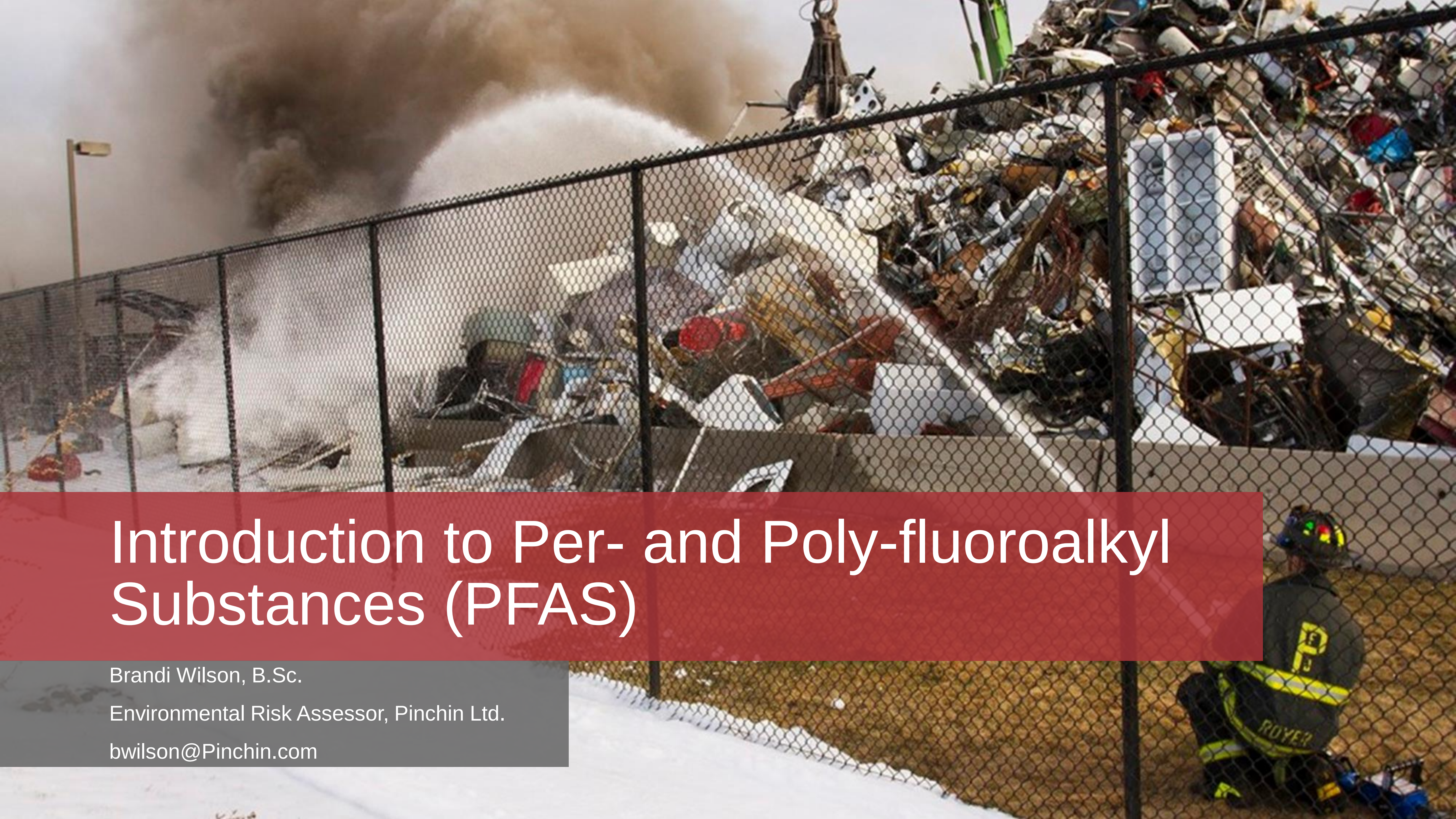

Introduction to Per- and Poly-fluoroalkyl Substances (PFAS)

