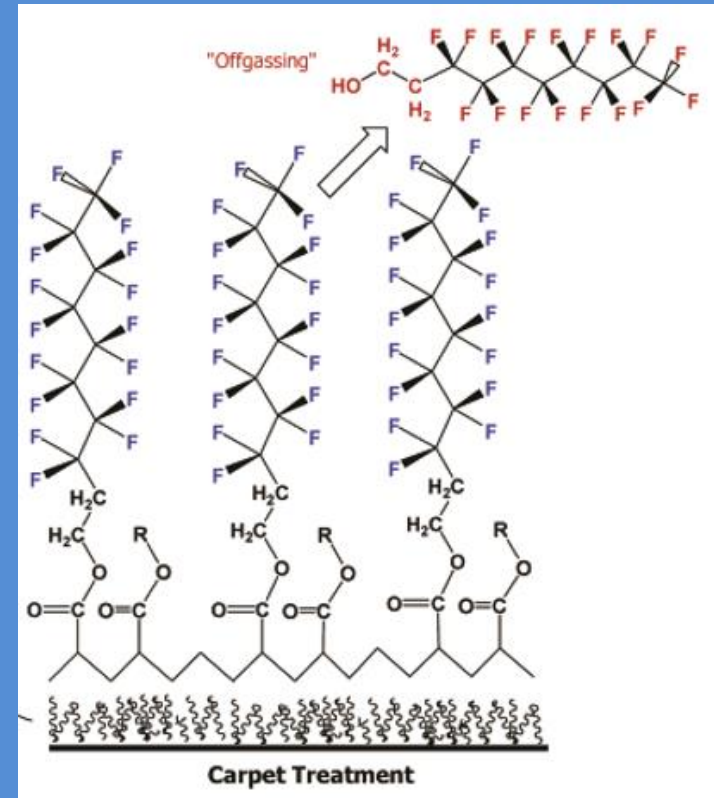
Polyfluoroalkyl Substances (degrades to perfluorinated substances)	Perfluoroalkyl Substances (non-degradable)
<p>5:3 Fluorotelomer Carboxylic Acid</p>  <p>The structure shows a chain of 8 carbon atoms. The first 5 carbons are fully fluorinated (5:3). The last 3 carbons are hydrogenated (3:0). The chain ends in a carboxylic acid group (-COOH).</p>	<p>Perfluorohexanoic Acid (PFHxA – C6)</p>  <p>The structure shows a chain of 6 carbon atoms, all of which are fully fluorinated. The chain ends in a carboxylic acid group (-COOH).</p>
<p>8:2 Fluorotelomer Alcohol</p>  <p>The structure shows a chain of 10 carbon atoms. The first 8 carbons are fully fluorinated (8:2). The last 2 carbons are hydrogenated (2:0). The chain ends in a hydroxyl group (-OH).</p>	<p>Perfluorooctanoic Acid (PFOA – C8)</p>  <p>The structure shows a chain of 8 carbon atoms, all of which are fully fluorinated. The chain ends in a carboxylic acid group (-COOH).</p>

PFASs on Products

- PFASs on products (i.e. carpet and non-stick pans) are fluoropolymers, not monomers
- Monomers can exist as a residual of manufacture
- Previous Major Unproven Assumption in Global Models: Fluoropolymers are considered recalcitrant and releases are zero (Wang et al. 2014)



TEFLON polymer (segment)



PFAS and Your Health

- The toxicology of PFOA and PFOS has been thoroughly researched, but there are hundreds of other PFASs being used on products and emitted as industrial waste with no toxicology data
- Human epidemiology PFOA Studies:
 - High cholesterol
 - Increased liver enzymes
 - Decreased vaccination response
 - Thyroid disorders
 - Pregnancy-induced hypertension and preeclampsia
 - Cancer (testicular and kidney)

