PFAS in Landfills: Garbage In, Garbage Out

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Agenda

- Background
- PFAS Cycle & Landfills
- Garbage In: Inputs into Landfills
- Transformation & Fate inside Landfills
- Garbage Out: Outputs from Landfills
- Concerns & Regulatory Issues
- Summary & Path Forward

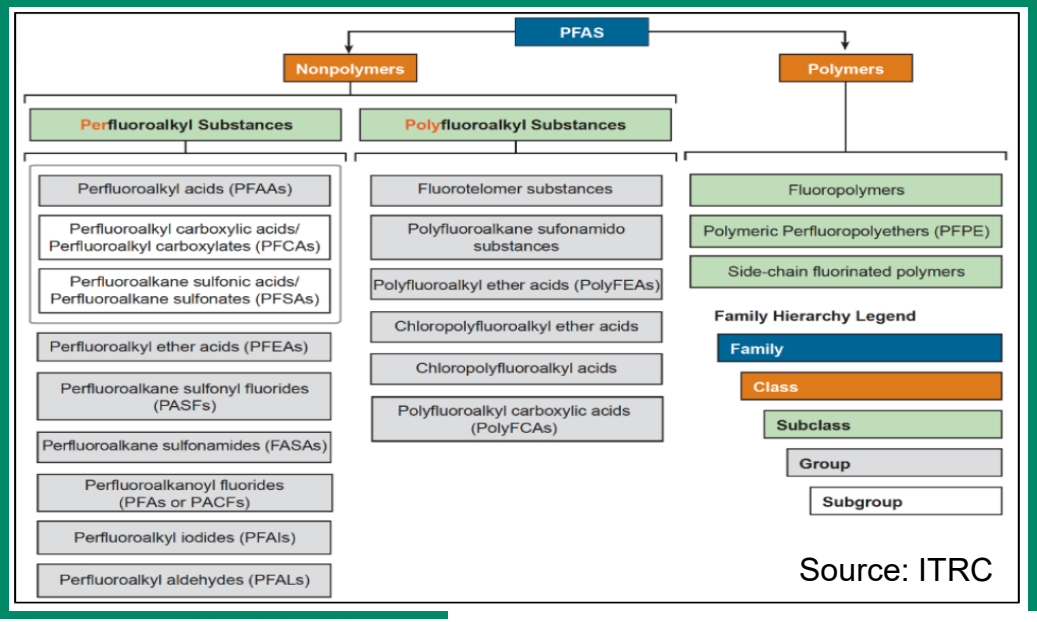
Background

What are PFAS?

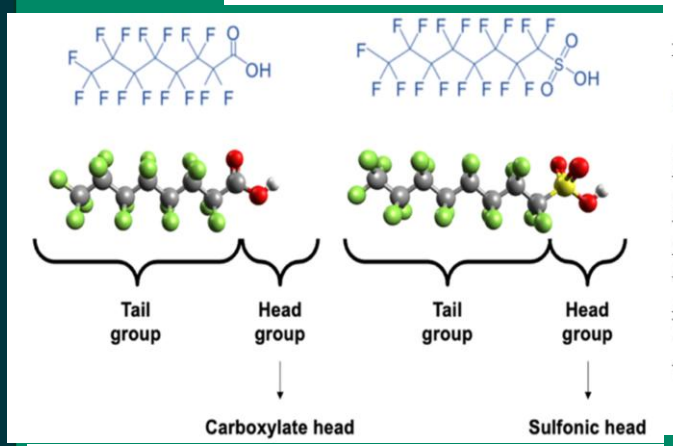
- 1000s of compounds exist
- Characterized by C-F chain length & functional head group (e.g., SO_4, CO_2)
- C-F Bond extremely strong
- Incredibly useful, durable, and versatile

- Resistant to degradation
- Often transform between PFAS species (e.g., poly→per, long→short)
- Individual monitoring & evaluation difficult
- Highly mobile (short-chain)

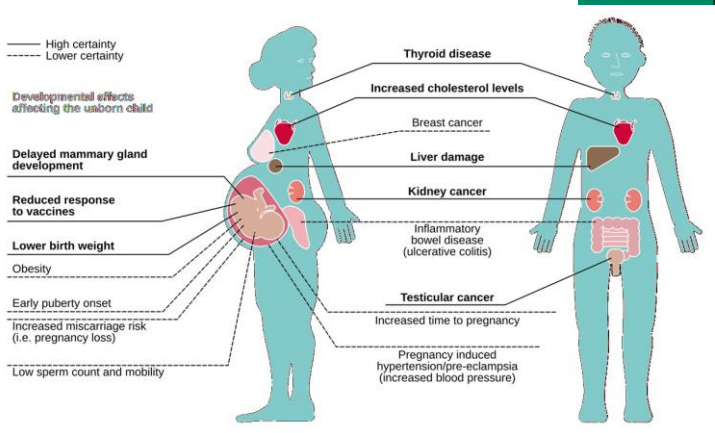
- Persistent and bioaccumulative
- Suspected negative health impacts
- Impacts at very low concentrations