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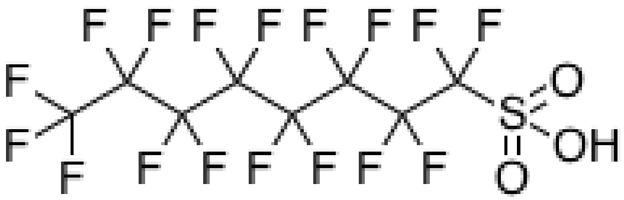
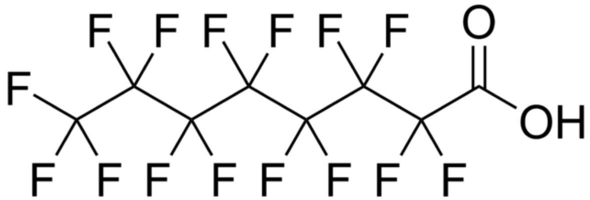
Agenda

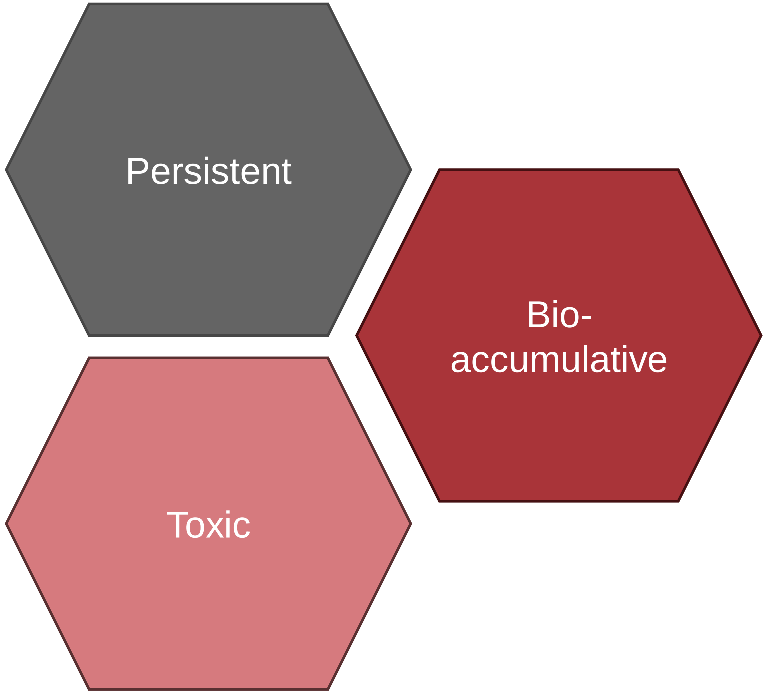
1. Chemistry – What are PFAS?
2. Sources of PFAS
3. The History of PFAS
4. Health Effects
5. Sampling for PFAS
6. Remediation and Treatment
7. Waste Disposal
8. Challenges and Uncertainties

Chemistry – What are PFAS?

- Per- and poly-fluoroalkyl substances (PFAS) are a class of man-made substances that do not occur naturally
- Widespread use in consumer and industrial processes since the 1940-1950s
- “ Forever Chemicals”
  - Persistent, Organic, Pollutants
  - Bioaccumulate
  - Mobile

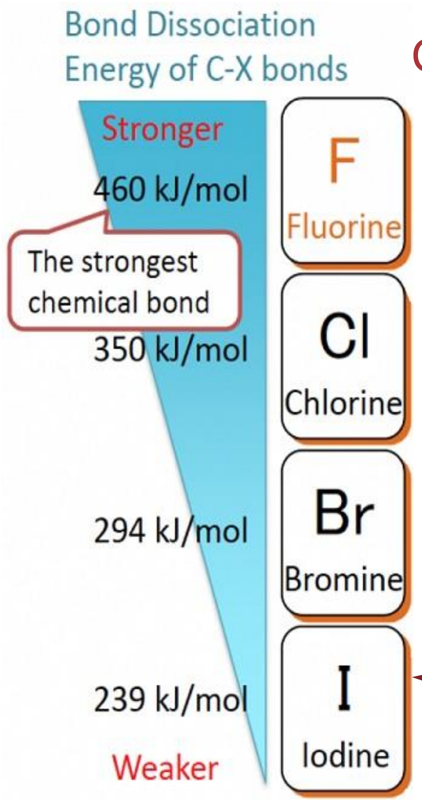






Chemistry

- Over 4,700 PFAS compounds identified
  - Must contain a perfluorinated methyl group (-CF3) or a perfluorinated methylene group (-CF2)
  - PFOS and PFOA most studied to date
- Diverse range of compounds
  - Chain length and functional group
- Synthetic substances with **carbon and fluorine backbone**



