

FOCUS ON

Per- and Poly-Fluoroalkyl Substances (PFAS)



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Key Findings

- PFAS (per- and poly-fluoroalkyl substances) are a large group of human-made chemicals, with PFOA (perfluorooctanoic acid) and PFOS (perfluorooctane sulfonate) as the most studied PFAS.
- The unique chemical properties of PFAS have led to their widespread use in a variety of industry and consumer products since the 1940s, but these same properties also result in PFAS persisting in the environment.
- Many PFAS have been phased out from products since the early 2000s, with some exemptions. All Canadians are exposed to some PFAS through food, water, and consumer products such as packaging, textiles, and cosmetics with average Canadian PFAS serum levels decreasing over time. Some Canadians may be exposed to above average concentrations due to local contamination.
- Our understanding of how PFAS behave in the environment and their association with potential human health effects is evolving with new research. Potential human health effects associated with high PFAS exposures include liver effects, adverse pregnancy outcomes, select cardiovascular risk factors, immune responses and some cancers. Effects found in epidemiological studies are generally consistent with findings from animal studies, but the human evidence, particularly for health outcomes other than liver effects, is less robust and the clinical significance of the findings, where effects are seen with biomarkers, are not clear.

- Environmental regulations for PFAS continue to evolve as the science around PFAS evolves. In 2024, Health Canada and the United States Environmental Protection Agency (US EPA) both updated their PFAS guidelines for drinking water. Health Canada's drinking water objective value is 30 ng/L for the sum of 25 PFAS while the US EPA's maximum contaminant levels are 4 ng/L for PFOA and PFOS and 10 ng/L for perfluorohexane sulfonate (PFHxS), perfluorononanoic acid (PFNA) and hexafluoropropylene oxide dimer acid (HPFO-DA). Ontario provincial drinking water guidelines may also be reviewed.
- Where individuals are known to be exposed to above average concentrations of PFAS (such as when PFAS contamination is discovered in a local drinking water source), exposure reduction measures can be taken while health effects research continues. Examples of exposure reduction measures include installing a drinking water treatment system where warranted and making informed consumer choices to purchase PFAS free products.

Introduction

PFAS (per- and poly-fluoroalkyl substances) are a group of human-made chemicals that have been used in a wide variety of industrial and consumer products since the 1940s. However, interest and scientific understanding of how they behave in the environment and their potential human health effects has been increasing more recently and is now a rapidly evolving area. This Focus On provides a general overview of PFAS and the Ontario/Canadian context to support public health practitioners. This document summarizes the following:

- general description, known sources and concentrations in the environment,
- exposures,
- potential health effects,
- actions that can be taken to reduce exposures, and
- current regulations in Ontario and Canada.

Methods

A rapid grey literature search of public health, environmental health and toxicology resources was conducted to identify information on PFAS, environmental sources, how individuals are exposed to PFAS, how their use is regulated in Canada and Ontario, and practical advice for reducing exposures. Information was generally sourced from reviews of PFAS from regulatory authorities.

A peer-reviewed published literature search was also conducted to obtain recent evidence summaries on human health effects associated with PFAS. Specifically, PHO Library Services conducted a search on September 1, 2022 for systematic reviews and meta-analyses in the Embase and MEDLINE databases on articles related to PFAS and human health. The library search excluded animal studies and limited results to English language articles published between 2012 and 2022. The full library search strategy is available upon request. This search was updated in July 2024 to identify additional health effect research. The update focused on new evidence related to clinical testing advice, human health effects, and regulation and treatment of drinking water. In situations where more than one systematic review evaluated a specific human health outcome, a full-text review was conducted only on the systematic review with the most recent literature search period.

What are PFAS?

PFAS are a group of synthetic chemicals with unique chemical properties such as resistance to extreme temperatures, resistance to breakdown/degradation, water and oil repellency and non-stick characteristics.¹⁻⁴ These unique properties resulted in their widespread use in a variety of industry and consumer products since the 1940s. There are thousands of PFAS chemicals which can be found in paper and cardboard coatings, leather products, stain-resistant carpet, upholstery, clothing, non-stick coatings on cookware, food packaging, paints, varnishes, sealants, cleaning products, personal care products and cosmetics, aqueous film-forming foam (AFFF) for fire-fighting, and in the production of electronics, plastics and metals.^{1,2,4-11}

