The Trouble with PFAS

Challenges in the Assessment of Uptake and Exposure to Perfluoroalkyl Substances at Contaminated Sites

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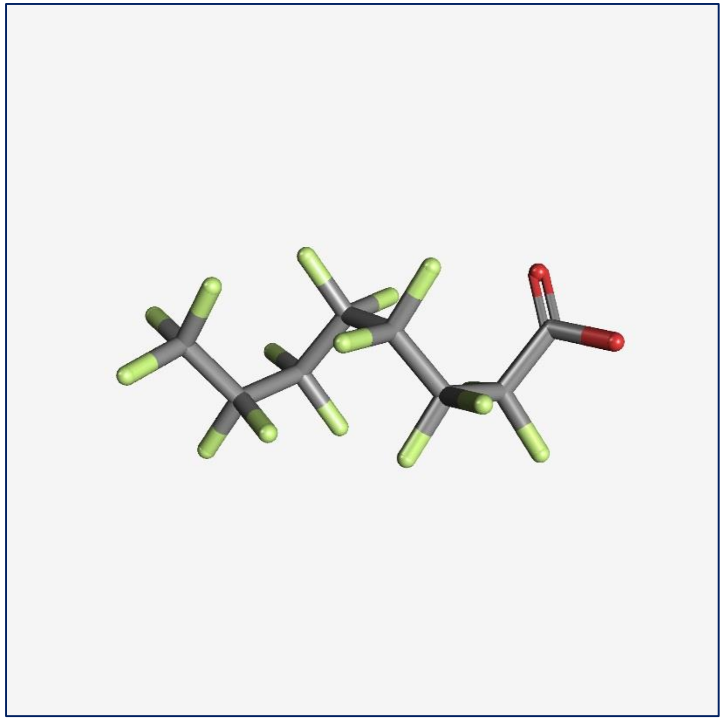
Outline

- Refresher on perfluoroalkyl substances (PFAS)
- Project Overview and Findings – PFOA and PFOS
- Other PFAS compounds
- PFAS at contaminated sites
- Regulatory Guidance in Canada
- Parting Thoughts
- Acknowledgements
- References

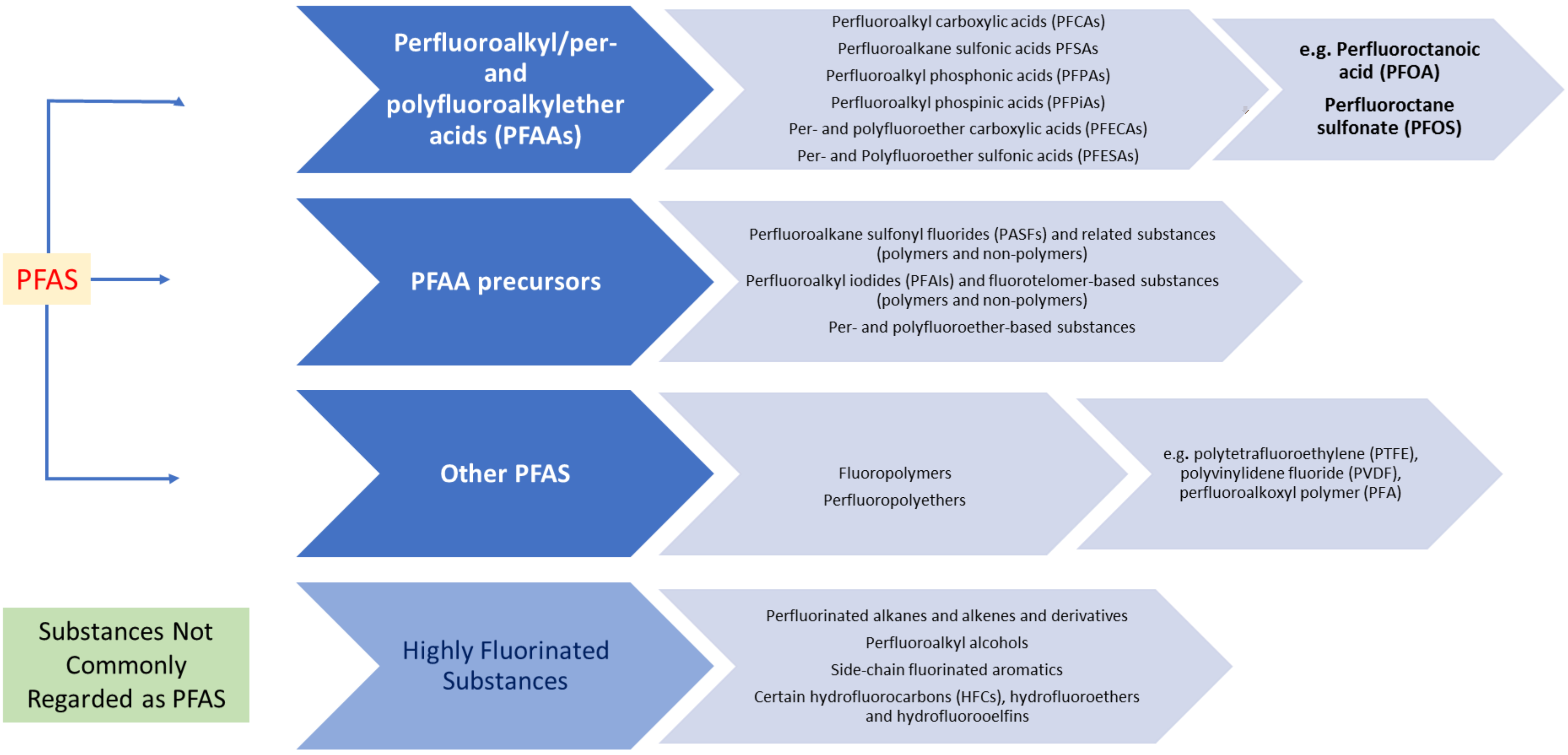
What are Perfluoroalkyl Substances (PFAS)?