C-F e.g. Teflon

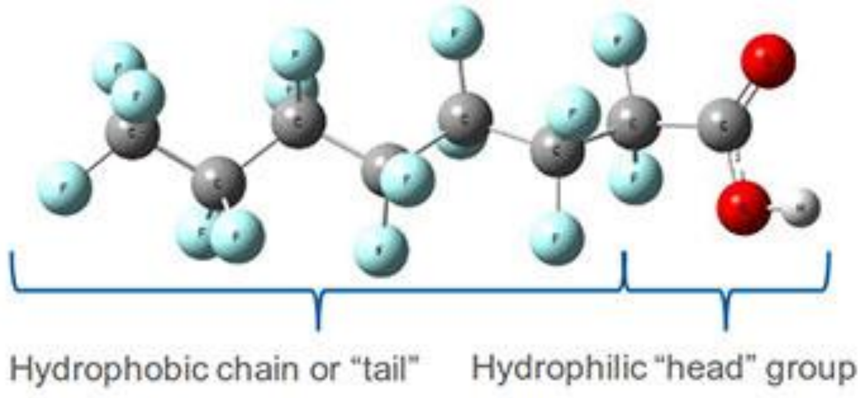
Stronger bonds = stable compounds C-F bonds survive organic transformations

C-Cl e.g. Trichloroethylene

Weaker bonds, used in organic synthesis as useful reagents

Chemistry – Properties of PFAS

- Resistant to oil and water
    - Provides stain resistance and non-stick properties
- Resistant to chemical, physical, and thermal degradation
    - Making these compounds very stable
- Low surface tension
    - Making PFAS good surfactants and lubricants
- Mobile in water due to their functional such as carboxylates or sulfonates (the hydrophilic head)



Sources

Brand names
Teflon
Scotchguard
Stainmaster
Stainsafe
Polartec
Gore-tex

Personal Hygiene Products
Sunscreen
Cosmetics
Shampoos
Bug Spray

Graphic Source: Australian Department of Defence

The History

1938: PTFE discovered by a DuPont Chemist

1947: 3M begins production of PFOA

1949: DuPont introduces Teflon® brand

1951: DuPont begins purchasing PFOA from 3M for use in Teflon® manufacturing

1956: Stanford University Study finds that PFAS binds to proteins in human blood

1961: DuPont’s toxicologist warns that C8 is toxic

1963: The United States Navy works with 3M to develop AFFF

1978: 3M reports PFOA found in blood of workers

1984: PFOA found in local drinking water near 3M plant

1987: 3M PFOA animal studies show tumors

1992: DuPont finds elevated cancer rates among workers

1940 | 1950 | 1960 | 1970 | 1980 | 1990

The History

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1998:
3M reports to USEPA, PFAS accumulates in blood

1999:
PFAS included as Toxic Substances in Schedule 1 of CEPA

2000:
3M announces phase out of C8 based chemistry and ceases production

2008:
Canada restricts use, sale, import of PFOS under CEPA; with exceptions

2009:
PFOS recognized under Annex B of the Stockholm Convention on Persistent Organic Pollutants

2012:
The *Prohibition of Certain Toxic Substances Regulation*, further restricted the use, sale, and import of these substances, with exceptions.

2016:
2008 PFOS Regulation replaced with 2016 Toxic Substances Regulation and stricter restrictions on manufacture, use, sale, import

2017:
CCME release environmental quality guidelines for PFOS

2017:
ON MECP releases interim drinking water guideline for the sum of 11 PFAS

2018:
Canada Gazette publishes the Health Canada PFOS and PFOA maximum acceptable concentrations for Canadian drinking water quality under CEPA

2000 | 2005 | 2010 | 2015 | 2020

The History

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2019:
BC adds PFOS, PFOA and PFBS to Contaminated Sites Regulation

2019:
Health Canada updates soil screening values for PFAS

2020:
BC includes PFOS, PFOA in drinking water standards

2021:
Health Canada Notice of Intent to address the broad class of PFAS

2021:
Atlantic Risk Based Corrective Action (RBCA) adds PFAS compounds to soil and water Standards

2021:
ON releases interim advice on PFAS in drinking water; provides toxicity reference values for risk assessment under O. Reg. 153/04

2022:
Proposed new Prohibition of Certain Toxic Substances Regulation – eliminate any exemptions in the 2016 TSR

