Per- and Polyfluoroalkyl Substances: History, Occurrence, and Future Treatment Prospects

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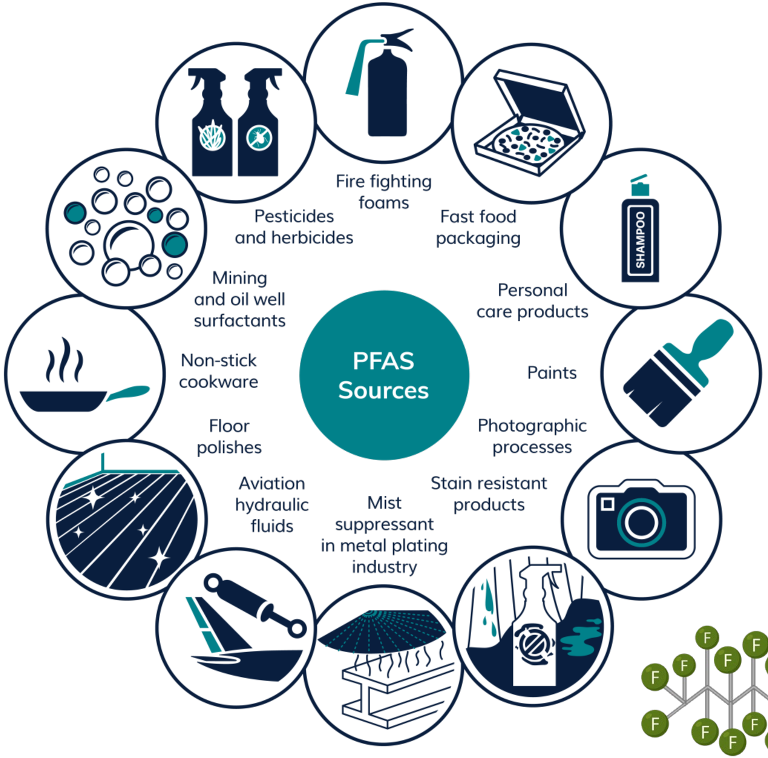
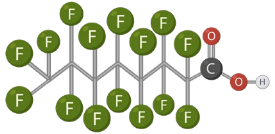
March 26th, 2025

Per- and Polyfluoroalkyl Substances (PFAS)

Group of > 14 000 synthetic organofluorine compounds





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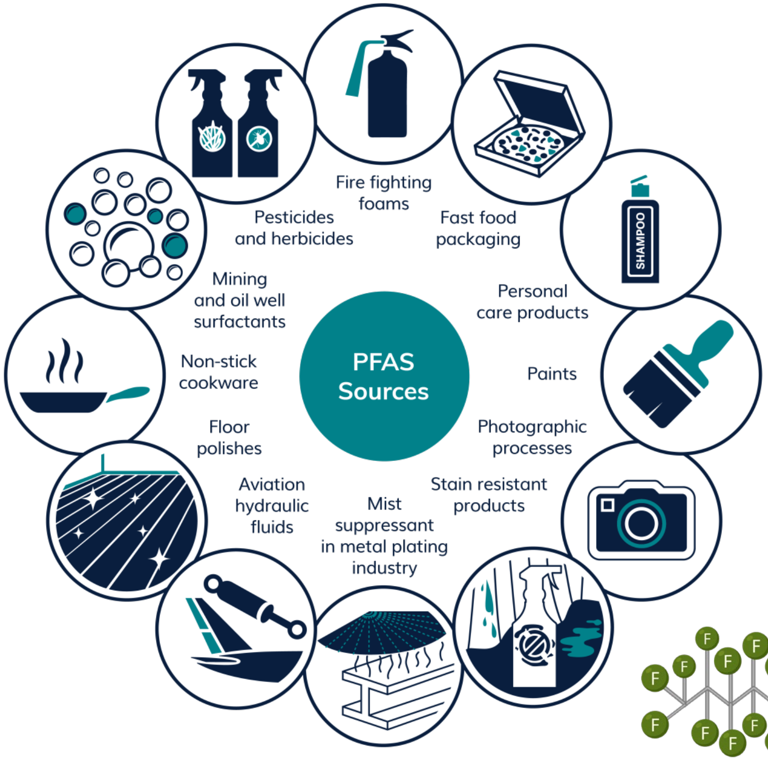
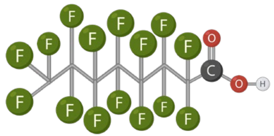
Chemical properties have resulted in their use across consumer industries





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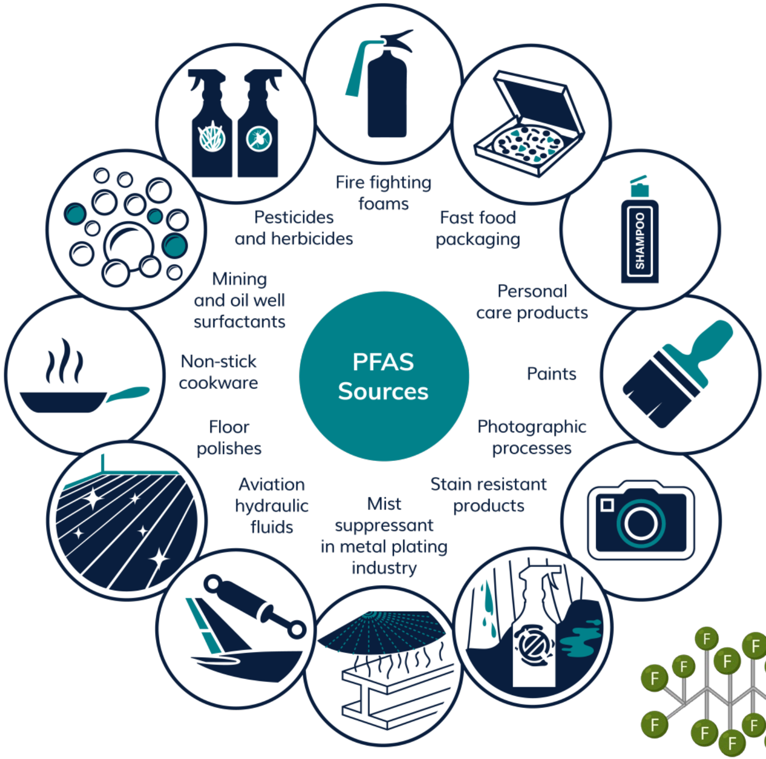
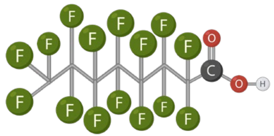
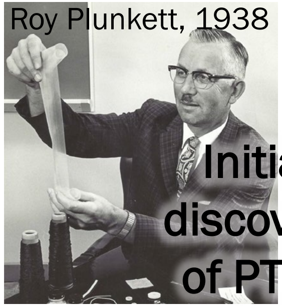
Inherent stability has resulted in environmental ubiquity