PFAS can be categorized based on their chemical structure, with PFOS (perfluorooctane sulfonate) and PFOA (perfluorooctanoic acid) being the most studied to date.^{2,8,12} Other PFAS of interest include perfluorohexane sulfonate (PFHxS), a known by-product in the production of PFOS and perfluorobutane sulfonate (PFBS) which is considered a potential replacement for PFOS. Other PFAS, such as perfluorobutanoic acid (PFBA), perfluorohexanoic acid (PFHxA), perfluorononanoic acid (PFNA), perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnDA), are also sometimes measured in the human population (i.e., in biomonitoring programs).⁴

The passing of the *Perfluorooctane Sulfonate Virtual Elimination Act* in 2008 added PFOS and its salts to the Virtual Elimination List under the Canadian Environmental Protection Act (CEPA), 1999.¹³ The passing of the *Prohibition of Certain Toxic Substances Regulations, 2012* further restricted the use of PFOS, PFOA and other select PFAS by prohibiting the manufacture, use, sale and import of these substances and products containing them (with some exceptions).¹⁴⁻¹⁷ A proposal is currently underway to revise this regulation to further restrict the use of PFOS and PFOA.¹⁸ While some companies voluntarily phased out the production and use of several PFAS substances in the early 2000s, and measures are in place within North America and Europe to restrict production, existing stocks are still in use and their manufacture continues in other parts of the world.^{9,10,19,20} In the United States, the Food and Drug Administration (US FDA) revoked regulations in 2016 which allowed the use of PFOS and PFOA in food packaging.²¹ Recently, a number of larger fast-food restaurant chains in Canada and the United States have reportedly committed to voluntarily phasing out packaging containing added PFAS.²²

PFAS IN THE ENVIRONMENT

Given their widespread use and chemical stability, PFAS have been widely detected in the environment. Major sources of PFAS in the environment include household waste (e.g., landfills), industrial sites where PFAS containing materials have been produced or applied, as well as AFFF firefighting events and training sites.²³⁻²⁵ These sources contribute PFAS to soil, air and water by leaching into groundwater, discharging to surface water, as well as releases to air and soil through spills and emissions. Once released into the environment, PFAS can remain for prolonged periods either within the water table or partitioning into sediment with a fraction of AFFF becoming airborne during fires as aerosols and diffuse chemicals.^{23,25}

PFAS persist in the environment and the body relatively unchanged due to their chemical structures.^{1,3-5,7} PFAS are unlikely to degrade or transform under ambient environmental conditions, but laboratory experiments have demonstrated that some physical, chemical and biological processes can change the chemical structure of PFAS under specific conditions. These transformations can result in changes in the form of PFAS within a mixture (e.g., alcohol to aldehyde), or the size of the molecules, potentially changing the toxicity of original mixture.^{24,25}

At this time, limited Canadian data with varying trends are available on PFAS concentrations in environmental media. According to Environment and Climate Change Canada, PFOS concentrations in fish (lake trout) showed an overall increase from 1979 to 2000, concentrations then stabilized for a few years before beginning to decrease.²⁶ This is consistent with a 2022 study that showed that Canadian freshwater concentrations of legacy PFAS (PFOS and PFOA) decreased between 2013 to 2020, while the concentration of other PFAS substances such as perfluoropentanoic acid (PFPeA) and PFBA increased during that timeframe (possibly due to their use as replacement PFAS in consumer products in lieu of PFOS and PFOA).²⁷ However, trends in specific environmental media and by PFAS chemical may vary, as shown by Gewurtz et al. for certain wildlife, sediment and water samples collected in and around Lake Ontario between the late 1970s and late 2000s.²⁸

In general, there is not enough information to predict PFAS trends in concentrations for water, sediment and air, but environmental concentrations, combined with PFAS stability and persistence, can result in bioaccumulation and biomagnification in the ecosystem. Table A in the Appendix shows PFOS levels measured in Canadian water, fish, sediment, and air from 2006 to 2017 as reported by Environment and Climate Change Canada.

PFAS EXPOSURES

All Canadians are exposed to some PFAS due to their persistence in the environment. Exposure to PFAS can occur through food and consumer products, soil, indoor dust and drinking water.^{4,9,10,20,29,30} PFAS exposure from drinking water may increase if consuming contaminated drinking water.^{10,20,29} The primary route of exposure may also be age-dependent, with oral exposure (via hand-to-mouth activity) to consumer products (e.g., treated fabrics and carpets) as the primary route of exposure for infants, toddlers and children.^{4,10,30}

Dietary (Food and Water)

Diet is one way Canadians are exposed to PFOA, PFOS and other PFAS.^{3,15,31,32} Food can become contaminated through the growing environment or processing equipment, through animal feed or water, or from food packaging material.³³ PFAS contamination in the growing environment does not necessarily indicate the grown foods will contain detectable levels of PFAS, as this will depend on the amount of PFAS in the growing environment, the type of PFAS present and the type of food/plant species.^{33,34} In general, most foods not grown or produced in specific areas with known PFAS contamination do not have detectable levels of PFAS.³⁴