2022:
AB includes guidelines for PFOS in soil and PFOS/PFOA in groundwater

2023:
Health Canada releases draft drinking water objective for a sum of up to 29 PFAS compounds

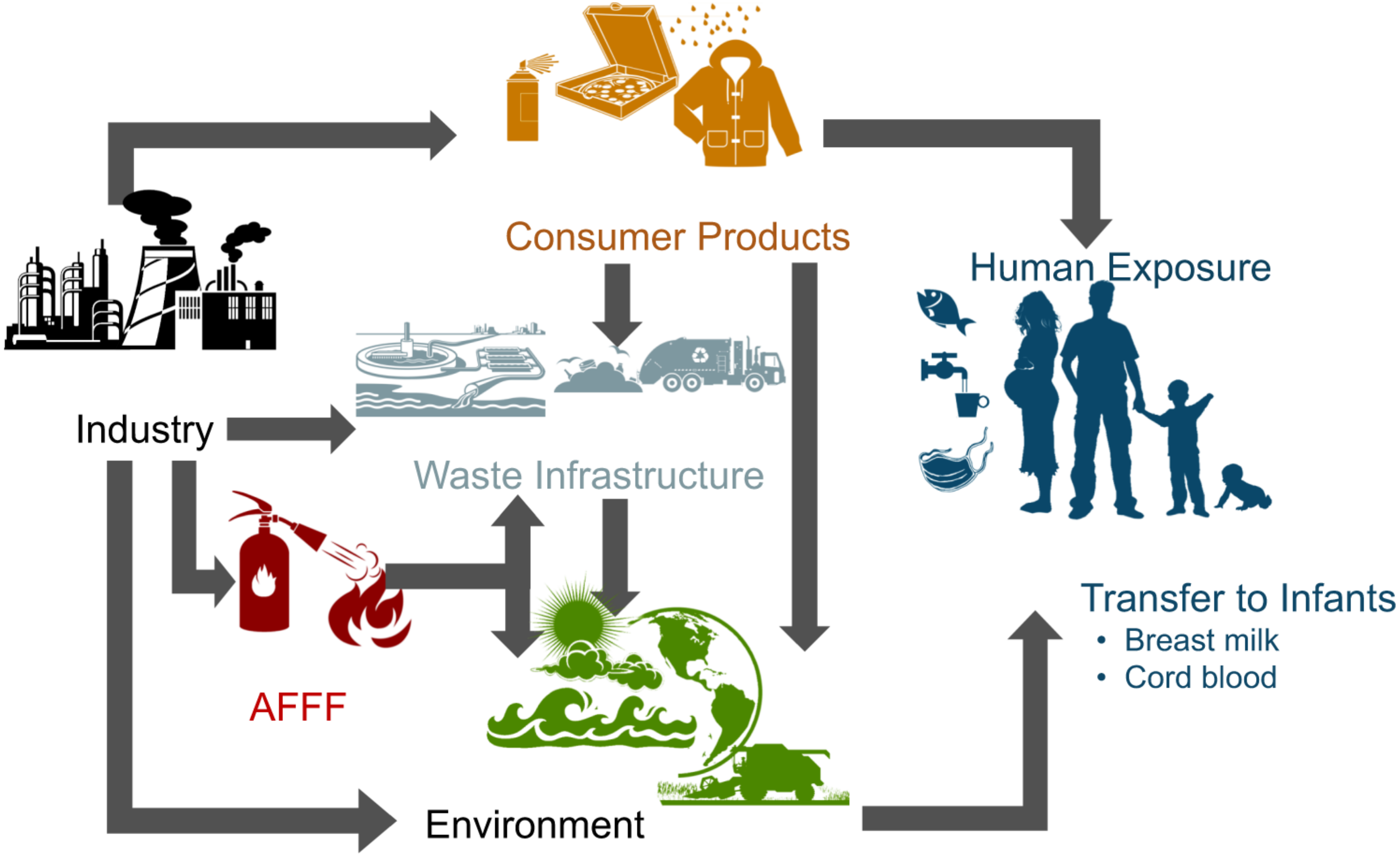
2023:
Health Canada and Environment and Climate Change Canada releases draft State of PFAS Report

2023:
ON Public Health Releases a fact sheet on PFAS

2023:
CCME releases the draft water quality guidelines for the protection of aquatic life for PFOA