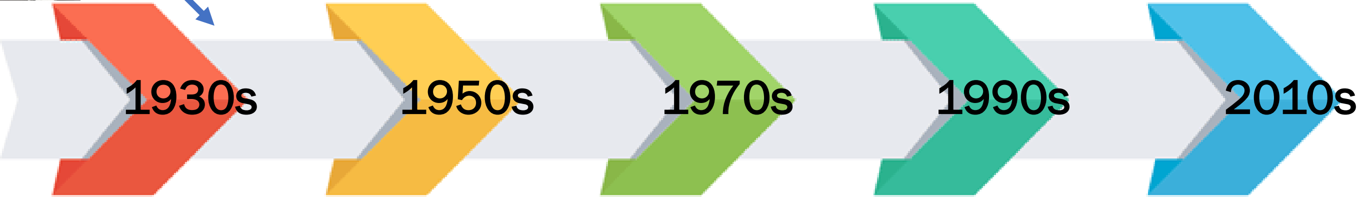




History of PFAS


Roy Plunkett, 1938

Initial discovery of PTFE



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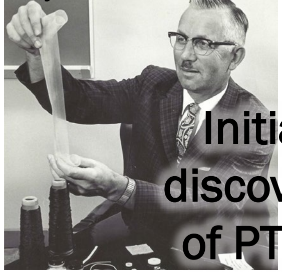

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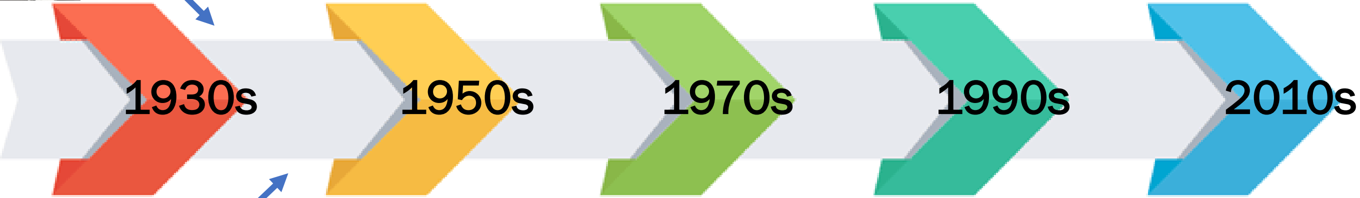

1942 - 1947

Use in Manhattan Project

History of PFAS

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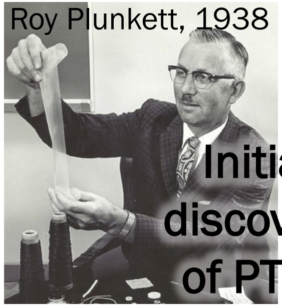

Initial discovery of PTFE

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Start of full-scale manufacturing

1930s

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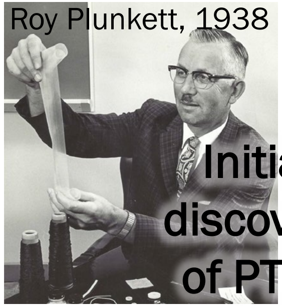

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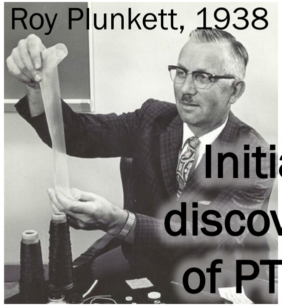

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EPA first alerted of potential PFAS health risks

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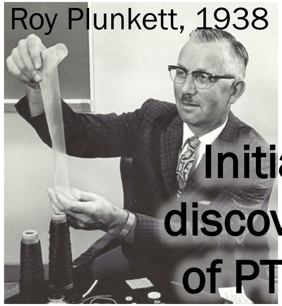

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Global Distribution of Perfluorooctane Sulfonate in Wildlife

JOHN P. GIESY* AND KURUNTHACHALAM KANNAN

Department of Zoology, National Food Safety and Toxicology Center, Institute for Environmental Toxicology, Michigan State University, East Lansing, Michigan 48824

1942 - 1947

Use in Manhattan Project

Development of AFFFs

1963

First study outlining widespread distribution of PFOS in environment

2001

History of PFAS

2000

Phaseout of PFOS-derived PFAS begins

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PFOS listed in Stockholm Convention

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Stockholm Convention

1st EPA health advisory on PFOA, PFOS

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History of PFAS

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3M

Phaseout of PFOS-derived PFAS begins

2016

Canada

PFOS, PFOA, & LC-PFCAs listed in PCTSA

PFOS listed in Stockholm Convention

2009 Stockholm Convention

1st EPA health advisory on PFOA, PFOS

2009 EPA

2018, 2019

1st Canadian drinking water guidelines on PFOA, PFOS

Health Canada

History of PFAS

2000

Phaseout of PFOS-derived PFAS begins

2016

PFOS, PFOA, & LC-PFCAs listed in PCTSA

Canada and USA release updated drinking water guidelines (Canada) and regulations (USA) 2024