- Made-made, highly persistent compounds that contain at least one perfluoroalkyl moiety (C_nF_{2n})
- Limited degradation, highly persistent and bioaccumulative, potential for long-range transport
- Have both hydro- and oleo-phobic properties
- Over 4,000 different compounds identified
- Longer-chain compounds – used historically
- Shorter-chain compounds – more recent



Perfluorooctanoic Acid (PubChem 2018)

OECD Categorization of PFAS



Adapted from OECD (2018)

Where are Perfluoroalkyl Substances (PFAS)?

- **Sources**
- Industrial and wastewater effluents
- Packaging
- Consumer products
- Landfills
- Fire-fighting foams

- **Exposure Pathways**
- Soil
- Biosolids
- Dust
- Sediment
- Surface water
- Groundwater
- Drinking water
- Biota (including foods)

- **Receptors**
- Ecological
  - Aquatic
  - Benthic
  - Terrestrial
  - Avian
- Human

Why do They Matter?

- **Potential Ecological Health Effects**
  - Wild birds and mammals – liver, endocrine and reproductive effects
  - Aquatic life – decreased survival, altered growth and development
  - Plants – decreased growth
- **Potential Human Health Effects**
  - Mammalian toxicity data suggests potential of immune, endocrine, neurological and pancreatic effects
  - Weight of evidence for human health is evolving

PFAS are highly persistent and widespread

Project Overview

- **Objectives:**
  - To complete a literature review and summarized available data regarding PFOA and PFOS in foods, including uptake to foods from various media (soils, sediment, water)
  - To identify information regarding the potential mechanisms of uptake and factors that might impact the bioavailability of PFOA and PFOS
- **Focus** was on documents published between 2012 and 2017
  - Included peer-reviewed literature
  - Grey literature from reputable organizations
  - Review primarily focused on uptake factors and food concentrations

Types of Uptake Factors Considered

- **Bioaccumulation Factor (BAF)** – concentration in organism attributable to *all* routes of exposure
- **Bioconcentration Factor (BCF)** – ratios of concentrations in biota relative to surrounding environmental media
- **Biomagnification Factor (BMF)** – quantification of increasing tissue concentrations from prey to predator
- **Trophic Magnification Factor (TMF)** – average value of prey to predator magnification over a whole or partial food chain
- **Biotransfer Factor (BTF)** – predicted contaminant uptake to a tissue relative to exposure

Key Findings – In a Nutshell

- **Available uptake factors are impacted by:**
  - Different units and likely analytical methods
  - Different accumulation patterns and mechanisms for PFOA and PFOS vary across species
  - Proximity to emission sources, species trophic level, plant part (root, stem, leaf or fruit), tissue (protein content and perfusion) and organic carbon
- Development of generic uptake factors for fish, root- or leafy-vegetables, fruits, etc., **not** feasible
- Octanol-water coefficient (K_{ow}) used to predict transfer of other persistent chemicals is **not** going to be useful