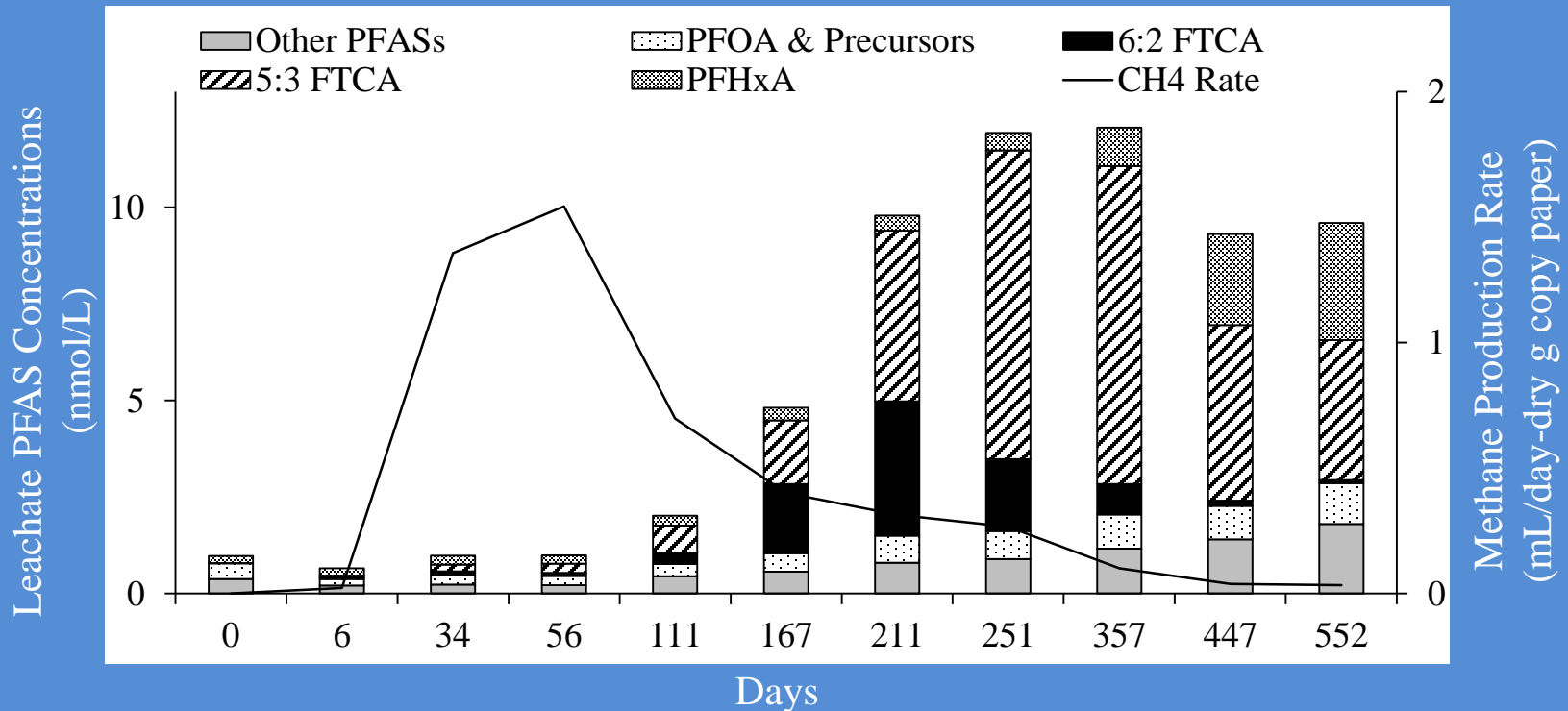
Physical and biological release of PFASs in laboratory-scale anaerobic bioreactors filled with carpet

ES&T 2016. 50, 5024–5032.



Objective: To measure aqueous phase concentrations of 70 PFASs released from carpet and clothing over time (>500 days)

PFAS Release Live Carpet Reactor



- The lag period (>100 days) before the majority of PFAS release indicates the source of release may not be limited to residual monomers
- 5:3 fluoroelomer carboxylic acids (FTCAs) are perfluoroalkyl precursors not commonly used on products

