



## Research article

# Estimating the number of airports potentially contaminated with perfluoroalkyl and polyfluoroalkyl substances from aqueous film forming foam: A Canadian example



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## ABSTRACT

Assessing the extent to which emerging contaminants (ECs) such as perfluoroalkyl and polyfluoroalkyl substances (PFAS) have been released into the environment is one of the foundations for developing effective management and remediation strategies for impacted sites. PFAS are known to have caused the contamination of soil, groundwater, and surface water as a result of aqueous film forming foam (AFFF) being accidentally or intentionally released into the environment. To date, the scope of the issue has not been evaluated in Canada. In this study we developed a framework, in the form of a decision tree, to estimate the number of potentially PFAS impacted airport sites in Canada as a result of AFFF releases. The screening process was completed using publicly available resources including airport websites, the Canadian Owners and Pilots Association website, Sky Vector, Transport Safety Board of Canada aviation investigation reports, the Aviation Safety Network website, and Google maps. The methodology presented in this study could be used to identify additional PFAS impacted sites in Canada or other jurisdictions worldwide. 2071 airport/heliport sites in Canada were investigated with indications that 152 (7%) of these sites likely have PFAS contamination as a result of the use of AFFF at firefighter training areas (FFTAs) and/or accidents where fires occurred. In addition, another 268 sites (13%) were identified as possibly impacted with PFASs primarily as a result of the location having the ability to store and dispense petroleum products, and therefore having AFFF systems onsite. Surficial geology was also identified for all sites determined to likely have PFAS contamination. An estimated 42.8% had surficial geology composed of sand, 27% had clay, 19.7% organic-based, with the remaining sites found on cryosols or rock. Methodological validation was also completed. The procedure used in this study successfully predicted occurrences of PFAS contamination at 25 sites where contamination, as a result of AFFF use, was confirmed by Canadian governmental departments. For these 25 sites, the distance from potential release areas to the nearest surface water was calculated. Five of the sites were within 200 meters of surface water, 19 were within one kilometer, and all 25 were within 2.5 kilometers. This suggests that surface water may have been historically impacted by PFAS at as many as 152 to 420 different airport locations in Canada.

## 1. Introduction

Aqueous film forming foam (AFFF) is a synthetic mixture containing both fluorinated and hydrocarbon-based surfactants, and has the ability to rapidly extinguish hydrocarbon fuel fires (Environment Canada, 2012). AFFF is used to cool the fire, and to coat the fuel layer, thus preventing its contact with oxygen and resulting in suppression of combustion. 3M historically manufactured AFFF which contained significant amounts of perfluoroalkyl and polyfluoroalkyl substances (PFAS), more specifically perfluorooctanesulfonic acid (PFOS) up until the early 2000s, and PFOA in formulations previous to 1976

(Prevedouros et al., 2006; Place and Field, 2012; Backe et al., 2013). Over the same periods competing manufacturers also marketed AFFF formulations which contained various types of fluorotelomers (C4 – C12) (Place and Field, 2012; Houtz et al., 2013). The properties of PFAS give them an inherent stability in high temperature fire fighting environments; however these same properties also make them resistant to degradation in the environment (Blum et al., 2015), and therefore highly persistent (Wang et al., 2017). Some PFAS, such as fluorotelomers, can be transformed in the environment and could ultimately become other more stable PFAS such as perfluoroalkyl acids (Houtz et al., 2013; Wang et al., 2017), like PFOA. AFFF containing PFOS is no

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longer manufactured in North America as a result of both 3M's voluntary phase-out of perfluorooctane sulfonyl fluoride-based chemicals (3M 2000), and the USEPA negotiated voluntary phase-out of perfluorooctanesulfonic acid (PFOS) production, for all manufacturers, by 2002. AFFF samples analyzed post 2010 indicate that manufacturers have begun to significantly reduce or eliminate fluorinated surfactants (C8-C12) in their formulations; however those same samples also contain significant amounts of 6:2 fluorotelomers (Houtz et al., 2013; Ouellette and Farley, 2013).

Firefighting training and emergency fire suppression are common historical and ongoing activities at Canadian airports, both military and otherwise. When AFFF is used for training activities, the potential for surface soil and subsurface contamination is based on the available facility infrastructure, which historically did not focus on containment. Additionally, when fighting fires in emergency situations, AFFF containment is not considered a priority requirement. Although the exact PFAS used in different AFFF formulations is largely unknown, given historical and current governmental regulations surrounding AFFF, it is expected that PFAS, as a group of chemicals, have been released into the environment at many locations across Canada. One instance of note was the deployment of 45,000L of AFFF on a fire at the Lester B. Pearson International (Toronto) Airport, Canada, resulting in the downstream contamination of surface water and fish (de Solla et al., 2012). At another Canadian location PFOS contamination was found in the groundwater, which is also the drinking water supply, of the Royal Canadian Air Forces' (RCAF) 14 Wing Greenwood, Nova Scotia (Kelly, 2010). Although these two instances are well known, no large scale screening of Canadian Airports has been conducted to estimate the potential breadth of PFAS impacted sites across the country.