An analysis of food samples collected between 1992 to 2004 conducted by Tittlemier et al. (2007) estimated an average daily dietary exposure of 250 ng/day using a subset of samples collected as part of the Canadian Total Diet Study.³⁵ More recent data on PFAS levels in Canadian food are not available, but an ongoing dietary exposure assessment study conducted by the US FDA shows that the majority of food samples analyzed since 2019 do not have measurable concentrations of PFAS.³⁶

PFAS have been used in non-stick cookware and in food packaging materials (e.g., fast-food wrappers, microwave popcorn bags, and paperboard take-out containers such as pizza boxes).²¹ However, the US FDA indicates the non-stick coating on cookware contains a negligible amount of PFAS capable of migrating into food and Health Canada's Food Research Division found food packaging was not a significant source of PFOA and PFOS.^{21,37}

Using an estimated average adult intake rate of 1.4 L/day, Tittlemier et al. (2007) used mean tap water concentrations from Calgary and Vancouver from another study to estimate 0.3 ng/day exposure to total PFAS via drinking water for the general Canadian population.^{31,35} A more recent analysis of 226

treated drinking water samples provides drinking water concentrations from 25 drinking water systems in Ontario using river, lake and groundwater sources between 2012 and 2016.³⁸ Mean and maximum concentrations of a group of ten PFAS were 6.1 ng/L and 20.0 ng/L, respectively. Detection of individual PFAS chemicals was variable, with percent detection ranging from 0 to 73%. Drinking water exposures can be higher in areas where water with elevated PFAS concentrations is relied upon as a drinking water source. Exposures from water during common household activities such as bathing, showering, washing dishes, brushing teeth and laundry are expected to be negligible.^{20,29,39}

According to the United States Centers for Disease Control and Prevention (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR), PFAS can be found in breast milk and the level of exposure to an infant through breastfeeding depends on a number of factors (e.g., level of PFAS in the mother, the amount of PFAS that transfers through milk, the duration of breastfeeding).^{5,10,30,40,41} A 2022 study of 664 Canadian breast milk samples found that total PFAS concentrations (sum of seven PFAS) ranged from 3.1 to 603 ng/L, with a median concentration of 106 ng/L.⁴² PFOA was the most frequently detected compound and generally contributed the most to the measured PFAS concentrations (approximately 30%).⁴² While further research on this potential route of exposure is needed, the CDC/ATSDR and the American Academy of Pediatrics state the benefits of breastfeeding outweigh any potential risks of PFAS exposure through breast milk.⁴⁰

Other

Other potential routes of exposure may include the ingestion of contaminated soil or household dust as well as the inhalation of aerosolized water.^{10,30,43-45} However, Health Canada reports that PFAS remain in water, they do not preferentially partition to air (i.e., it does not volatilize) and the primary mechanism for exposure to PFAS in drinking water is via ingestion.^{20,29,39} While Health Canada and the United States Environmental Protection Agency (US EPA) recognize that exposures to PFAS by inhaling water aerosols contaminated with PFAS can occur, the total mass of aerosolized water is low and due to its low volatility, PFAS will not concentrate in air, making this route of exposure negligible.^{20,29,43} PFAS exposure can also come from use of consumer products such as personal care products, leather products, carpets, upholstery and clothing.^{9,10,46,47}

PFAS LEVELS IN THE HUMAN BODY

Population-based biomonitoring data for select PFAS concentrations in human blood plasma are available via the Canadian Health Measures Survey (CHMS). The CHMS measured PFAS in healthy volunteers between 2007–2019. PFOA and PFOS were found in 100% and 99.3% of Canadians, respectively, in Cycle 6 of CHMS (2018-2019) (Table 1).^{46,48} Complete CHMS biomonitoring results by age group, sex and survey cycle are also available online.

Table 1: PFAS blood plasma levels in the Canadian population aged 3-79 years (2018-2019)⁴⁶

PFAS Chemical	Detection Frequency (%) (95% confidence interval)	Geometric Mean (µg/L) (95% confidence interval)
Perfluorooctane sulfonate (PFOS)	99.3 (98.6–99.7)	2.5 (2.3–2.8)
Perfluorooctanoic acid (PFOA)	100	1.2 (1.1–1.3)
Perfluorohexane sulfonate (PFHxS)	99.6 (99.1–99.9)	0.76 (0.69–0.85)
Perfluorononanoate (PFNA)	98.5 (97.3–99.1)	0.44 (0.41–0.47)
Perfluorodecanoic acid (PFDA)	67.6 (61.4–73.2)	0.12 (0.11–0.14)

Note: Although PFBA, PFHxA, PFUnDa, and PFBS were also measured as part of the CHMS, geometric mean values for concentrations in blood plasma were not reported for these chemicals as >40% of the data were below the limits of detection.