Source: ITRC



Source: Meedgoa et al. (2022). DOI: 10.3390/ijerph192416397

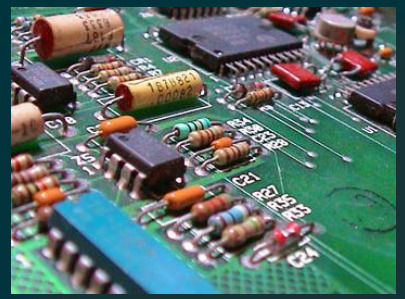


Source: European Environment Agency, Wikimedia Creative Commons

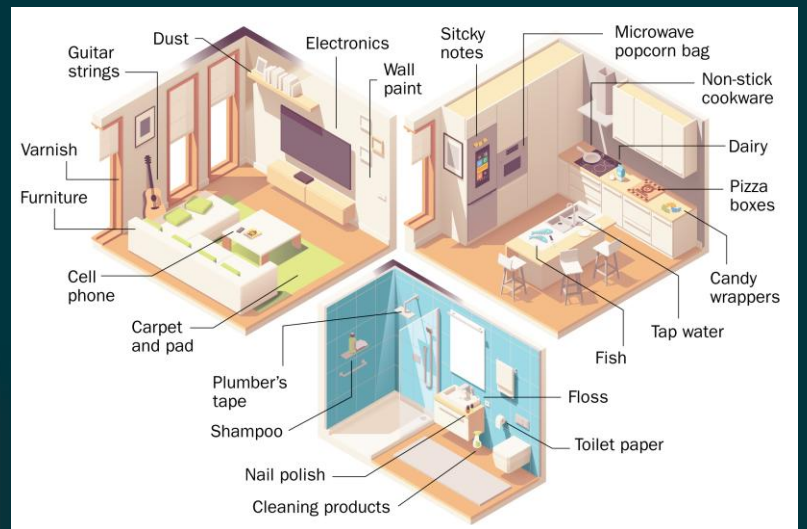
PFAS	Short-Chain	Long-Chain
PFCAs	4-7	8-12
PFSA	4-5	6-12

PFAS Sources and Uses

Food Packaging



Electronics



Source: Time Magazine (2023) All The Stuff in Your Home That Might Contain PFAS 'Forever Chemicals'

Houseware and furnishings

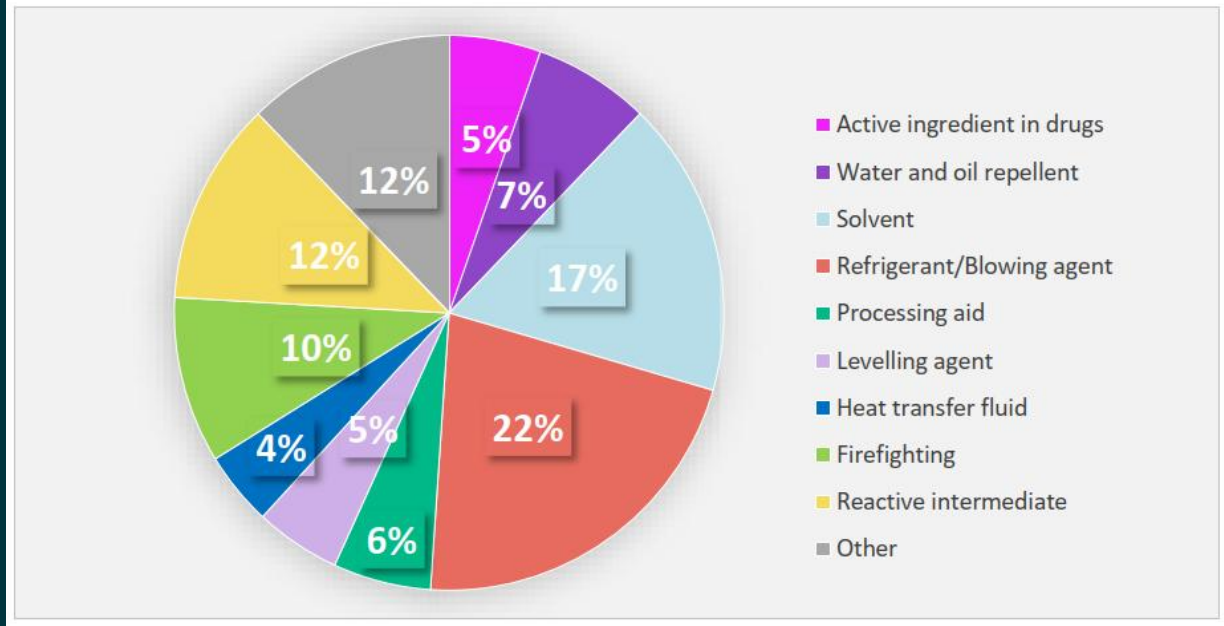


Figure 1. Uses of chemical PFAS notified under the NSNR since 1994. Percentage of total notified uses for notifications.