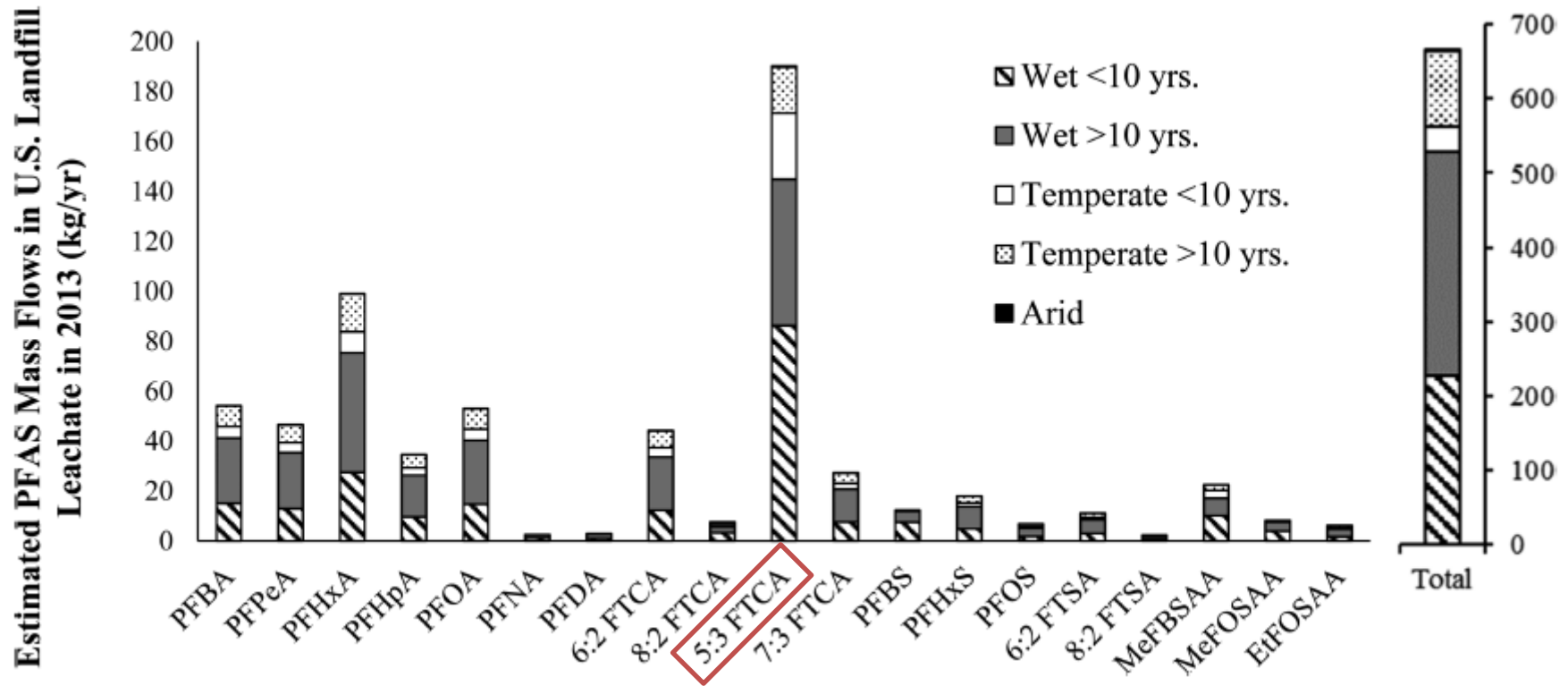
National Estimate of PFAS Release to U.S. Municipal Landfill Leachate

Concentrations of 70 PFASs in 95 samples of leachate were measured in a survey of U.S. landfills of varying climates and waste ages

ES&T, 2017, 51 (4), pp 2197–2205



PFAS Release from U.S. Landfills to WWTPs for waste landfilled in 2013



- Similar to carpet reactors, 5:3 FTCA a major component of total PFAS release in landfill leachate
- Total PFAS release for the US in 2013 is estimated at ~650 kg/yr

Landfill Conclusions

- Carpet releases PFASs to landfill leachate
- PFCA precursors contribute significantly to total PFAS release from landfilled carpet
- Release is Slow: The majority of PFAS release did not occur until >100 days of operation in model landfill carpet reactors
- The mass of PFAS released yearly for a single year of municipal waste (650 kg/yr) is small relative to industrial sources but may continue at low levels for many years

Questions?