PER- & POLYFLUOROALKYL SUBSTANCES (PFAS) FATE & TRANSPORT

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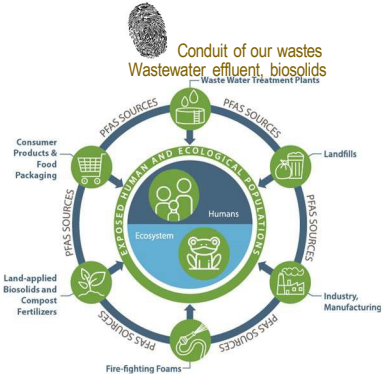

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Indiana Water Summit
August 21-22, 2024

PFAS USED IN MANY PRODUCTS & PROCESSES

Industries & Infrastructures	Products
• Municipal water and waste treatment • Industrial manufacturing of PFAS • Oil and gas operations • Metal plating and coating • Aviation and transportation fire extinguishing	• Water, oil, and stain-resistant textile • Floor coatings and cleaners • Food wrappers • Personal care products • Aqueous Film-Forming Foams (AFFFs)

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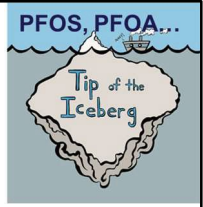
EPA April 10, 2024 PFAS MCLs in ppt (ng/L)



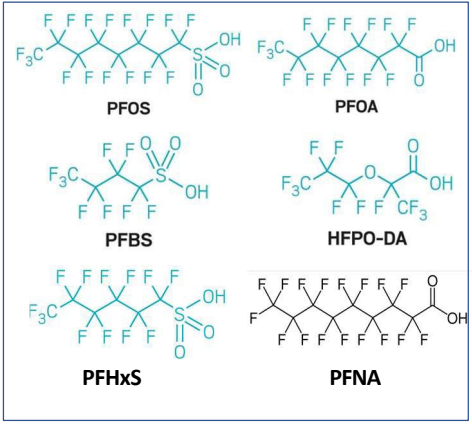
PFAS	MCLG	MCL (enforceable levels)
PFOA (C8)	Zero	4.0 ppt
PFOS (C8)	Zero	4.0 ppt
PFNA (C9)	10 ppt	10 ppt
PFHxS (C6)	10 ppt	10 ppt
PFBS (C4)	1000 ppt	1000 ppt
HFPO-DA (GenX Chemicals)	10 ppt	10 ppt
Mixtures of 2 or more PFNA, PFHxS, PFBS, and HFPO-DA	1.0 (unitless) Hazard Index Σ MCL/measured concentration	

MCLG = maximum contaminant level goals

Poly- $CF_3CF_2CF_2CF_2CF_2CF_2CH_2CH_2SO_3^-$

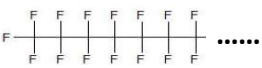
6:2 Fluorotelomer sulfonate (6:2 FTS)

Per-



Per- & Polyfluoroalkyl Substances (PFAS) – A Large Family

Currently
> *10,000* PFAS produced



- Contain a perfluoroalkyl chain of varying length
- Numerous subclasses
  - each with a unique differentiating characteristic
  - each with several different perfluoroalkyl chain lengths
- An individual PFAS may have multiple isomers (linear versus different types of branching)

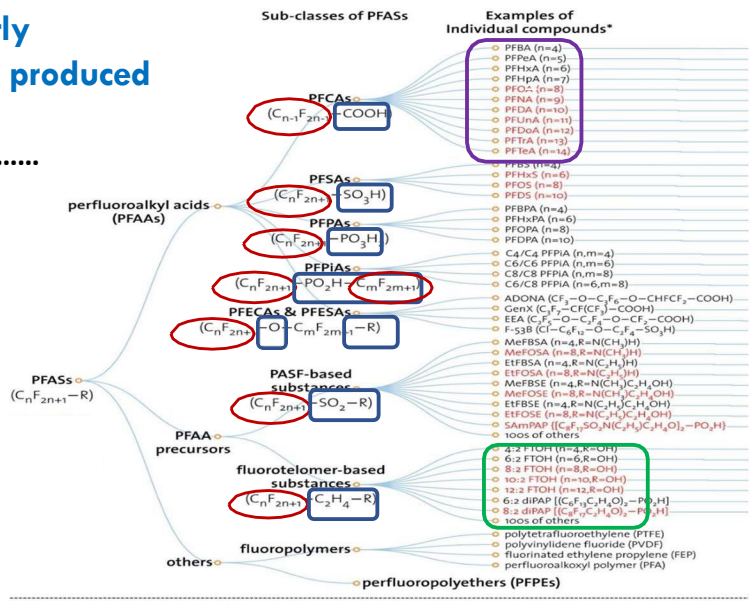
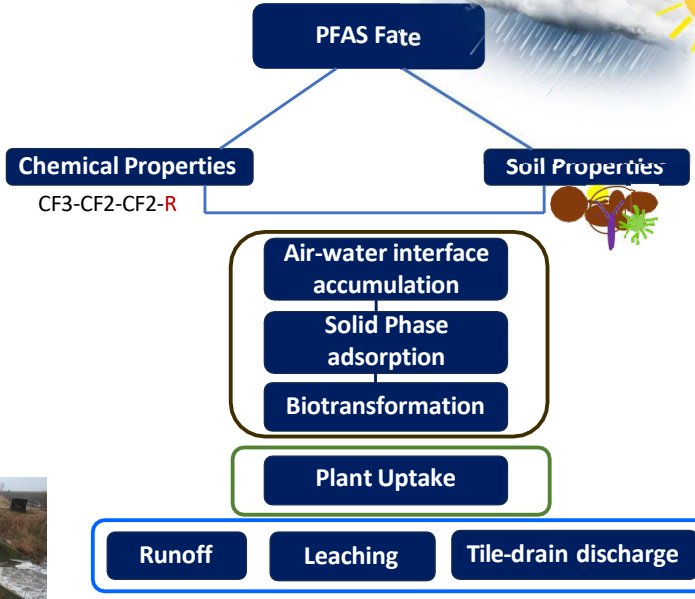