PFOS listed in Stockholm Convention

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2009

2018, 2019

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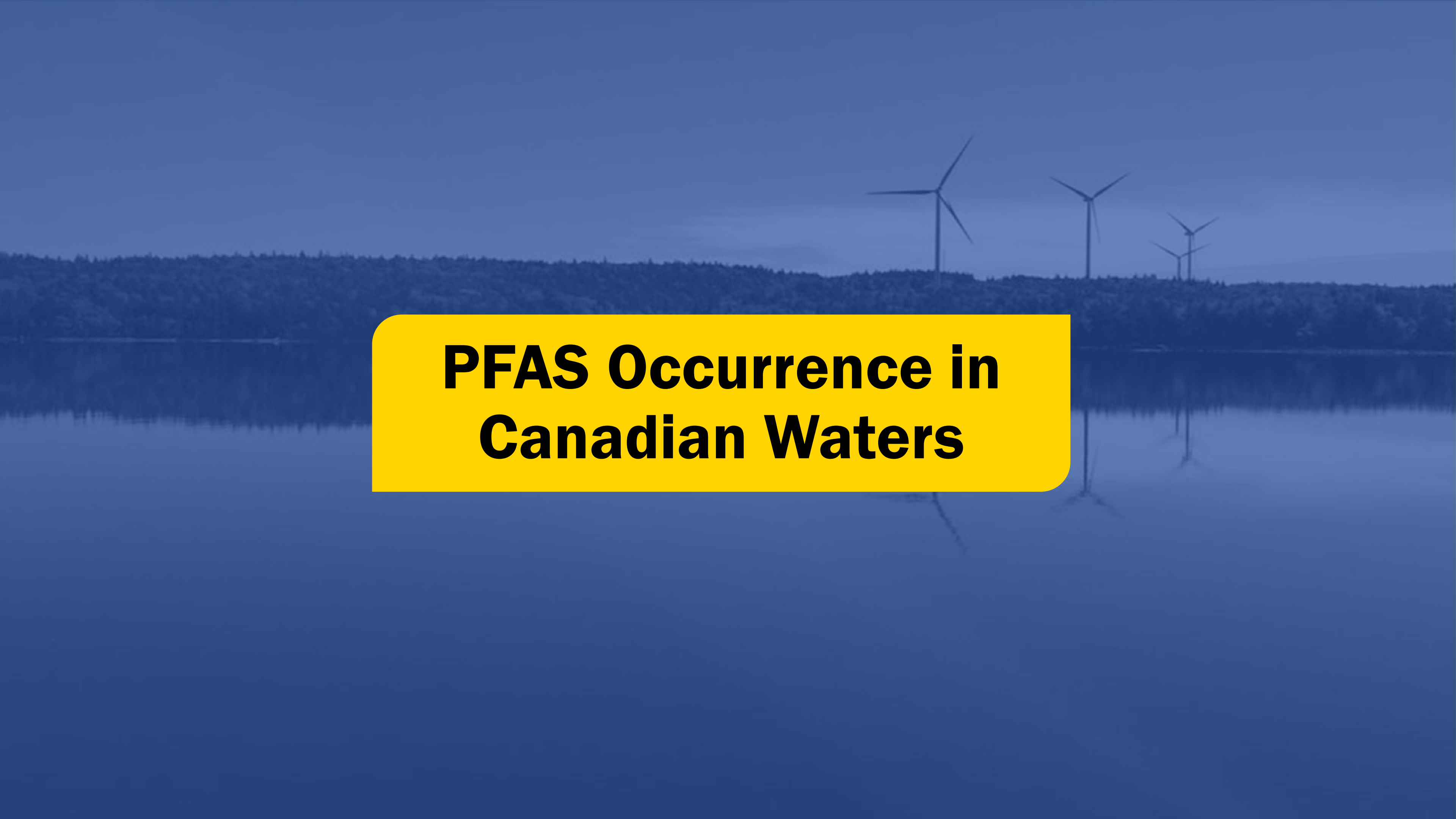
Current Guidelines and Regulations

Canadian Drinking Water Guidelines (*August 2024*)	∑ 25 PFAS *(as per EPA 533 or 1633)*	**∑30 ng/L**
Canadian Drinking Water Guidelines (Previous)	*PFOS*	*600 ng/L*
	PFOA	*200 ng/L*

US EPA National Primary Drinking Water Regulation	PFOA	4 ng/L
	PFOS	4 ng/L
	HFPO-DA	10 ng/L
	PFNA	10 ng/L
	PFHxS	10 ng/L
	PFAS Mixtures	Hazard Index of 1 (unitless)

Canada & USA have recently released stringent guidelines and regulations on PFAS in drinking water.

https://www.canada.ca/en/health-canada/services/publications/healthy-living/objective-drinking-water-quality-per-polyfluoroalkyl-substances.html
https://www.federalregister.gov/documents/2024/06/11/2024-12645/pfas-national-primary-drinking-water-regulation-correction