Source: Environment and Climate Change Canada / Health Canada - (2023) Draft state of per- and polyfluoroalkyl substances (PFAS) report

Cosmetics and Pharmaceuticals

Aqueous Film Forming Foam

Defense

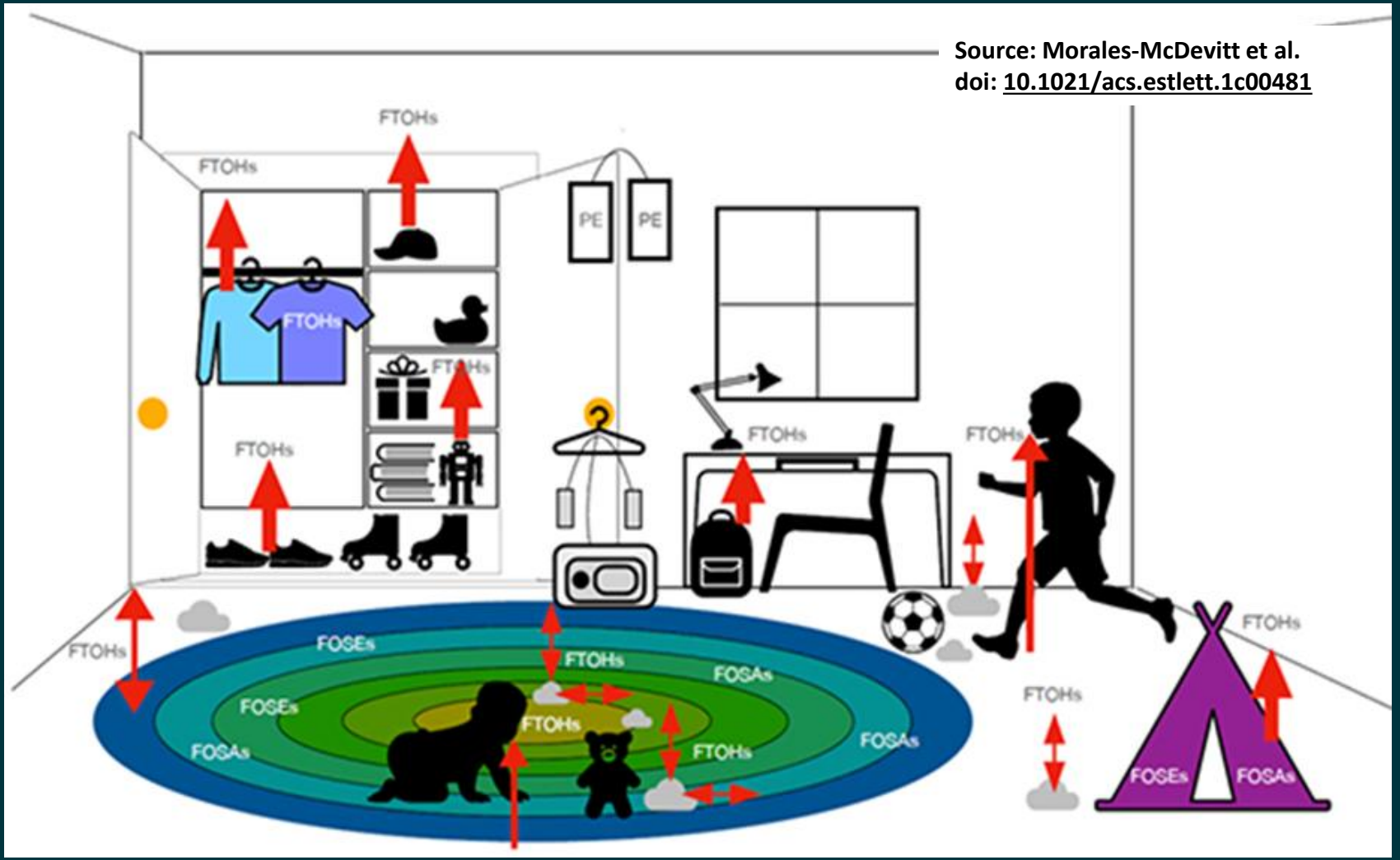
Oil & Gas

Transportation

Manufacturing

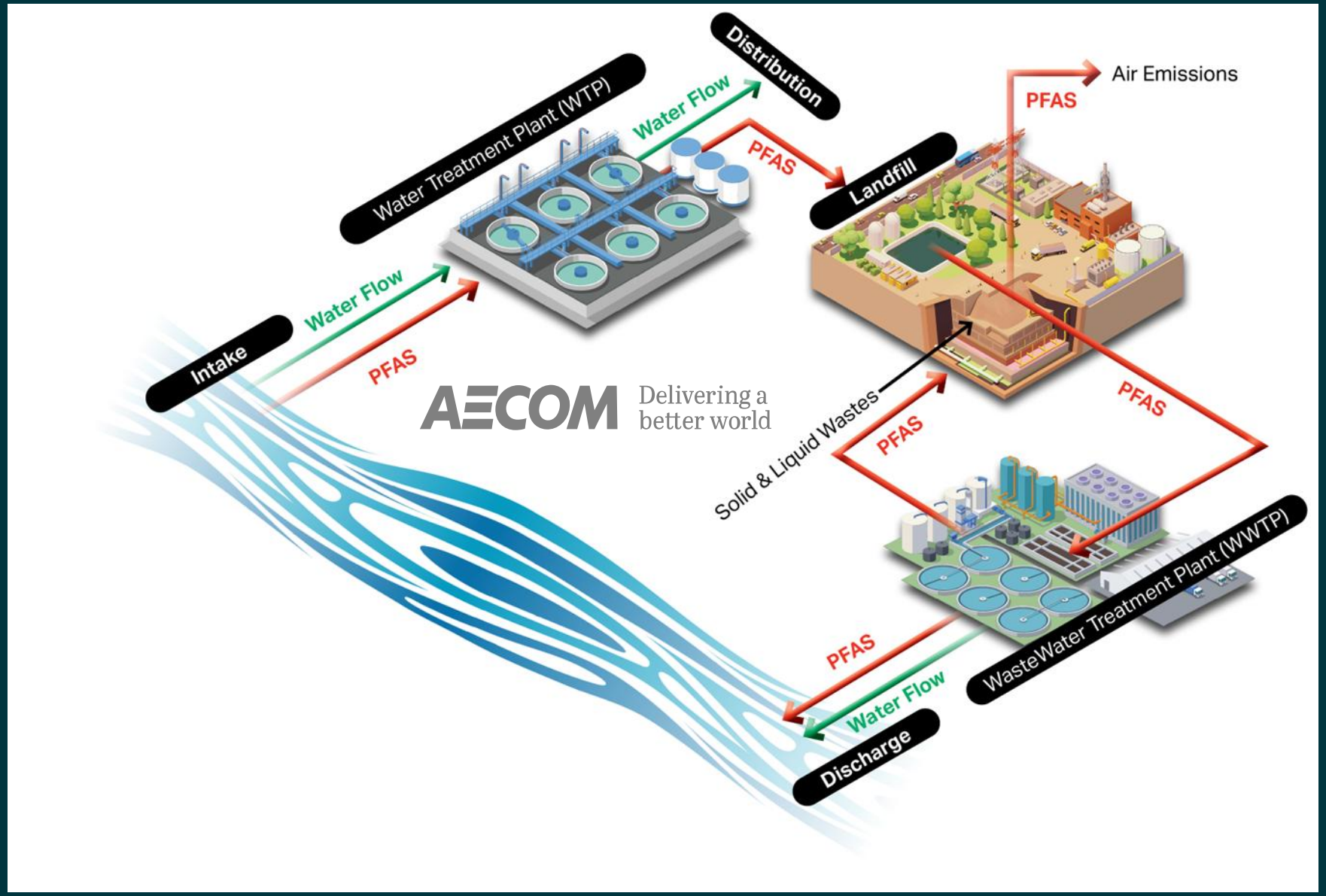
Source (All Other Images): Creative Commons

What are some concerns around airborne PFAS



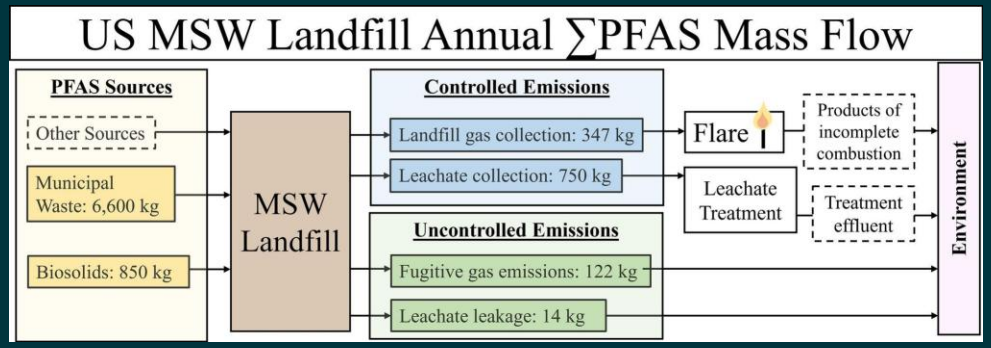
- Consumer and industrial products lead to household exposures
- Inhalation pathways not yet quantified for exposure risk evaluation
- Exposures from atmospheric PFAS require further research

PFAS Cycle


Distribution
Water Treatment Plant (WTP)
Water Flow
PFAS
Air Emissions
PFAS
Landfill
Intake
Water Flow
PFAS
AECOM
Delivering a better world
Solid & Liquid Wastes
PFAS
PFAS
PFAS
WasteWater Treatment Plant (WWTP)
PFAS
Water Flow
Discharge