2020 **2021** **2022** **2023** **2024** **?**

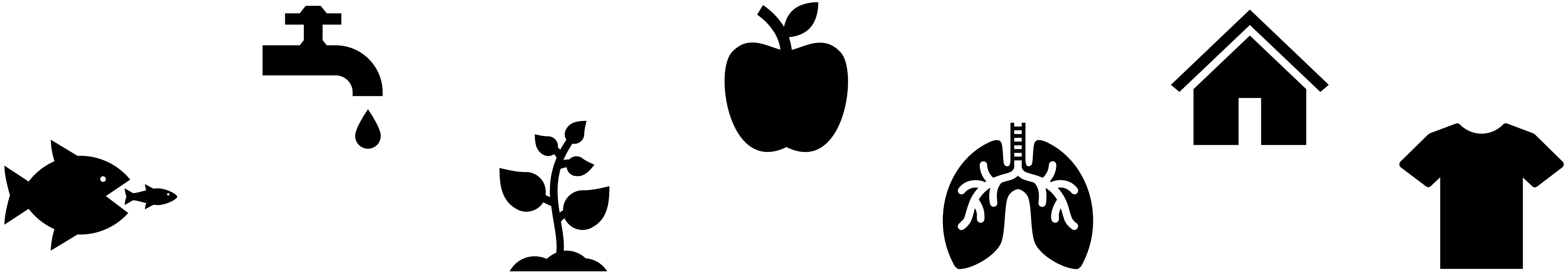
Toxicology – Entering the Environment



[1]Sunderland et al. 2019. A review of the pathways of human exposure to poly- and perfluoroalkyl substances (PFASs) and present understanding of health effects. Journal of Exposure Science & Environmental Epidemiology 29, 131–147

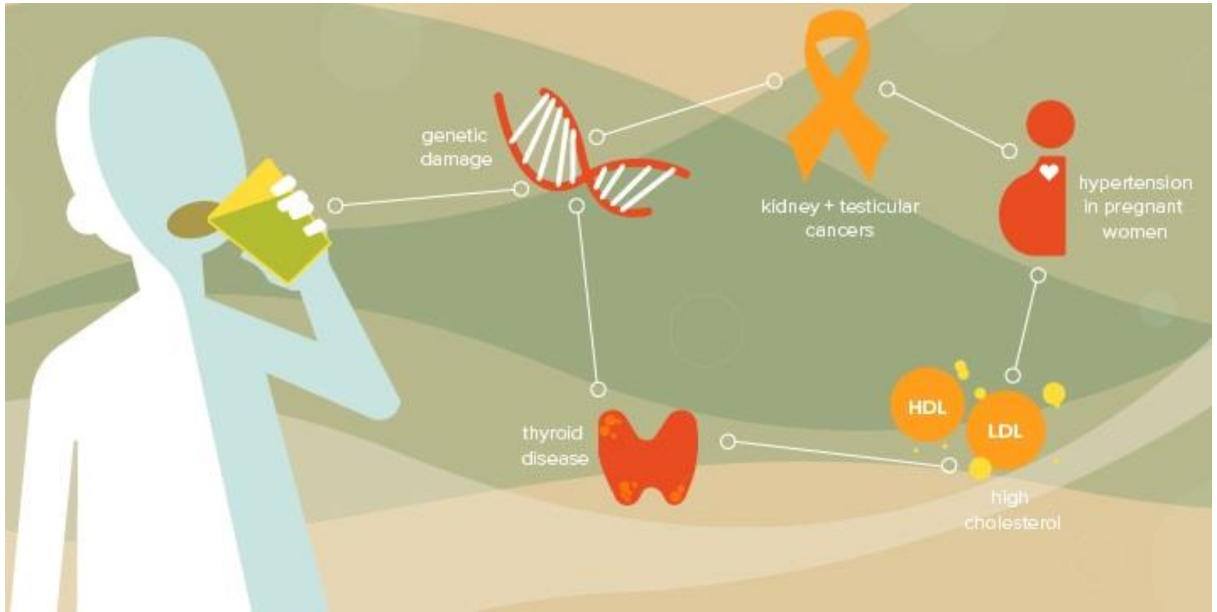
Toxicology – Exposure Pathways

- Exposure to PFAS can occur through several mechanisms (in order of significance):
  - Diet – ingestion of food and water containing PFAS
  - Direct contact with contaminated media (soil and groundwater)
  - Direct contact with PFAS containing consumer items (personal care products, carpets, clothing etc.)
  - Inhalation of vapours containing PFAS