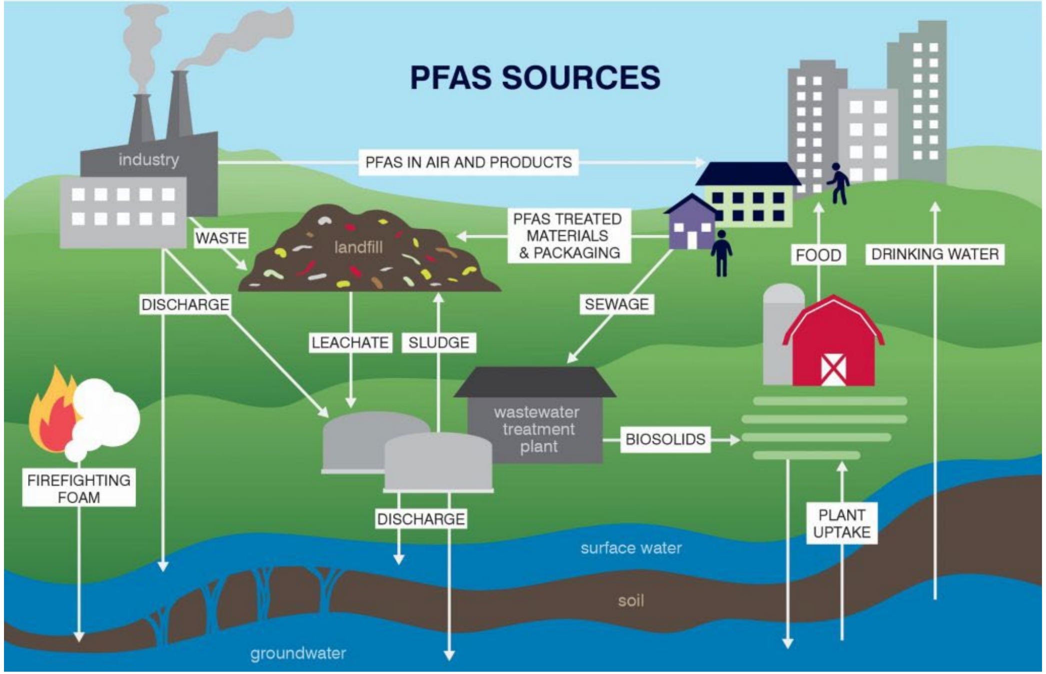
PFAS Occurrence in Canadian Waters

Transport of PFAS into the Environment

PFAS are released into the environment through anthropogenic sources

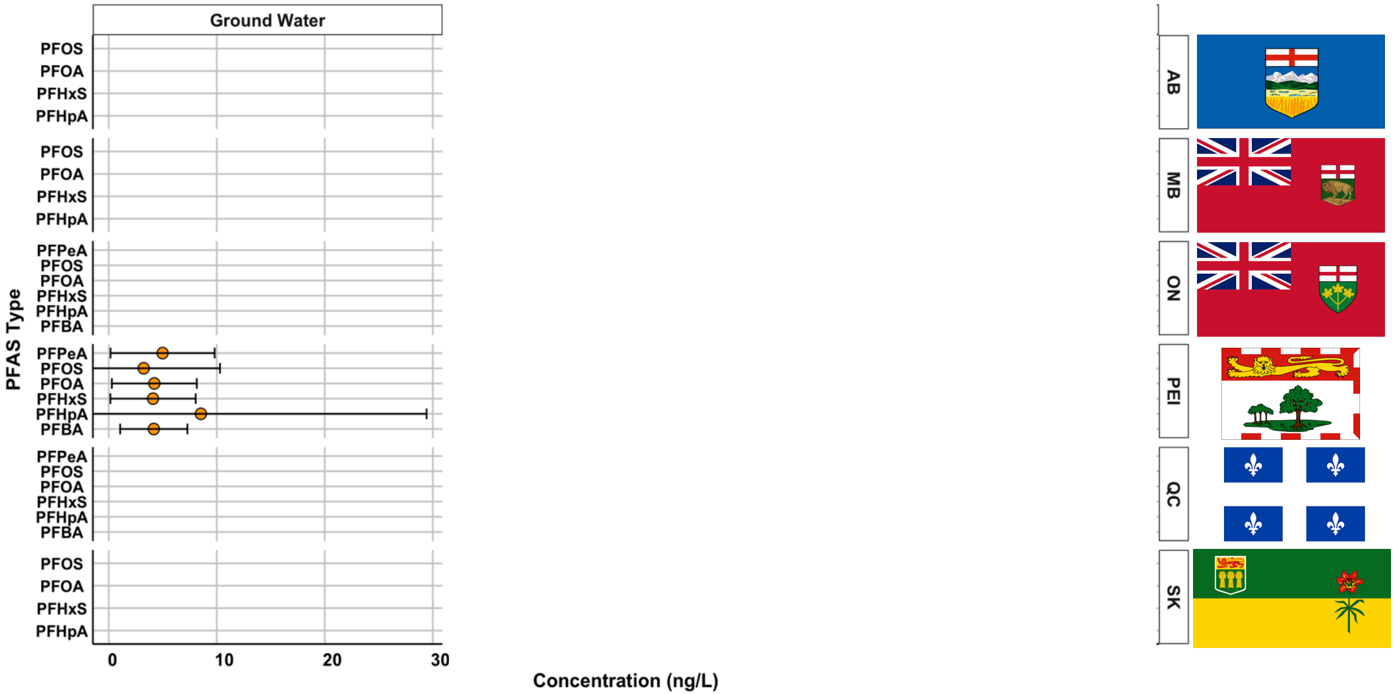
More highly industrious and populated areas are at higher risk of contamination