Garbage In:
PFAS Inputs into Landfills

- Consumer Goods: Non-stick cookware, waterproof textiles, food packaging
- Industrial/Commercial Sources: Industrial waste, firefighting foams, wastewater treatment sludge, contaminated drinking water treatment residuals, etc.
- Construction and Demolition Debris: Stain-resistant carpeting, adhesives, insulation, etc.
- 7.5 metric tons of PFAS enter US landfills annually (Tolamat et al., 2023 Estimate)



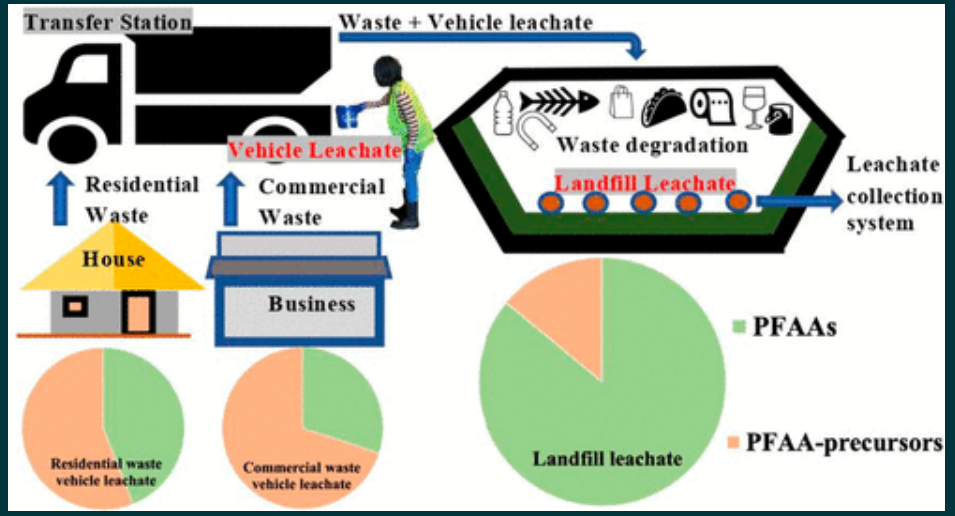
Source: Tolamat et al. (2023)
https://www.sciencedirect.com/science/article/abs/pii/S0048969723058126

Source: PFAS Circle (2025) / Henning Larsen

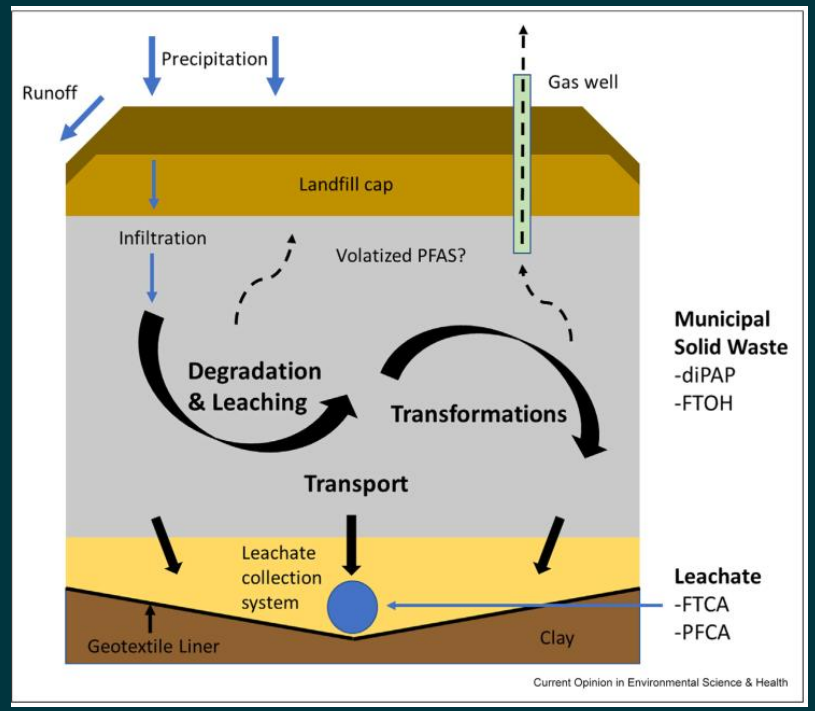
PFAS Fate and transformation

- Analytical gap: TOP, TOF, Non-target analysis
- MSW: diPAP and FTOHs
- Leachate: FTCAs and PFCAs
- FTOH to FTCA to PFCA?
- Final products and perfluorinated compounds
- WWTP transforming conditions: PFAS Increase?