Toxicology – Human Health Effects

- PFOS and PFOA readily absorbed after oral exposure
- Accumulates in serum, liver, kidneys
- Human epidemiological studies suggest associations between exposure and several health outcomes:
  - Pregnancy-induced hypertension
  - Liver damage
  - Increases in serum lipids (cholesterol, LDLs)
  - Increased risk of thyroid disease
  - Decreased antibody response to vaccines
  - Increased risk of asthma
  - Increased risk of decreased fertility
  - Small decreases in birth weight



Toxicology – Human Health Effects

- Some human epidemiological show increased risk of thyroid, kidney, and testicular cancers
- Results have not been consistent between studies and are generally inconclusive or lack statistical significance
- In the end, the non-cancer health effects are the current driver

Toxicology – Ecological Health Effects

- Biomonitoring studies show that PFAS can accumulate in a variety of organisms and wildlife
- Little is known about the adverse affects that exposure has on wildlife, especially terrestrial receptors
- PFAS are toxic to aquatic life
  - Freshwater studies are more abundant than saltwater
- Significant data gaps

Regulation – Canada (Federal)

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Jurisdiction	Available Standard or Guidelines	PFOS	PFOA	Other
Health Canada	2018 Guidelines for Canadian Drinking Water Quality	X	X	-
	2019 Soil Screening Values for 11 PFAS	X	X	PFBA, PFBS, PFGeA, PFHxS, PFHxA, PFHpA, PFNA, 6:2 FTS, 8:2 FTS
	2023 Draft Objectives for Canadian Drinking Water Quality	-	-	Sum of up to 29 PFAS
Environment and Climate Change Canada	2018 Federal Contaminated Sites Action Plan in Surface Water, Fish Tissue, Wildlife Diet (Mammalian and avian) and Bird Egg	X	-	-
Canadian Council of Ministers of the Environment	2021 Canadian Soil and Groundwater Quality Guidelines for the Protection of Environmental and Human Health	X	-	-

Regulation – Canada (Provincial)

Jurisdiction	Available Standard or Guidelines	PFOS	PFOA	Other
British Columbia	Contaminated Sites Regulation (B.C. Reg. 375/96)	-	-	-
	Drinking Water Standards	X	X	PFBS
	Aquatic Life Standard	X	-	-
	Soil Standards	X	-	PFBS
Alberta	*Contaminated Sites Policy Framework*	-	-	-
	Tier 1 Soil Remediation Guidelines	X	-	-
	Tier 1 Groundwater Remediation Guidelines	X	X	-
	Tier 1 Surface Water Guidelines	X	X	-
	Tier 2 Surface Water Guidelines	X	X	-

Regulation – Canada (Provincial)

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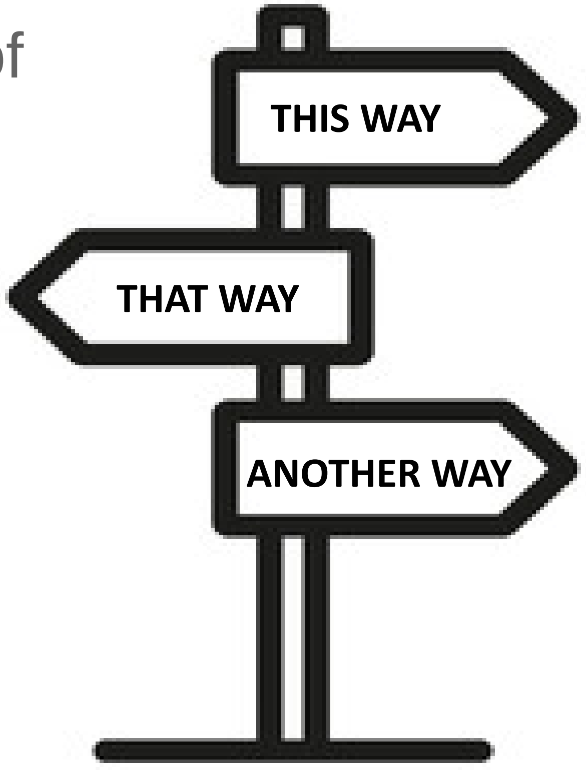
Jurisdiction	Available Standard or Guidelines	PFOS	PFOA	Other
Ontario	Interim Drinking Water communications from the MECP for a sum of 11 PFAS.	X	X	PFHxA, PFHpA, PFNA, PFDA, PFUnA, PFDoA, PFHxS, PFDS, PFOSA
Quebec	Ministry of the Environment, the Fight Against Climate Change, Wildlife and Parks Surface Water Criteria	X	X	-