In general, concentrations of PFAS in blood plasma of Canadians aged 12 to 79 (or aged 20 to 79) have decreased over time.³ Between 2007–2009 and 2018–2019, PFOA concentrations declined by 52%, PFHxS concentrations declined by 64% and PFOS concentrations declined by 67% in Canadians aged 20-79. Between 2009–2011 and 2018–2019, PFNA concentrations declined by 47% and PFDA concentrations declined by 36% in Canadians aged 12-79.³ Comparisons between age groups found higher blood plasma concentrations among adults versus children, with highest levels reported in the 60 to 79 age group. Blood serum levels in the United States from 2007 to 2016 are similar to Canadian blood plasma levels.^{3,49,50}

In July 2022, the National Academies of Sciences, Engineering, and Medicine (NASEM) published the “Guidance on Perfluoroalkyl and Polyfluoroalkyl substances (PFAS) Exposure, Testing, and Clinical Follow-up Consensus Report” which reviews the health effects of PFAS and provides recommendations for clinical management of PFAS exposure.⁵¹ While the NASEM report recommends that clinical laboratories use methods similar to those used by the CDC to test for PFAS, few laboratories currently use this method and have the necessary quality control processes.⁵¹ The NASEM report recommends individuals with “a history of elevated exposure” be tested but does not define who this refers to; in addition, some authors state that testing could lead to further unnecessary investigations.^{51,52}

The Agency for Toxic Substances and Disease Registry (ATSDR) information for clinicians suggests efforts should be focused on identifying and reducing potential sources of exposure and to follow appropriate standard preventive care measures.⁵³ Other limitations in testing include inability to attribute or predict disease, identify the source of exposure for what is being measured (since PFAS are ubiquitous), distinguish if measured levels are related to recent or past exposures (due to the long half-life of many PFAS in the body, with some in the order of decades), and a lack of guidance for management following PFAS testing (most testing does not lead to clinical action) and prohibitive costs (PFAS testing is not publicly funded).^{52,53}

HUMAN HEALTH EFFECTS

Health Canada reports some PFAS are well absorbed in the body, poorly excreted and not extensively metabolized.^{3,4} The potential health risks from exposure to PFAS depends on the level and duration of exposure (i.e., how much and for how long).³⁹ Toxicological studies involving laboratory animals have found high levels of PFAS are associated with reproductive, developmental, endocrine, liver, kidney and immunological effects.^{3,10,54} However, effects observed in animals do not necessarily translate to humans.

The majority of systematic reviews and meta-analyses focused on epidemiological (human) studies that examined human health effects associated with exposure to PFOS and PFOA, while those published in the last two years have looked at health effects associated with more types of PFAS.

Overall, epidemiological data from cross-sectional studies demonstrate sufficient evidence that elevated exposures to certain PFAS, particularly PFOS and PFOA are associated with increased liver enzymes which may indicate the presence of liver disease or damage.⁵⁵

There is also limited evidence across studies that elevated exposures to certain PFAS are associated with hypertension,⁵⁶ higher lipid levels,⁵⁷ increased risk of select adverse pregnancy outcomes including low birthweight and preterm birth,⁵⁸⁻⁶¹ and allergic outcomes in children including exposure to PFOS and atopic dermatitis, and exposure to PFOA and allergic rhinitis.⁶² There is limited evidence that PFAS is associated with decreased immune response to diphtheria, rubella, tetanus, measles, mumps, and influenza vaccines based on recent systematic review and meta-analyses,^{63,64} as well as limited evidence of an association with lower body mass index in children.^{65,66} Studies do not consistently show an association between PFAS and type 2 diabetes,⁶⁷ pregnancy outcomes including small for gestational age,^{58,61,63} miscarriage,⁵⁹⁻⁶¹ and hypertensive disorders of pregnancy,^{61,68} as well as effects on reproductive hormones (e.g., testosterone, estradiol)⁶⁹, lower sperm motility,⁷⁰ and prostate cancer.⁷¹

Systematic reviews and meta-analyses examining other health outcomes have not demonstrated an association with PFAS exposure. This includes neurodevelopment in children, childhood obesity,⁶⁶ stroke, bone health, age of menarche, and hyperuricemia.⁷²⁻⁷⁸

Based on the health effects evidence for PFAS, agencies such as the ATSDR and Health Canada have identified that industrial workers with occupational exposure to PFAS, individuals with pre-existing conditions affecting the same systems (e.g., those with compromised liver function or immune systems), pregnant women and young children may be at a higher risk of health effects.^{10,31,32}

Our literature search did not identify systematic reviews or meta-analyses that examined the relationship between potential human health effects and PFAS mixtures. The gap in scientific research on how PFAS chemicals behave in mixtures is a challenge for evaluating the potential health effects associated with the mixtures people are exposed to.