MSW – Municipal solid waste
DiPAP – Polyfluoroalkyl Phosphoric Acid Diesters
WWTP - Wastewater treatment plant
TOP – total oxidizable precursors assay
TOF – total organic fluorine
FTOHs - fluorotelomer alcohols
FTCA - fluorotelomer carboxylic acid
PFCA - perfluorocarboxylic acid



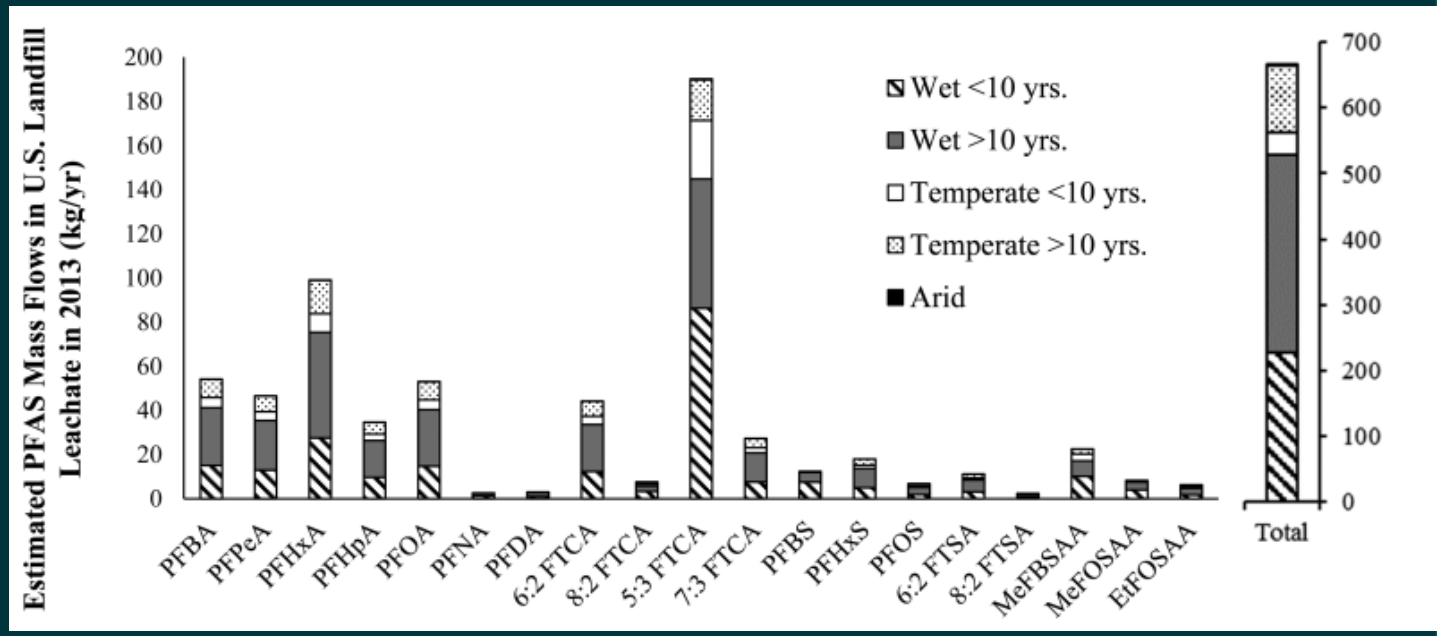
Source : Liu et al. (2023)
Environ Sci Technol Lett. 2021 ; 8: 66–72.



Source : Coffin et al. (2023)
Curr Opin Environ Sci Health, 31 (2023), Article 100418

Garbage out: PFAS in Leachate

- US Study based on 95 samples from 18 landfills
- Arid, temperate and wet regions
- Primarily receiving MSW and in some cases biosolids
- Estimate of 563-638 kg PFAS in 2013
- Assuming 61.1 million m^3 (Mm^3) of US generated leachate
- 5:3 FTCA dominant
- High variations depending on:
  - Waste age
  - Climate