Transport to soils, surface water and groundwater can affect humans and wildlife



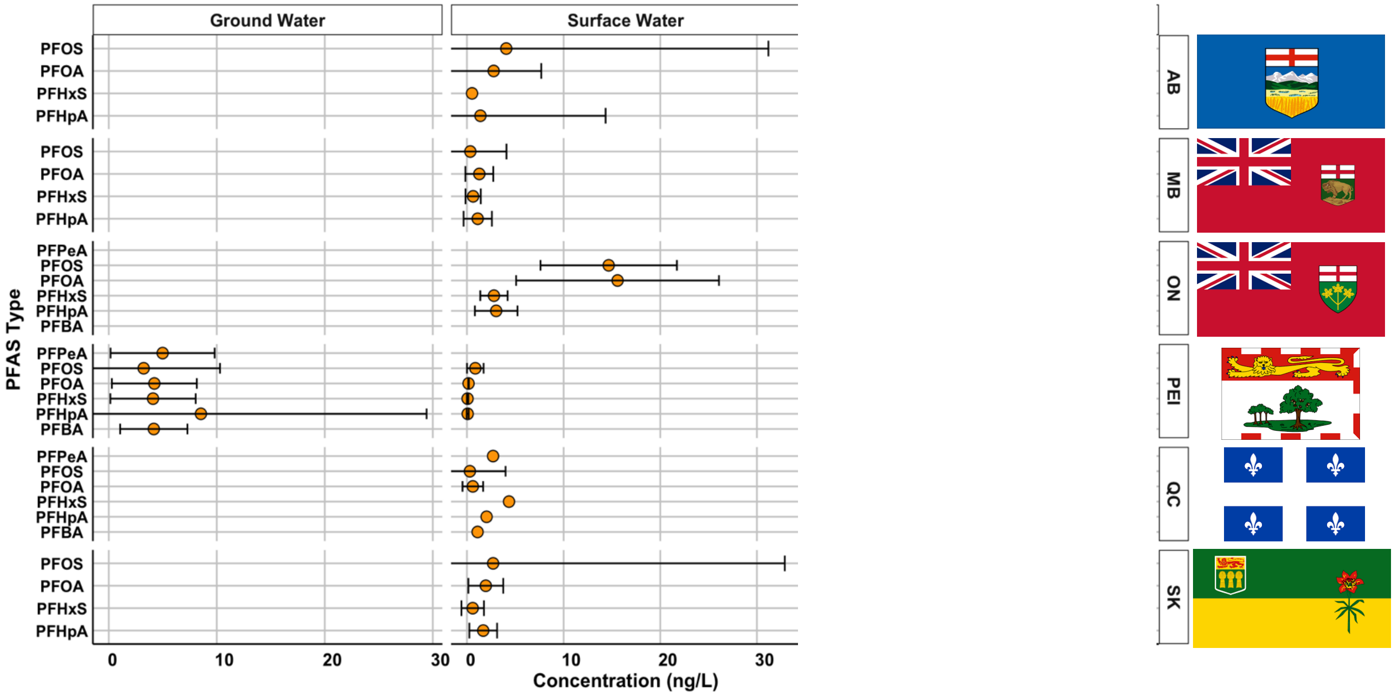
Weston & Sampson 2022

Occurrence of PFAS in Canadian Waters



Occurrence of PFAS in tap water, surface water, and groundwater in six Canadian Provinces

Occurrence of PFAS in Canadian Waters



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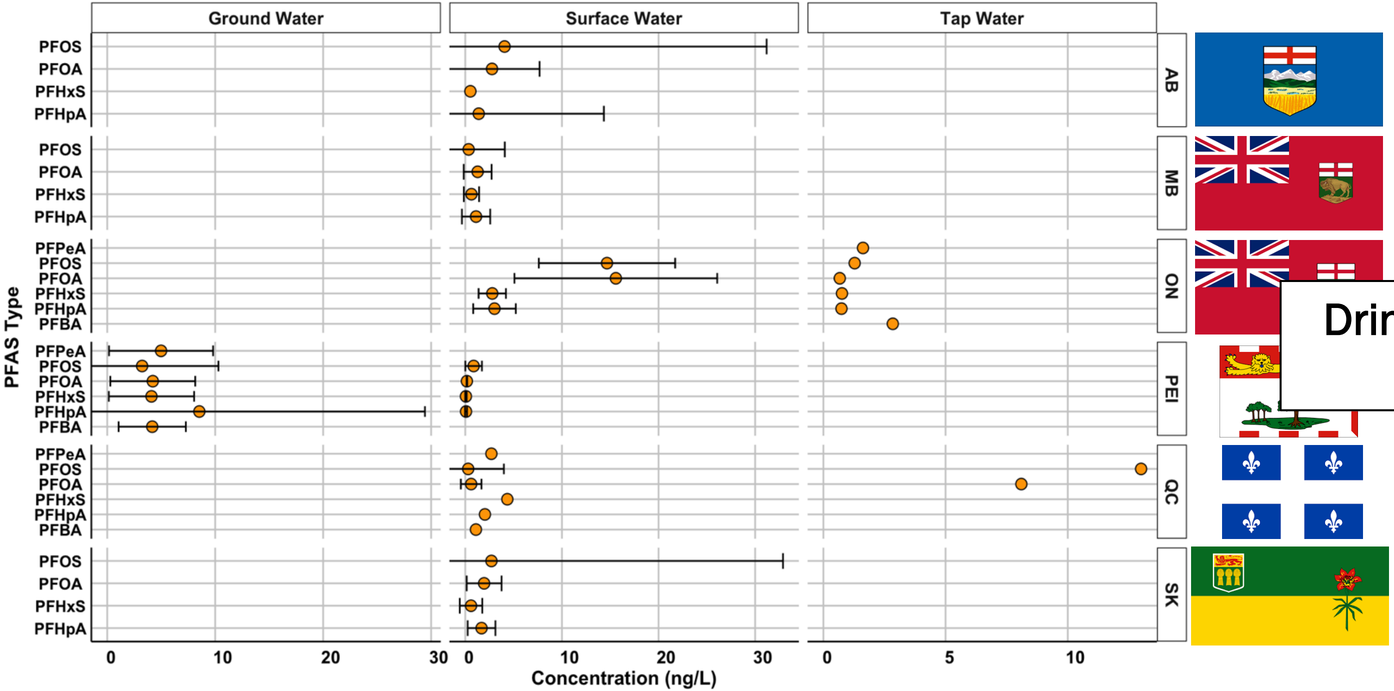
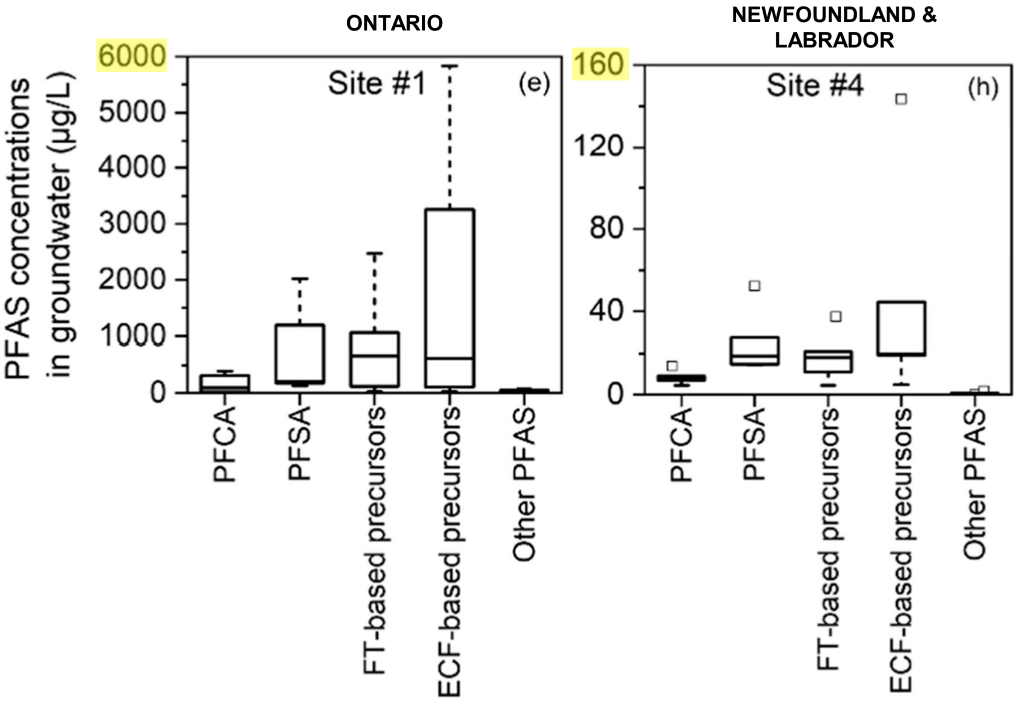