In 2023, the International Agency for Research on Cancer (IARC) classified PFOA as a human carcinogen (Group 1) based on “sufficient” evidence for cancer in experimental animals and “strong” mechanistic evidence in humans (for epigenetic alterations and immunosuppression). There was also “limited” evidence for renal and testicular cancer in humans. PFOS was classified as possibly carcinogenic to humans (Group 2B) based on “strong” mechanistic evidence (for epigenetic alterations and immunosuppression), “limited” evidence for cancer in experimental animals and “inadequate” evidence for cancer in humans.⁷⁹

In general, further research is required to understand the adverse health effects associated with PFAS exposure.

PFAS Guidelines, Regulations and Exposure Reduction Measures

While the following guidelines and regulations may not be directly applicable to all Ontario settings, they provide context for interpreting environmental measurements and may help indicate when further investigation of potential PFAS contamination could be useful. Many jurisdictions have derived PFAS guidelines for drinking water, while some guidelines for soil and groundwater are also available. Although PFAS are not specifically regulated in food and consumer products, the *Prohibition of Certain Toxic Substances Regulations, 2012* has prohibited the manufacture, use, sale and import of PFAS and PFAS-containing products (with some exceptions).¹⁴

In general, environmental guidelines are developed to be protective of populations and assume lifetime of exposure to a substance (i.e., protective of chronic exposures). During the guideline development process, it is common to factor in a margin of safety or uncertainty factors such that they are protective of sensitive populations and life stages that may be more susceptible to chemical exposures (e.g., those with pre-existing chronic conditions or young children).^{12,31,32} Guidelines may also take into account other potential sources of exposure to PFAS (e.g., total exposures from food, water, air, consumer products).¹² Therefore, short-term exposures to PFAS at concentrations above guideline levels are not expected to result in health effects. The potential for health risks resulting from prolonged exposures to high levels of PFAS depend on how much and how long a person was exposed.

Different jurisdictions may also take different approaches in deriving guidelines for chemicals in the environment. They may vary in assessing benchmark studies, weight of evidence, technical feasibility, background concentrations, and for certain similar chemicals whether to address them individually or as a group.^{18,80}

DRINKING WATER

Ontario Ministry of the Environment, Conservation and Parks (MECP) interim drinking water advice

In 2017, following the identification of a 'widespread PFAS release' from firefighting foam that impacted groundwater, the MECP introduced a drinking water guidance value of 70 ng/L for 11 PFAS which is applied where PFAS have been detected in water in Ontario.^{81,82} It is anticipated that Ontario drinking water guidance will be reviewed in response to the recent publication of the federal drinking water objective in Canada and national drinking water regulations in the United States (see below).

Health Canada Drinking Water Objectives

Drinking water objective (2024)

Health Canada released a drinking water objective value for total PFAS in 2024. This objective replaces the two previous drinking water guidelines and nine screening values derived for individual PFAS (see below). The drinking water objective serves to address concerns and reduce exposures to certain chemicals from drinking water while a formal guideline is revised or developed (the development of a guideline follows a comprehensive scientific process and takes many years).^{83,84} The objective value is not solely based on potential health effects because of the following limitations:⁸⁴

- Rapidly evolving, complex science about PFAS,
- Lack of consensus regarding the most sensitive health effects, and
- Different approaches to hazard and risk assessments amongst various organizations.

Instead, the objective value is based on:⁸⁴

- Technical feasibility of drinking water treatment using current technologies,
- Limit of quantification using approved analytical methods, and
- Environmental concentrations of PFAS reported by Canadian monitoring data.