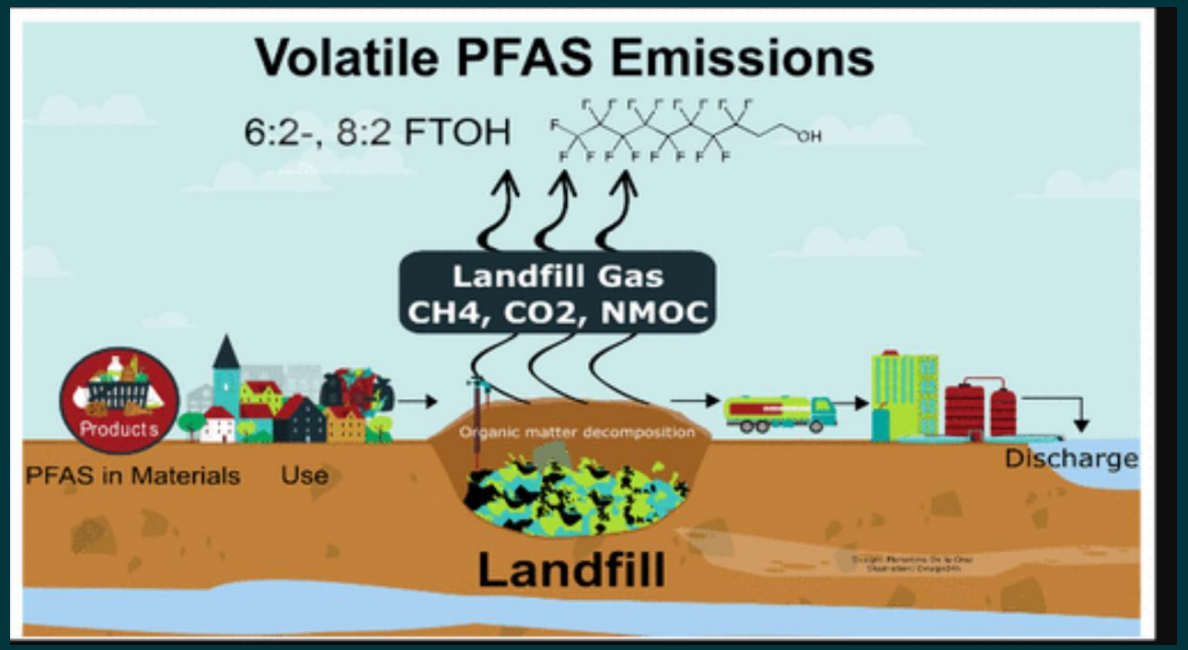


Source : Lang et al. (2017)
Environ. Sci. Technol. 2017, 51, 4, 2197–2205

Garbage out: PFAS Emissions in Landfill Gas (LFG)

- US Study based on 30 landfills in 17 states
- Arid, moderate and wet regions
- Dominance of FTOH (6:2 and 8:2) - median concentration of 19,000 ng/m^3.
- Estimate of 836 kg/yr of volatile PFAS in uncollected gas
- Assuming the annual volume of LFG :
  - Treated: 2.18 × 10^4 Mm^3
  - Released as fugitive emission 2.30 × 10^4 Mm^3
- PFAS release mechanisms
  - Off-gassing
  - Biotic and abiotic transformation of SCFP
- Factors influencing PFAS emissions:
  - Precipitation
  - Temporal site-specific factors
  - Spatial site-specific factors

FTOHs - fluorotelomer alcohols
SCFP - side chain fluoropolymers



Source : De La Cruz et al. (2025) https://pubs.acs.org/doi/pdf/10.1021/acs.est.5c08763?ref=article_openPDF

Existing Canadian Regulatory Limits – Highlights

- Most regulations were for specific PFAS
- PFOS, PFOA and LC-PFCA most regulated
- **Objective** for Canadian drinking water quality- PFAS 30 ng/L for 25 PFAS listed in US EPA method 533
- Quebec introduced a new management code for the use of fertilizing residuals including 13 PFAS to be monitored
- Canadian Food Inspection Agency (CFIA) PFAS interim standard in commercial biosolids marketed as a fertilizer at 50 ppb (µg/kg) of PFOS

Media	Federal	Atlantic (NB, NL, NS, PE)	British Columbia	Quebec	Saskatchewan
Surface Water (µg/L)	Ecological PFOS – 7	PFOS – 6.8	Drinking Water PFOA – 0.2 PFOS – 0.3 PFBS – 80	Human Health PFOA – 0.066 PFOS – 0.011 Aquatic Organisms PFOA – 0.17 PFOS – 0.012 FAV PFOA – 15,000 AMV PFOA – 7,700 FCV PFOA – 880 PFOS – 6.8	Potable PFOS – 0.6 Freshwater Aquatic PFOS – 6.8 Livestock Water PFOS – 60
Biosolids (mg/kg)	Canadian Food Inspection Agency Interim Standard : PFOS – 0.05				
Drinking water (µg/L)	Health Canada - Canadian Drinking Water Objective				
	Objective (not a guideline) Sum of 25 PFAS – 0.03	MACs PFOA – 0.2 PFOS – 0.6	Screening Values PFBA – 30 PFBS – 15 PFHxS – 0.6 PFPeA – 0.2 PFHxA – 0.2 PFHpA – 0.2 PFNA – 0.02		

Data Aggregated by AECOM

Evolving Canadian Regulatory Limits – Highlights

- National Pollutant Release Inventory
  - New guide 2025-2027, includes PFAS
  - PFAS-specific guide to support
  - 163 PFAS and PFAS salts and precursors listed on the NPRI substance list
- Change of approach, PFAS as a class
- PFAS restrictions in goods (Canadian risk management approach, 2025)
- Regulations are rapidly evolving
- List of PFAS to monitor growing
- Quebec to introduce mandatory PFAS monitoring in landfills for leachate
- Utilities must remain dynamic and prepared