Drinking water sampling data are scarce

Occurrence of PFAS in tap water, surface water, and groundwater in six Canadian Provinces

Occurrence of PFAS in AFFF-Impacted Areas in Canada

GROUNDWATER DATA



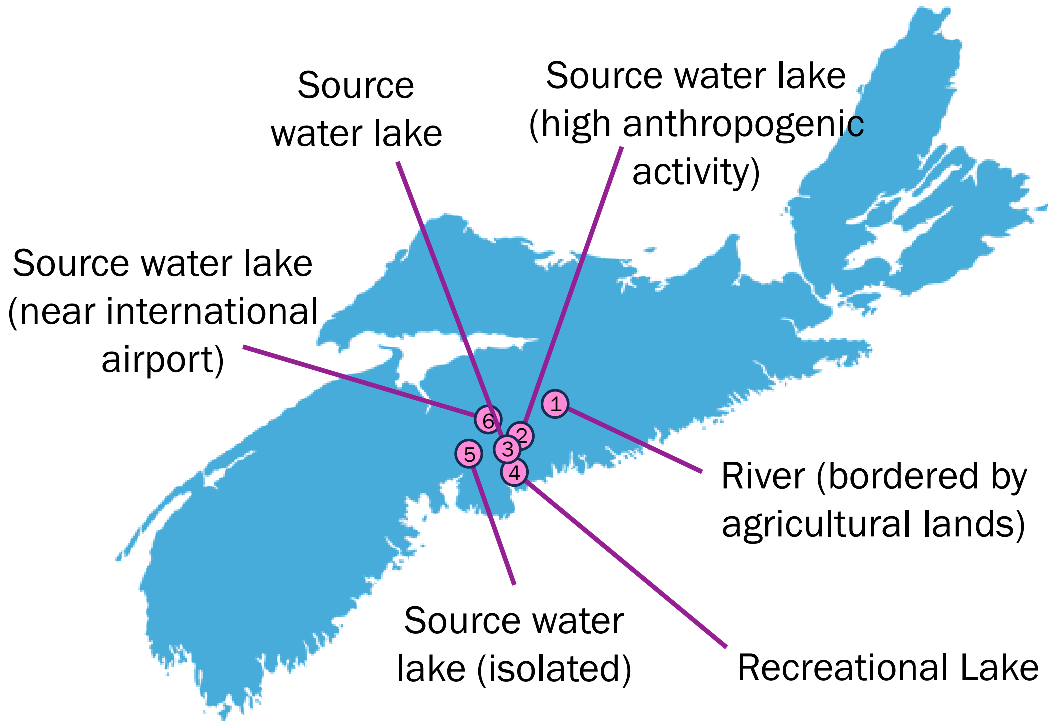
Historical use of AFFFs can result in substantial (**mg/L**) PFAS contamination

Groundwater sources may be particularly vulnerable

Liu, M., Munoz, G., Vo Duy, S., Sauvé, S., & Liu, J. (2021). Per-and polyfluoroalkyl substances in contaminated soil and groundwater at airports: a Canadian case study. *Environmental science & technology*, *56*(2), 885-895.

PFAS Research at Dalhousie University

Development of a PFAS Sampling Program in Nova Scotia



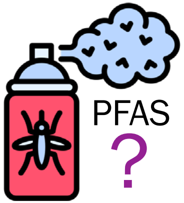
Occurrence of PFAS in Nova Scotian freshwater sources is not well understood

Objective: Determine PFAS occurrence in local freshwater systems to inform effects of human activity and land use patterns

Development of a PFAS Sampling Program in Nova Scotia – Sampling Considerations

UNACCEPTABLE MATERIALS

PTFE, GORTEX, waterproof materials



Personal care products, insect repellent, sunscreens containing PFAS

Glass, low-density polyethylene, aluminum foil, Teflon tape

Potential for unintentional contamination of samples is high

Care must be taken to avoid problematic materials and self contamination

Appropriate inclusion of sample blanks is important

Development of a PFAS Sampling Program in Nova Scotia – Sampling Considerations

Blank Type	Rationale
Field Reagent Blank	Assesses PFAS contamination occurs during sample collection and handling
Equipment Rinse Blank	Verifies decontamination effectiveness of sampling equipment
Trip Blank	Detects background contamination from cooler/transportation recipient.

Follow proper sample handling

Use verified PFAS-free containers, adhere to preservation and shipping requirements, and ensure compliance with holding times.

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Implement proper QA/QC measures

Incorporate necessary blanks and standardize sampling techniques to ensure sample integrity

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Maintain thorough documentation

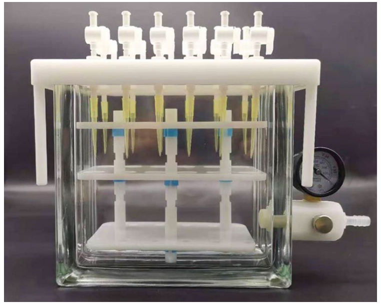
Record all sampling details, decontamination steps, deviations from protocols, and environmental conditions to support sampling effort