Regulation – Canada (Provincial)

Jurisdiction	Available Standard or Guidelines	PFOS	PFOA	Other
Atlantic Provinces (Nova Scotia, PEI, New Brunswick, and Newfoundland and Labrador)	Nova Scotia Contaminated Sites Regulation / Atlantic Risk-Based Corrective Action (RBCA) Guidelines	-	-	-
	Human Health Based Tier I Environmental Quality Standards for Soil and Groundwater	X	X	PFBA, PFBS, PFHxS, PFPeA, PFHxA, PFHpA, PFNA
	Human Health Based Tier II Pathway Specific Standards for Soil and Groundwater	X	X	PFBA, PFBS, PFHxS, PFPeA, PFHxA, PFHpA, PFNA
	Ecological Tier I Environmental Quality Standards for Soil, Surface Water, and Groundwater	X	-	-
	Ecological Tier II Environmental Quality Standards in Soil, Surface Water, and Groundwater	X	-	-

Regulation – Where is it going?

- Updates to guidelines and standards based on updated scientific studies and laboratory sampling capabilities
- Regulated only in BC, Alberta, and Atlantic provinces. Rest of available values are guidelines.
- Expanded list of PFAS with standards and guidelines
- More soil and ecological standards and guidelines
- Reliance on international research and standards and guidelines
- Potential regulation as hazardous contaminants and waste



Sampling – When to sample for PFAS

- BC is the only province to outline when PFAS standards apply to a site used for industrial or commercial purposes
  - Schedule 2 of the Contaminated Sites Regulation:
    - Fire retardant manufacturing or wholesale bulk
    - Metal plating and finishing
    - Sites which have been or likely have been contaminated by substances migrating from other properties
    - Aircraft maintenance, cleaning or salvage
- There may be other reasons to sample:
  - Government facilities such as power plants
  - A known fire occurred on a property
  - Fire training schools or facilities
  - An industrial facility known to use components containing PFAS in manufacturing
  - Landfills
  - Sewage bio-solids application sites

Sampling – Cross Contamination Mitigation

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- Hygiene
  - Natural fibres vs. water resistant or stain treated clothing
  - Personal Hygiene - sunscreens, bug sprays, cosmetics, lotions etc.
  - Food containers
- Sampling Equipment
  - HDPE or silicone
  - Laboratory provided sampling bottles (Teflon free)
  - Decontamination procedures (PFAS free water)
    - Equipment and field blanks for confirmation
  - PPE – change gloves and wash hands
  - No gel or blue ice packs
  - Notes (paper and pen)

Remediation and Treatment Technologies – Soil

Ex-Situ Thermal Desorption

- Rotary kilns operating at temperatures of up to 815C to 1200C with off-gas treatment.
- At these temperatures PFAS are mineralized, releasing fluorine that must be captured via off-gas treatment systems.

Incineration

- High temperature thermal destruction of waste (>1,100C)
- At these temperatures PFAS are mineralized.
- Incinerators treat off-gasses by thermal oxidation with temperatures of up to 1,400C and combustion products captured using condensation and wet scrubbing

Remediation and Treatment Technologies - Soil

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Excavation

- Issues with where soil will go (which landfills will accept PFAS containing soil)
- US EPA proposing hazardous waste designation

Soil Stabilization

- Manufactured amendments to sorb PFAS and reduce leaching
- Effectiveness varies based on site conditions, types of PFAS, and mixing conditions

Soil Washing

- Requires large scale engineered plant to handle liquid and solid waste streams generated. Flocculated sludge may also need to be managed.
- Less suitable for clay soils
- Treatment of liquid waste required.