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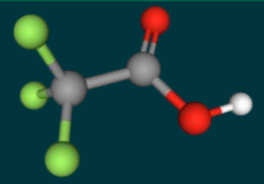
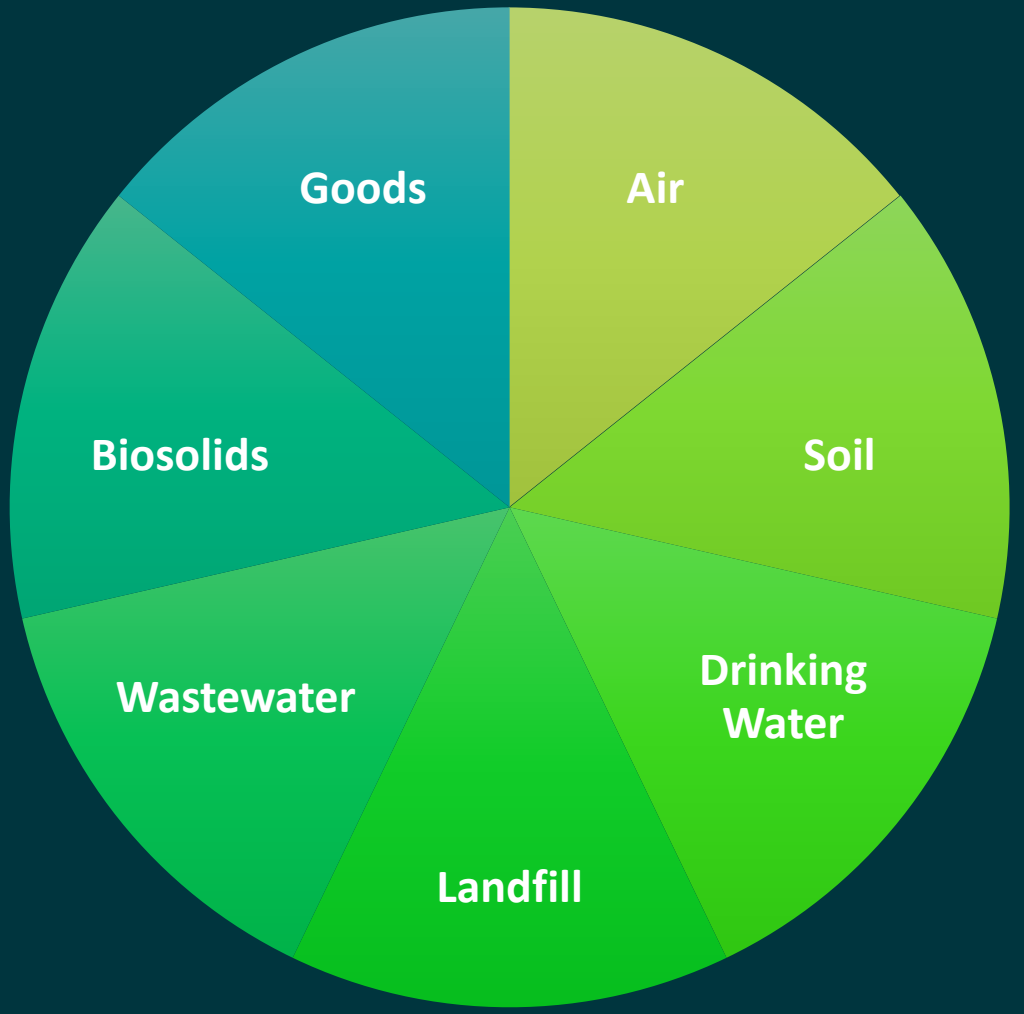
Data Aggregated by AECOM

Regulating throughout the PFAS cycle



Restrictions in manufacturing

Volatile sources in goods
Air monitoring



Biosolids reuse under scrutiny

Airborne deposition creates ambient background
Soil limits for protection of groundwater

Monitoring wastewater

Infiltration from soil to groundwater
Groundwater discharge to surface water
Drinking water restriction

Disposal releases PFAS into leachate and Landfill Gas

Conclusions

- ✓ PFAS are an issue for landfills because:
  - ✓ Diverse and significant PFAS sources in solid waste
  - ✓ Transformation might occur inside landfills
  - ✓ What you put in is not necessarily what you get out

- ✓ Unknown factors:
  - ✓ Risks for humans and the ecosystems are not fully understood and still being assessed
  - ✓ Difficult to quantify and identify
  - ✓ Amount in leachate and transfer from solid waste to leachate and site-specific environmental factors
  - ✓ Air emissions being overlooked as an emission point and hard to identify as a source : getting more attention

- ✓ Everchanging regulatory environment and public attention

Tackling the PFAS challenge

- ✓ PFAS are an issue for landfills because:
  - ✓ Identifying potential sources : know what you put in
  - ✓ Use the right analyses (TOP, TOF, Non-targeted, etc.)
  - ✓ Assess all exiting media

- ✓ Unknown factors:
  - ✓ Scientific based approach of risk assessment
  - ✓ Adequate and professional sampling and data acquisition methods
  - ✓ Modelling and using appropriate tools from experts
  - ✓ Start collecting data

- ✓ Being proactive and having a good communication plan before issues emerge

- ✓ The water cycle is a … cycle!

Questions?

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