EPA 533 for Analysis of PFAS in Drinking Water

Sample Collection → Solid Phase Extraction → LC-MS/MS

HDPE or PP containers following PFAS sampling protocol

Anionic exchange SPE



LC-MS/MS analysis

Method reporting limits 0.5 – 1 ng/L for most PFAS

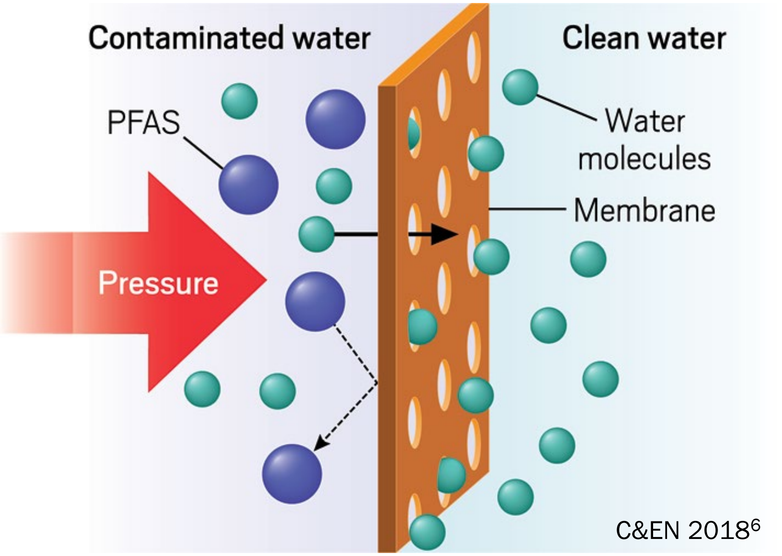
PFAS Treatment Methods: Current State-of-the-Art

Separation methods (e.g., granular activated carbon, anion exchange, high-pressure membranes)

- Resulting PFAS-laden adsorbent or concentrate

Some pilot-scale evaluation of electrochemical technologies

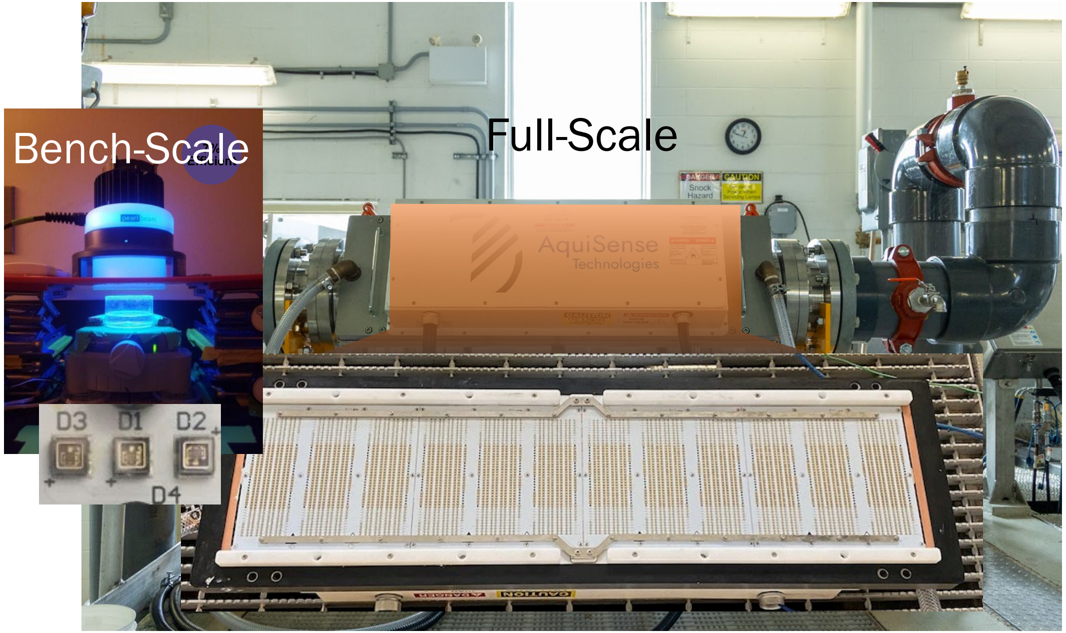
- Have not been tested at scale



C&EN 2018[6]

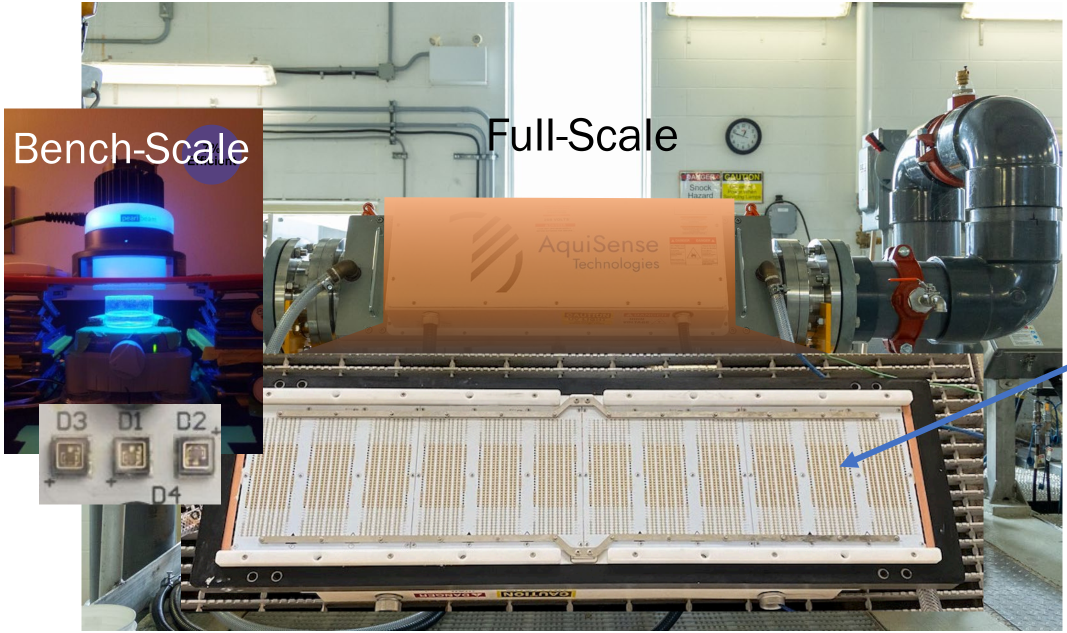
Chemical & Engineering News. 2019. 'Forever chemicals' no more? These technologies aim to destroy PFAS in water. Accessed June 21, 2023. https://www.limno.com/sampling-for-pfas-requires-caution/