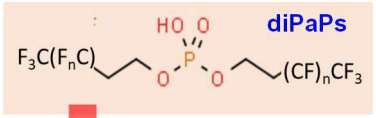
Figure modified from Wang et al., 2017, ES&T, 51:2508-2518

PFAS Fate ONCE LAND APPLIED

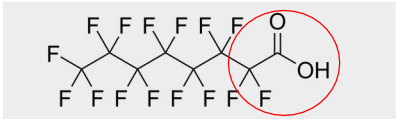


PFAS TRANSFORMATION IN SOLIDS PROCESSING AND AFTER LAND APPLICATION: A CASE OF MULTIPLICATION

Telomer-based PFAS Example



Intermediates



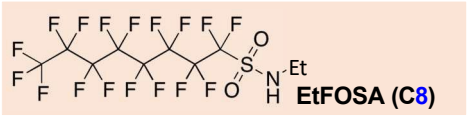
Perfluoroalkyl carboxylic acids (PFCAs) e.g., PFOA plus others

Precursors to PFAAs

Multiple steps, pathways, and rates

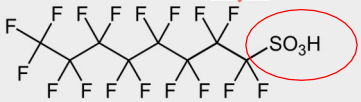
Intermediates and Terminal Metabolites (the PFAAs) More mobile than precursors

Electrochemically-derived PFAS Example



EtFOSA (C8)

Intermediates

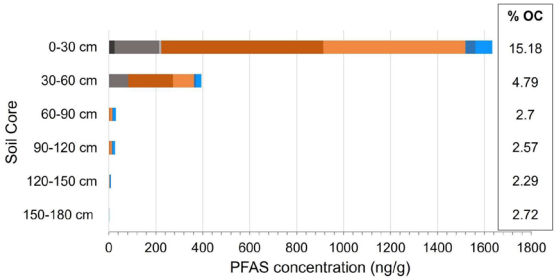


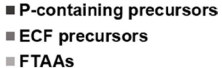
C8, PFOS

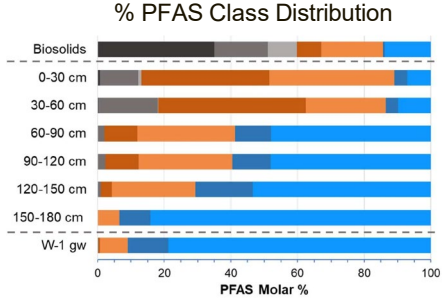
Perfluoroalkyl sulfonic acid (PFSA)

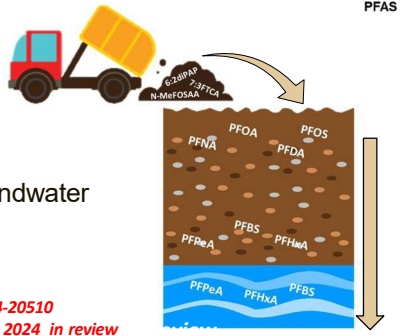
PFCAs + PFSAs = Perfluoroalkyl acids (PFAAs)

40-y Dedicated Land Disposal Site (Western USA)









- Most precursors breakdown to PFAAs within 1 year
- Long-chain PFAS retained in the upper soil profile
- Short-chain PFAAs dominate what is getting to groundwater
- Interestingly, only PFOA exceed new EPA MCLs

EPA United States Environmental Protection Agency

THE Water Research FOUNDATION

Do not cite; STOTEN-D-24-20510 manuscript Alvarez et al. 2024 in review

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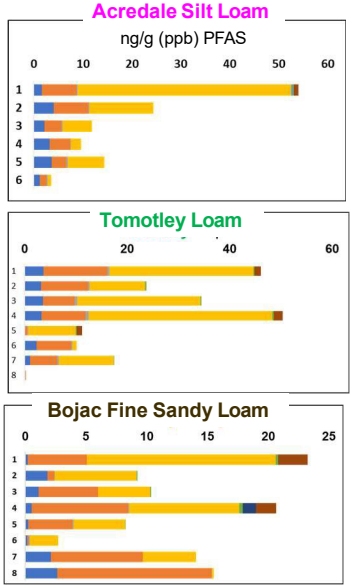
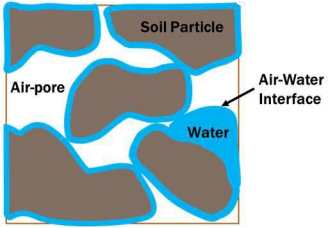
Biosolid-applied Agricultural Sites