Health Canada’s rationale described the need to adopt a precautionary, group-based approach in addressing PFAS chemicals due to “*the potential for exposure to multiple PFAS at the same time, the potential for negative health impacts, the uncertainty and the limited data on many PFAS*”. In general, Health Canada emphasized “[t]he lower the levels of PFAS, the lower the risk to public health” and recommends that PFAS levels in drinking water be maintained as low as reasonably achievable (ALARA).^{83,84}

The objective value is 30 ng/L for the sum of 25 specific PFAS detected in drinking water (full names provided in Appendix B):

PFBA	PFPeA	PFHxA	PFHpA	PFOA
PFNA	PFDA	PFUnA	PFDoA	PFBS
PFPeS	PFHxS	PFHpS	PFOS	4:2 FTS
6:2 FTS	8:2 FTS	HFPO-DA	ADONA	PFMPA
PFMBA	NFDHA	9C1-PF3ONS	11C1- PF3OUdS	PFEESA

The laboratory method used to analyze drinking water samples should provide results for the above 25 PFAS and conform to current best practices for accurate PFAS testing; Health Canada recommends the use of US EPA Method 533.⁸⁴

Previous maximum acceptable concentration (MAC) and drinking water screening values

Prior to the 2024 drinking water objective for PFAS, Health Canada previously developed maximum acceptable concentration (MAC) guideline values for two PFAS; PFOA (200 ng/L) and PFOS (600 ng/L) which are both based on liver effects observed in laboratory studies involving rats.^{31,32} Following the release of the MACs, Health Canada also released drinking water screening values where the sum of the ratios of the concentrations of PFOS and PFOA relative to their MACs should not exceed 1 to account for the similar mechanism for toxicological effects of PFOA and PFOS. Drinking water screening values for a number of other PFAS are also available from Health Canada.³⁹

MACs and screening values are designed to protect the health of the general public (including children) from lifetime exposures to the substance (i.e., chronic exposures) in drinking water.³⁹ As substance-specific information is lacking for most PFAS, development of guideline values often factor in a grouping approach to consider PFAS as a class of chemicals rather than conducting separate evaluations of individual substances.

United States Environmental Protection Agency National Primary Drinking Water Regulations

The US EPA announced final National Primary Drinking Water Regulations (NPDWRs) in April of 2024. These regulations include legally enforceable Maximum Contaminant Levels (MCLs) for five individual PFAS (4 ng/L for PFOA and PFOS and 10 ng/L for PFHxS, PFNA and HFPO-DA) as well as PFAS mixtures containing two or more of PFHxS, PFNA, HFPO-DA and PFBS which are addressed using a Hazard Index approach to account for combined and co-occurring PFAS.⁸⁵ The Hazard Index is a sum of individual PFAS fractions, with each fraction comparing levels of specific PFAS measured in water against the highest level below which there is no risk of health effects; the MCL for PFAS mixtures is a Hazard Index value of 1 (unitless).^{85,86} The NPDWR also includes health-based, non-enforceable Maximum Contaminant Level Goals (MCLGs) for these PFAS (zero for PFOA and PFOS and 10 ng/L for PFHxS, PFNA, HFPO-DA and a hazard index value of 1 for PFAS mixtures).⁸⁵

The MCLGs are non-enforceable public health goals that represent the level of a contaminant in drinking water below which there is no known or expected health risk and allow for a margin of safety. In contrast, the MCLs are legally enforceable standards and represent the highest level of a contaminant allowable in drinking water. The MCLs are set as close to MCLGs as possible while taking into consideration the best available treatment technology as well as cost.⁸⁷ A select number of individual US states have also enacted their own drinking water regulations for PFAS. Currently, a total of 20 states have established drinking water guidelines for PFOS and/or PFOA with some also having guidelines for other PFAS chemicals.⁸⁸

Exposure Reduction Measures for Drinking Water

PFAS are not regularly monitored in drinking water in Canada, but levels are generally expected to be low.^{31,32} If a drinking water source is known to be contaminated with PFAS, drinking water system owners can reduce overall exposure by using water treatment, or an alternative water source for drinking, cooking and preparing infant formula. Options can be explored with professionals specialized in water treatment, but examples of treatment processes effective at removing PFAS include adsorption by granular activated carbon (GAC), ion exchange (IX) resin, or high pressure membranes (i.e., nanofilters (NF) and reverse osmosis (RO)).^{20,29,89} These can be adapted to suit all sizes of treatment systems. NSF International lists specific water treatment products that have been independently verified to reduce levels of PFAS in drinking water; these will be listed as certified to NSF 53, and/or NSF 58 to specifically include reduction of 7 individual PFAS (PFHpA, PFOA, PFNA, PFDA, PFBS, PFHxS and PFOS) to less than or equal to a total concentration of 20 ng/L.⁸⁴ As with any water treatment system, it is important to follow the manufacturer's recommendations for operation and maintenance of a treatment system (e.g., replacement of filter media).