Bespoke Treatment of Trace Organics using UV LEDs



UV LEDs have proven effective for disinfection of water at scale[5]

Bespoke Treatment of Trace Organics using UV LEDs



UV LEDs have proven effective for disinfection of water at scale[5]

Light emission can be tailored to their use case

UV LEDs can serve a dual purpose for bespoke destruction of trace contaminants

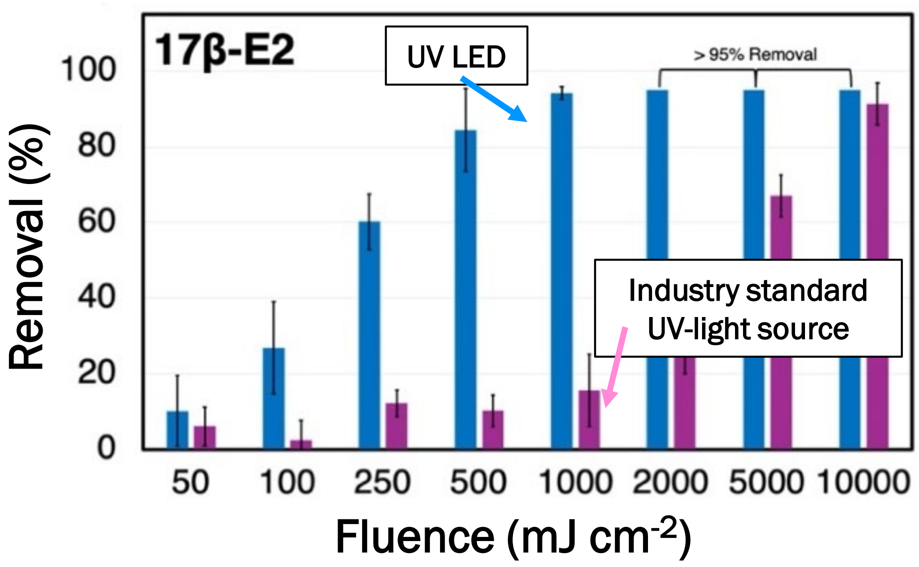
Bespoke Treatment of Trace Organics using UV LEDs

UV LEDs substantially reduce fluence requirements for estrogen degradation

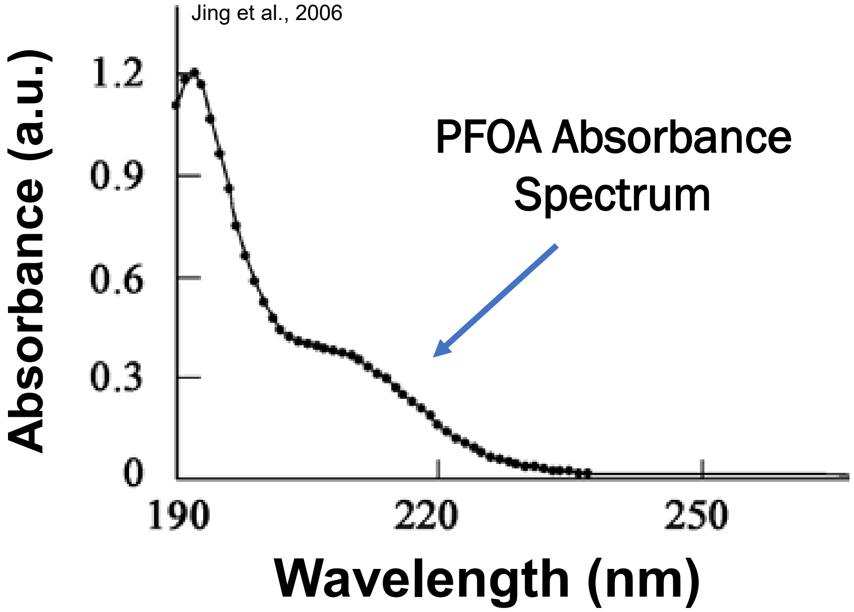
Energy requirements were reduced by > **four-fold**

275 nm = **2.66 kwh m^3 order^{-1}**

MP UV = 11.31 kwh m^3 order^{-1}



Future Potential for Bespoke Treatment of PFAS using UV LEDs



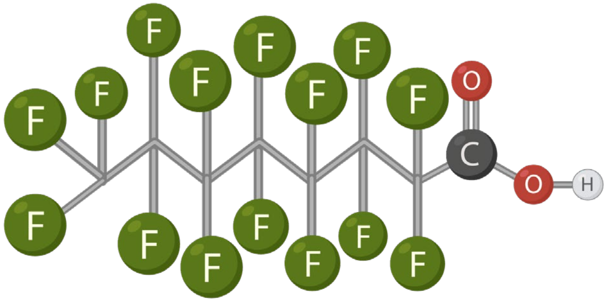
All PFAS absorb light in the far UVC region

Use of far-UVC LEDs could see bespoke remediation of legacy compounds

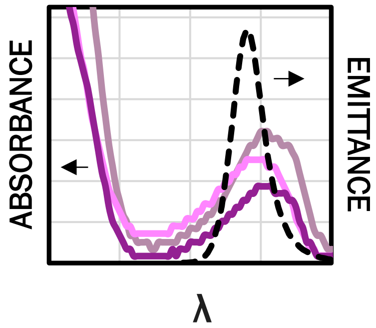
Jing, C. H. E. N., Zhang, P. Y., & Jian, L. I. U. (2007). Photodegradation of perfluorooctanoic acid by 185 nm vacuum ultraviolet light. *Journal of Environmental Sciences*, *19*(4), 387-390.

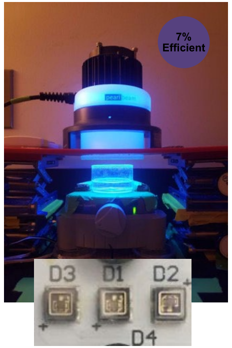
Conclusions

Increased monitoring effort is needed to understand the occurrence of PFAS in Canadian waters



UV LEDs are a versatile technology that could see the development of chemical-free destruction of legacy contaminants





The research team acknowledges funding through our NSERC Alliance Partnerships.

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STRAIGHT from the SOURCE

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