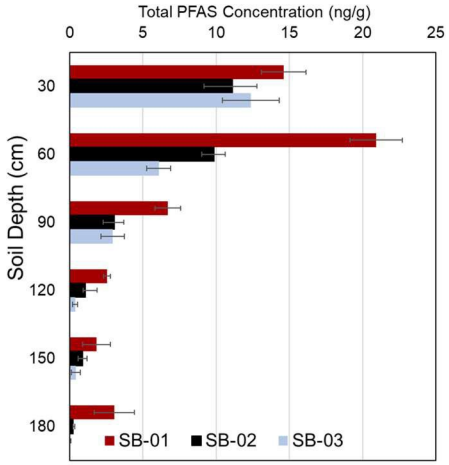
East Coast Farm (2 app decades)



- Short chain PFCAs
- Long chain PFCAs
- Short chain PFSAs
- Long chain PFSAs
- P containing FT precursors
- Sulfonamides
- Sulfonamidoacetic acids
- Sulfonamido ethanols



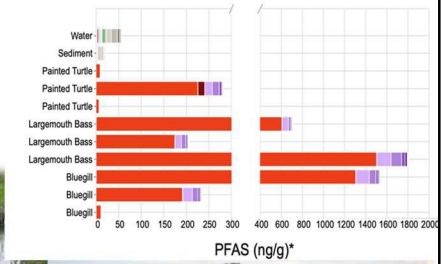
Midwest Farm (4 app decades)



- Precursors degrade – most (not ECFs) within 1-y post land application
- Long-chain PFAS retained in the upper soil profile
- Finer texture soil, greater retention to soil particles & air-water interface
- Short-chain PFAS less sorption to soil and AWI, thus higher mobilization and availability for plant uptake

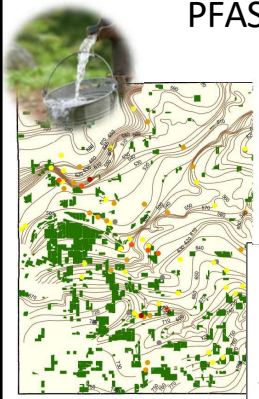
Do not cite, Manuscripts Peter et al Klamerus et al in process

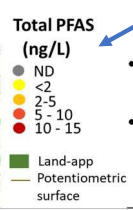
What about Impact of RUNOFF from Land-Application?



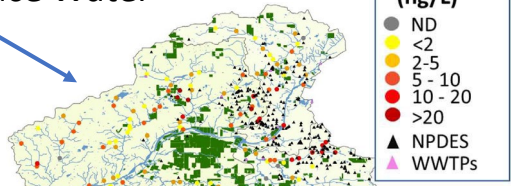
With high PFAS retention in surface soils, runoff into streams, wetlands, and farm ponds may be a significant PFAS exposure pathway to fish, wildlife, and grazing cattle, and subsequently, humans.

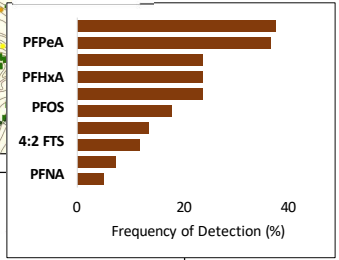
Indiana: Greater Tippecanoe County: PFAS in Rural Water Supplies & Surface Water

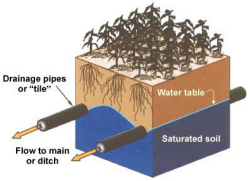


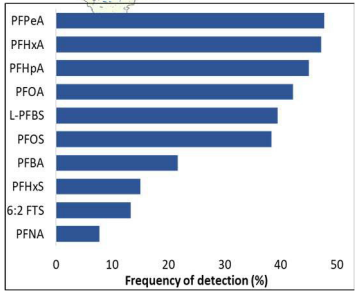


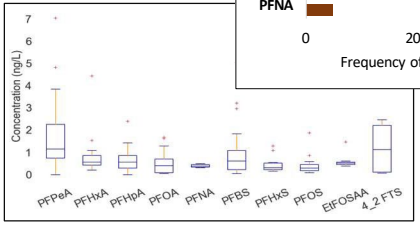
- Major sources: agricultural, industrial and WTTP discharges
- Most agriculture fields are tile-drained











- PFAS detected in 88% of surface water samples.
- 20 PFAS detected in surface water with highest concentration 85 ng/L PFBS (C4).

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Manuscript Peter et al., 2024 in process

EPA United States Environmental Protection Agency