SOIL

Canadian soil quality guidelines for PFOS are available from the Canadian Council of Ministers of the Environment (CCME). The PFOS soil quality guideline for protection of human health is 0.01 mg/kg for all land uses (agricultural, residential/parkland, commercial and industrial).⁹⁰ Although CCME did not develop soil guidelines for PFOA, they note that the health effects associated with PFOS and PFOA are similar and additive effects need to be taken into consideration. Similar to the approach taken by Health Canada, the sum of the ratios of the concentrations of PFOS and PFOA relative to the PFOS soil quality guideline should not exceed 1 to account for additive toxicological effects.⁹⁰ Given that the CCME soil guidelines were derived using Health Canada's assessment of health effects, these guidelines may be affected following Health Canada's 2024 revision to their PFAS drinking water guidelines.

GROUNDWATER

The CCME has also developed groundwater quality guidelines for PFOS. CCME groundwater quality guidelines are intended to represent concentrations of contaminants in groundwater below which no appreciable human health risk are expected from long-term (chronic) exposure.⁹¹ The PFOS groundwater guideline for the protection of human health is 0.0006 mg/L (equivalent to 0.6 µg/L) and the sum of the ratios of the concentrations of PFOS and PFOA relative to the PFOS groundwater quality guideline should not exceed 1 to account for the additive toxicological effects of PFOA and PFOS.⁹⁰ Given that the CCME groundwater guidelines were derived using Health Canada's assessment of health effects, these guidelines may be affected following Health Canada's 2024 revision to their PFAS drinking water guidelines.

Discussion and Conclusions

The unique physical properties of PFAS have resulted in their widespread use in many consumer products and industrial processes such as paper and cardboard coatings, stain-resistant carpet, non-stick coatings on cookware, and aqueous film-forming foam (AFFF) for fire-fighting. However, the same physical properties have also allowed PFAS to persist in the environment, gaining public and scientific attention in recent years.

Studies have identified landfills, industrial sites and areas where firefighting activities have occurred as sources of PFAS in the environment. Once in the environment, PFAS can enter groundwater and surface water, and may eventually enter the food chain, providing multiple sources of potential exposure for the general public. The sources of exposure may include diet, soil, indoor dust and drinking water, in addition to consumer goods and textiles.

Guidelines for PFAS are most commonly available for drinking water though there are some for soil and groundwater. These guidelines are typically developed to protect populations from chronic exposures to PFAS and incorporate margins of safety. Some drinking water regulatory guidelines have recently been lowered as evidence is emerging on potential health effects.

Animal studies on PFAS exposure show an association with increased liver, reproductive, endocrine, kidney and immunological effects. This is supported by an association with elevated liver enzymes particularly for PFOS and PFOA in cross-sectional epidemiological studies, but human data are otherwise limited and further studies are needed on their clinical significance.

Currently, all Canadians are exposed to some PFAS however health effects cannot be clearly attributed. Where individuals are exposed to elevated levels of PFAS in the environment over an extended period, actions to reduce exposures can be taken. For example, elevated concentrations above applicable guidelines can occur in areas of known PFAS contamination, or in workplaces (e.g., using AFFF), leading to exposures. In these situations, efforts to reduce PFAS exposures are generally recommended by various organizations. Measures such as drinking water treatment systems for homeowners with impacted drinking water wells, making informed consumer choices such as purchasing PFAS free products as indicated and following fish consumption guidance in Ontario can reduce overall exposures until more evidence on the health effects of PFAS are established.⁹²⁻⁹⁶

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Appendix A: PFAS Levels in the Environment

Table A: PFOS levels measured in Canadian water, fish, sediment, and air as reported in various studies.^{26,27,38,97,98}

Environmental Sample Type	Sample Description	Measured PFOS Concentrations
Surface Water	Samples collected from 29 sampling sites across Canada between 2013-2020	Median concentration of 2.3 ng/L Maximum concentration of 27.6 ng/L
	Samples collected from the Great Lakes Nearshore Index and Reference Stations between 2005 and 2019	Median concentrations of 2.30 ng/L (2005-2007) and 2.15 ng/L (2018-2019) Mean (95% CI) concentrations of 3.74 ng/L (2005-2007) and 2.03 ng/L (2018-2019) Maximum concentrations of 15 ng/L (2005-2007) and 10 ng/L (2018-2019)
	Samples collected from the Great Lakes basin between 2006 and 2018 (includes precipitation and surface water)	Median concentration of 0.93 and 2.1 ng/L in precipitation and surface water, respectively Maximum concentration of 7.4 and 14 ng/L in precipitation and surface water, respectively
	Samples collected from 8 drainage sites across Canada between 2016-2017	Concentration range of 2 – 26.1 ng/L
	Samples collected from 11 drainage regions across Canada between 2007-2010	Maximum concentration of 10 ng/L
Fish	Lake Ontario lake trout tissue collected between 2013-2014	Concentration range of 40-60 µg/kg
	Lake Ontario lake trout and walleye collected in 2006 and 2010	Geometric mean of 62 µg/kg