Key Findings – Fish and Seafood

- Fish are significant contributors to human exposure
- Proximity to emission sources influences concentrations
- PFOS more commonly detected than PFOA – greater ability to bind to organic matter due to longer PFA chain
- Benthic species generally present higher PFOS concentrations than pelagic
- Lack of clear relationship between fish weight or length and concentration
- Concentrations and uptake influenced by local trophic levels and feeding behaviours
- Presence of precursors in environment can result in accumulation within aquatic food webs

One size does not fit all for transfer factors and accumulation

Key Findings – Mammals

- Comparatively much less information than fish
- Mammals **can** metabolize and eliminate PFAS (slowly) - tissue concentrations lower than in fish
- PFOS generally detected at **higher** concentrations and **more** frequently than PFOA
- Blood and highly blood-perfused tissues (liver, kidney, lung, bone marrow) generally had higher concentrations than muscle or fat
- Aquatic mammals found to contain varying levels of PFOS
  - 'onshore' animals presented higher concentrations than 'offshore' animals
  - PFOS detected in deep ocean species

Key Findings – Bioaccumulation in Fish and Mammals

- Potential for bioaccumulation increases with chain length
- Variability in available uptake data attributable to:
  - Organ or tissue-specific studies – weighted mean or whole-body concentrations more accurate
  - Lack of normalization to protein content – uptake highly dependent on protein
  - Non-attainment of steady-state concentrations (exposure, growth)
  - Limited information regarding feeding ecology and surrounding environment
  - Metabolism and elimination
  - Presence of other PFAS in exposure media

Key Findings – Breastmilk, Dairy and Eggs

Breastmilk

- PFOA more commonly detected than PFOS
- Data suggest exposure is widespread

Dairy Milk

- PFOS detected more frequently than PFOA
- Depends on milk product type (higher fat – PFOS, higher water – PFOA)
- Removal of water in processing may increase concentrations

Eggs

- PFOA and PFOS primarily found in yolk
- Farming operation type can impact PFOA and PFOS content

Key Findings - Plants

- Mixture of greenhouse/laboratory and field studies
- Involved different combinations of soil treatments and site types
- PFOS detected at higher concentrations in roots relative to rest of plants (lipophilicity)
- PFOA tends to accumulate more in edible portions
- Protein content of plant tissue also seems to influence accumulation

- Cereal crops presented lower concentrations and a higher number of non-detects compared to fruits and vegetables – thought to be due to water content
- Relatively smaller contributor to human exposure compared to fish, meat and dairy

Key Findings - Plant Bioaccumulation

- Uptake in plants result of root uptake (liphophilic compounds) and transfer via water phase (sap)
- Variability in plants attributable to:
  - Use of compost or biosolids and **application rates**
  - **Soil organic matter** (total organic content, organic matter) is an important variable
  - Nature of acid moiety (sulfonic vs. carbonic) and chain length
  - Rooting systems and root lipophilicity
  - Potential for translocation between plant compartments and the role of biological barriers
  - pH, temperature and chloride
  - Presence of other PFAS and precursors