Remediation and Treatment Technologies - Water

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Activated Carbon

- Source materials include coconut shells, wood, lignite, and bituminous coal
- Each source material provides varied adsorption characteristics
- Bituminous coal has been shown to be most effective for PFAS
- Longer chain PFAS are removed better than shorter chain PFAS
- Can be used in water treatment

Ion Exchange

- Adsorption through ion exchange resins
- Can be selective to type of PFAS
- Presence of suspended solids, organic compounds, and oil and grease can reduce effectiveness

Remediation and Treatment Technologies - Water

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Foam Fractionation

- Uses the surfactant properties of PFAS to concentrate PFAS
- Small air bubbles are introduced into a column of contaminated water, as bubbles rise, they surfactants partition to the air/water interface

Sonolysis

- Application of sonic energy to contaminated water to partition PFAS to air/water interface as bubbles

Electrochemical Oxidation

- Submerged electrodes to producing highly reactive hydroxl radicals at the anode surface to destroy PFAS
- Anode materials have different PFAS removal efficiencies

Remediation and Treatment Technologies - Challenges

- PFAS resist chemical, physical, and thermal degradation
- Destruction takes temperatures of >1,000C
- Often large groundwater plumes due to mobile nature
- There are >4,700 PFAS with varying physical and chemical properties
- Comingled plumes with multiple COCs
- Most technologies have a waste biproduct to deal with

Waste Management

- PFAS waste products are not currently regulated
- Due to uncertainty on the regulation on PFAS, waste handlers and receiving sites are wary to transport or accept PFAS wastes

Challenges and Uncertainties

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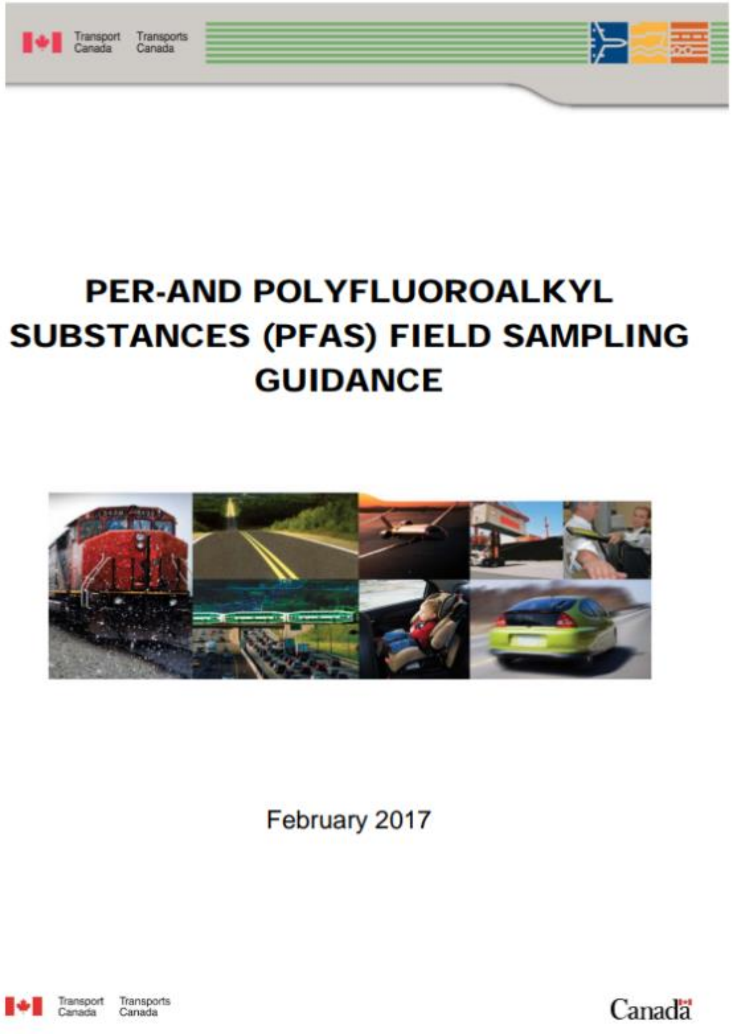
- Rapidly changing science leading to uncertainty in future regulation
- The guidance is vague about when to sample
- PFAS have no obvious field parameters to identify worst case samples (i.e. no visual, vapour, or olfactory clues)
- Sampling PFAS is expensive due to:
  - Individual sample costs
  - Additional QA/QC samples (equipment and field blanks)
  - Sourcing PFAS free water
  - Waste disposal
- Sampling turn around time is 15-21 days
- High chance of cross contamination from PPE, clothing, and equipment
- Remediation technologies are still in development
- Risk assessments have limited toxicity information available


Transport Canada Transports Canada

PER-AND POLYFLUOROALKYL SUBSTANCES (PFAS) FIELD SAMPLING GUIDANCE

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