PFAS fall into a broad category of environmental chemicals known as emerging contaminants (ECs). ECs are a group of contaminants that were previously unknown or unrecognized as being of concern but are under increasing scientific and regulatory scrutiny (Covaci et al., 2011). There are usually significant gaps in the current understanding of ECs, including their toxicity, bioaccumulation, occurrence, transport, and transformation mechanisms (Yan et al., 2010). This is currently the case for the majority of PFAS (Wang et al., 2017). However, in the case of some PFAS, such as PFOS and PFOA, several jurisdictions have adopted interim guidance values. For example, in Canada, Environment and Climate Change Canada (ECCC) publishes federal environmental quality guidelines (FEQGs) which provide benchmarks for the quality of the ambient environment. These FEQGs range across different land uses and exposure scenarios. As of November 2017 the FEQG was 6.8 µg/L for surface water, and 10 µg/kg for agricultural and residential/parkland soils (ECCC, 2017). Aside from ECCC, Health Canada (HC) provides guidelines related to human exposures, which encompasses drinking water. As of November 2017 the HC screening value for PFOS in drinking water was 0.6 µg/L (HC, 2017). In addition to PFOS, HC also has interim screening values for 8 additional PFAS including perfluorooctanoic acid PFOA (0.2 µg/L). Table 1 outlines the current federal based guidelines on PFAS in Canada, and gives some comparison to the current USA (USEPA, 2016) and Australia government guidance (DER, 2016; DoH, 2018).

It has been estimated that more than 3000 different PFAS have been on the market and therefore potentially released to the environment (Wang et al., 2017). Although Canada does have some of the most comprehensive PFAS guidance (in terms of number of different PFAS covered), replacement compounds for some PFAS, such as PFOS and PFOA, are already in many products and therefore likely to have already been released to the environment. Some jurisdictions have put in place guidance for the most ubiquitous replacement compounds. For example, the Danish EPA has defined a drinking water guidance value of 0.1 µg/L for 6:2 FTS telomers (PFOS replacement in AFFF), and the North Carolina Department of Environmental Quality in the USA has a drinking water guidance value of 0.14 µg/L for perfluoro-2-propoxypropanoic acid (PFPrOPrA), which has the trade name GenX, and is

**Table 1**

Selected PFAS guidance in Canada, Australia and the United States. HC- Health Canada, ECCC – Environment and Climate Change Canada, DoH – Department of Health (Australia), USEPA – United States Environmental Protection Agency. \*PFNA is currently undergoing additional scientific review by HC. ECCC values are derived for ecological receptors, where HC values are derived for human receptors.

Drinking water (µg/L)	HC	PFOA	0.2
	DoH	PFOA	0.56
	HC	PFOS	0.6
	HC	PFHxS	0.6
	HC	PFBA, PFBS, PFPeA, PFHxA, PFHpA, PFNA	30, 15, 0.2, 0.2, 0.2, 0.2*
	USEPA	PFOA + PFOS (combined)	0.07
Soil – residential/ parkland/ agricultural (mg/kg)	DoH	PFOS + PFHxS (combined)	0.07
	ECCC	PFOS	0.01
	HC	PFOA	0.8
	HC	PFOS	2.6
	HC	PFBA, PFBS, PFPeA, PFHxS, PFHxA, PFHpA, PFNA	114, 61, 0.95, 2.3, 0.95, 0.95, 0.35
	DoH	PFOS (residential specific)	4
Surface water (µg/L)	ECCC	PFOS	6.8
Recreational water (µg/L)	DoH	PFOA	5.6
	DoH	PFOS/PFHxS	0.7
Groundwater (µg/L)	ECCC	PFOS	6.8
	DoH	PFOS (non-potable)	5

generally produced as a PFOA replacement (Sun et al., 2016). Given the complexities of AFFF mixtures used, it is not practical to detect all PFAS at a contaminated site. However the PFAS currently targeted in the HC DW guidance is relatively inclusive to the most abundant and/or likely compounds, save the fluorotelomers, in current use. Given the similar range of guidance values for most PFAS, perhaps the most effective way to think about PFAS contamination is with respect to total PFAS present. In this respect a more simplified understanding of whether PFAS has been released to the environment (no matter what the specific chemistry) could serve as a starting point for identifying suspected PFAS contaminated sites. The scope of the issue regarding PFAS contaminated sites has not been evaluated in Canada to date. It is unknown how many sites may be contaminated, and therefore it is unknown what level of risk mitigation or clean-up is likely to be required into the future.

Consequently, this study focused primarily on the possible extent of PFAS contamination in Canada as a result of airport/heliport operations across the country. Four aspects of airport/heliport operations formed the basis of the investigation. The first is that PFAS were a component of the AFFF that was used to fight/prevent fires in aircraft accidents, and this AFFF has been used in large fire suppression systems for aircraft hangars since 1960. The second aspect is that at some airports, firefighters will deploy a layer of AFFF-containing foam on the runway or tarmac whether the accident resulted in a fire or not. This is done as a fire prevention measure to shield any spilled fuel from potential ignition sources, such as sparks and/or hot aircraft parts. The third aspect is that fire fighters use AFFF at firefighter training areas (FFTAs), found at all Royal Canadian Air Force Bases/Wings and many large commercial airports. These facilities are necessary to ensure firefighting skills and equipment meet the standards required to react quickly and appropriately in the event of an emergency. As such, these facilities use live fire exercises to simulate real-life situations such as employing AFFF to extinguish fuel-based fires, specifically Class B (petroleum-based) fires. Traditionally, these sites did not capture and treat firefighting water and consequently it was released into the environment. Over the years these sites began to implement more environmentally conscious practices such as capturing and treating fire-fighter water and using propane in the place of diesel as the main fuel source in simulated/practice fires. However, these water treatment efforts focus predominantly on the removal of hydrocarbons and not PFAS. This is for

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