PFOA and PFOS – Environmental Media

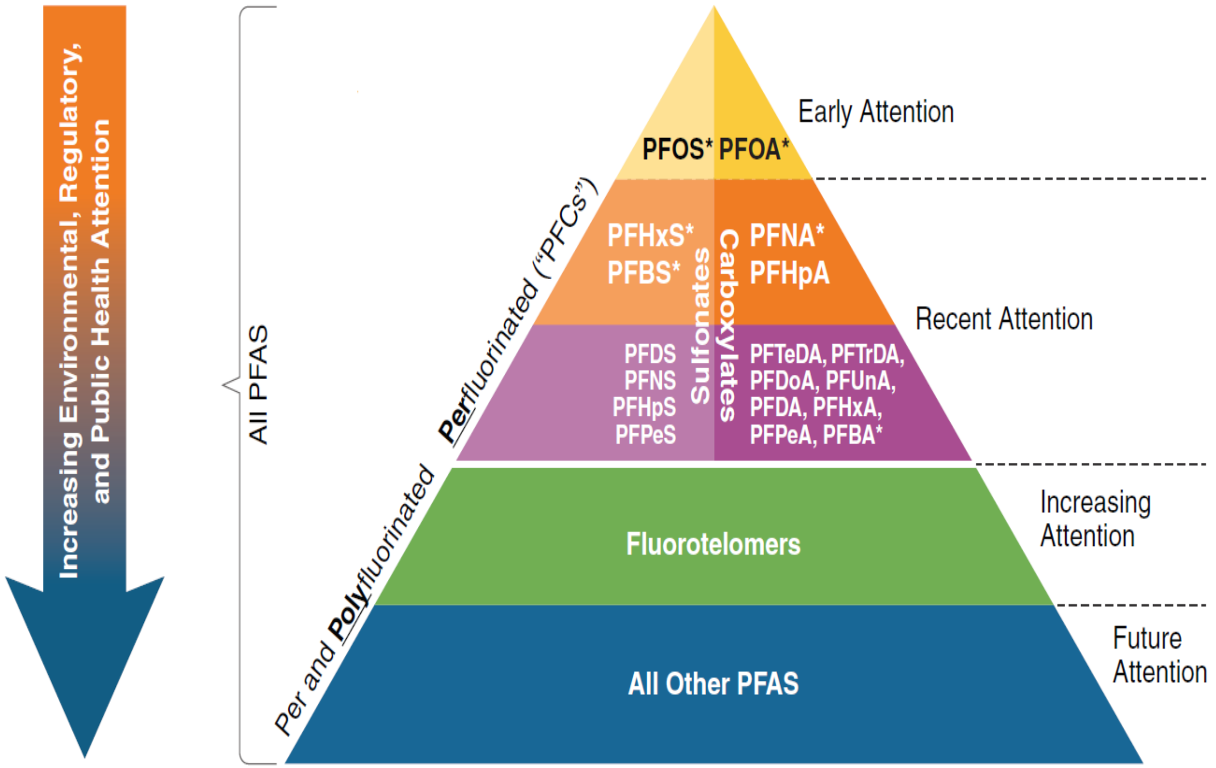
- **Findings of limited review**
  - Limited soil and sediment data identified for PFOA
  - More information for North America identified for surface and drinking water – less data for Europe and Asia (particularly for PFOS)
  - Concentrations of PFOA and PFOS in Canadian waters in general seem to be due to historical sources (firefighting foams, landfill), but difficult to determine

Uncertainties and Data Gaps

- Information regarding proximity to emission sources, ecosystem and feeding behaviours not always noted in documents
- European Market-basket food data – not clear where the food was sourced from (local farms or foreign)
- Limited information regarding PFOA and PFOS in North American foods
- High potential for sample contamination in field or lab

What About the Other PFAS?

- Search was focused only on PFOA and PFOS
- 34 of documents included in our search had data for other PFAS in foods or media
- Presence of other PFAS (especially precursors) can influence data
- The OECD (2018) has recently compiled a database of over 4,000 unique PFAS according to CAS number



Adapted from ITRC (2017)

State of knowledge is constantly evolving

intrinsik SCIENCE INTEGRITY KNOWLEDGE

Why Does any of This Matter to Contaminated Sites?

- **Development of meaningful data set**
  - Understand local ecosystem and feeding behaviours, species of interest, presence of precursors, proximity to source
  - Consider whole-body concentrations OR weighted-average of tissues
  - Talk to your lab about field procedures and analytical issues **beforehand**
  - Talk to your risk assessment team **before** doing sampling about data needs
  - Measure pH, organic carbon, total protein, fat and moisture
  - Consider normalizing data to protein content

Why Does any of This Matter to Contaminated Sites?

- **Risk assessment**
  - Evidence suggests that generic values for PFAS **can not** be used across a species or as surrogates for other PFAS
  - Octanol water coefficient (K_{ow}) **unreliable** as a predictor of uptake
  - Database is **evolving** – large variability in values, most information for Europe, parts of Asia, North and South America.
  - Consider using transfer factors derived from site-specific data or sufficiently similar sites
  - Impacts the derivation of regulatory **guidelines**, **exposure estimates** for human and ecological risk, and the derivation of site-specific **remediation targets**

*Is there a potential use for this biological uptake information in the **development of remediation technologies**?*

Current Regulatory Guidance in Canada

- Health Canada Drinking Water Screening Values (9 PFAS)
- Health Canada Human Health Soil Screening Values (9 PFAS)
- Federal Environmental Quality Guidelines for Water, Tissues (bird eggs), Soil for PFOS
- Federal Groundwater Quality Guideline for PFOS
- Health Canada guidance for HHRA and risk management
- Transport Canada guidance for site investigation and management
- British Columbia Contaminated Site Regulation 2017

Parting Thoughts and Questions

- **PFAS might be co-contaminants with glycols and PHC** – are there historic PFAS at previously PHC-remediated sites?
- Does biology have a potential role in PFAS site remediation?
- **Zürich statement (August 2018)**
  - Coordinated scientific and regulatory efforts ongoing
  - Regulatory schemes to address PFAS with high or very high persistence within the environment
  - Data and monitoring to help fill knowledge gaps
  - Development of standardized analytical methods

***Keep watching** – things are constantly changing*

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