Environmental Sample Type	Sample Description	Measured PFOS Concentrations
	Lake Erie lake trout and walleye collected in 2006 and 2010	Geometric mean of 90 µg/kg
Sediment	Samples collected from 18 sites across Canada in 2008	Maximum concentration of 0.010 µg/g dry-weight from Lake Ontario
Air	High-volume air samples collected from three locations in 2009	Geometric mean: Toronto, ON: 1.5 pg/m ³ Lake Superior: 0.43 pg/m ³ Alert, NU: 0.2 pg/m ³
	Passive air samples collected from eight locations in 2009	Single sample results: Northern Ontario: 18 pg/m ³ Toronto, ON: 8 pg/m ³ Saskatchewan: 5 pg/m ³ Whistler, BC: 4 pg/m ³ Alert, NU: 2 pg/m ³ (Not detected at other sites)
Groundwater	Samples collected from sites with known PFAS contamination (firefighting training areas at airports)	Concentration range: London, ON: 5,000 – 130,000 ng/L Hamilton, ON: <20 – 560,000 ng/L

Note: Groundwater data has been converted from µg/L to ng/L for comparison purposes

Appendix B: Drinking water objectives for PFAS in Canada

Table B - Health Canada drinking water objectives for PFAS expressed in nanograms per litre (ng/L)

PFAS Chemical	Abbreviated Name	Health Canada Drinking Water Objective ⁸⁴
11-Chloroeicosafluoro-3-oxaundecane-1-sulfonic acid	11Cl-PF3OUdS	-
9-Chlorohexadecafluoro-3-oxanonane-1-sulfonic acid	9Cl-PF3ONS	-
4,8-Dioxa-3H-perfluorononanoic acid	ADONA	-
Hexafluoropropylene oxide dimer acid	HPFO-DA	-
Perfluorobutanesulfonic acid	PFBS	-
Perfluorodecanoic acid	PFDA	-
Perfluorododecanoic acid	PFDoA	-
Perfluoroheptanoic acid	PFHpA	-
Perfluorohexane sulfonic acid	PFHxS	-
Perfluorohexanoic acid	PFHxA	-
Perfluorononanoic acid	PFNA	-
Perfluorooctane sulfonic acid	PFOS	-
Perfluorooctanoic acid	PFOA	-
Perfluoroundecanoic acid	PFUnA	-
Nonafluoro-3,6-dioxaheptanoic acid	NFDHA	-
Perfluorobutanoic acid	PFBA	-

PFAS Chemical	Abbreviated Name	Health Canada Drinking Water Objective ⁸⁴
1H,1H,2H,2H-Perfluorodecane sulfonic acid	8:2 FTS	-
Perfluoro(2-ethoxyethane) sulfonic acid	PFEESA	-
Perfluoroheptanesulfonic acid	PFHpS	-
1H,1H,2H,2H-Perfluorohexane sulfonic acid	4:2 FTS	-
Perfluoro-3-methoxypropanoic acid	PFMPA	-
Perfluoro-4-methoxybutanoic acid	PFMBA	-
1H,1H,2H,2H-Perfluorooctane sulfonic acid	6:2 FTS	-
Perfluoropentanoic acid	PFPeA	-
Perfluoropentanesulfonic acid	PFPeS	-
Sum of twenty five PFAS	-	30

Summary of Revisions

Changes in this revision are summarized in the table below.

Date of Implementation	Description of Major Changes	Page
Sept 2025	Key findings updated to describe new drinking water guidelines from Health Canada and the US EPA	2
Sept 2025	Description of methods changed to include updated literature search	2-3
Sept 2025	Added guidance on clinical testing for PFAS	6
Sept 2025	Updates to scientific evidence on potential human health effects associated with PFAS and updated cancer classification for PFOS and PFOA	7-8
Sept 2025	Updates to drinking water guidelines for PFAS	8-11
Sept 2025	Performance of NSF-certified water treatment systems for the reduction of PFAS levels in drinking water	12
Sept 2025	Removed table containing previous Health Canada drinking water guidelines for PFAS (MACs and screening levels) and Ontario PFAS drinking water advice	23
Sept 2025	Added table describing 2024 Health Canada drinking water objectives for PFAS, including full chemical names for the 25 individual PFAS chemicals	23

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