Development of Canadian Soil Quality Guidelines for PFOS and PFOA

Darcy Longpré[1], Philippa Cureton[2], Luigi Lorusso[3]

[1] Environmental Health and Internationally Protected Persons, Controlled Substances and Environmental Health, Regulatory Operations and Regions Branch, Health Canada, Longueuil, QC, Canada, J4K 1C7
[2] National Guidelines and Standards Office, Science and Technology Branch, Environment and Climate Change Canada, Gatineau, Quebec, Canada, K1A 0H3
[3] Safe Environments Directorate, Chemicals and Environmental Health Management Bureau, Contaminated Sites Division, Health Canada, Ottawa, ON, Canada, K1A 0K9

Introduction

In recent years perfluoroalkylated substances (PFAS) have been the focus of much attention due to their persistence and unique chemical properties. Perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) are generally emitted to the environment from chemical mixtures that contain several PFAS and their precursors. Therefore, due to the degradation of more volatile precursors, PFOS and other PFAS may be found in areas distant from any source, despite their relatively low volatility.

Numerical values that can be used to screen soils at potentially contaminated sites are useful and necessary to assess and manage contaminated sites. No Canadian screening values were available to assist in assessing federal contaminated sites and values from other jurisdictions were not adapted to the Canadian context. Health Canada and Environment and Climate Change Canada have developed soil screening values (SSVs) for several PFAS. Interim values are now available for PFOS (ecological and human health), PFOA (human health) and others are currently being developed (including the ecological values for PFOA and -eco and human health values for some additional PFAS).

Following *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (SQGs) (CCME 2006), both environmental and human health soil quality guidelines were developed and the lowest of value generated from the two approaches, for each of four generic land use scenarios was recommended as the Soil Screening Value (SSV) for use on federal contaminated sites in Canada. These same values, accompanied by extensive background documentation, will undergo a peer review process before being considered as Canadian Environmental Quality Guidelines (CEQGs, or SQGs in the specific case of soil) by the Canadian Council of Ministers of the Environment (CCME).

The proposed SSVs for PFOS are: 0.01 mg/kg for agricultural and residential land uses and 0.14 mg/kg for commercial and industrial land uses. These PFOS values are based on the protection of environmental health, as these values were lower than the values calculated for the protection of human health. The proposed human health SSVs for PFOA are: 0.85 mg/kg for agricultural and residential land uses; 1.28 mg/kg for commercial land uses; and 12.1 mg/kg for industrial land uses. The PFOA values are based solely on the protection of human health since no values for the protection of environmental health could be calculated at the time of publication.

For human exposures, both PFOS and PFOA have similar critical effects and therefore their risks should be summed to determine overall risk.

The derivation process for the development of the human health values for PFOS and PFOA will be presented herein. The ecological values for PFOS will be described briefly as will future work.

Materials and methods

In order to derive environmental quality guidelines for PFOS and PFOA, reviews of the chemical and physical properties, sources and emissions in Canada, environmental fate and behaviour, and toxicological effects in environmental species, humans and laboratory animals were carried out (Sanexen 2015a; b). Human toxicology and ecotoxicology were evaluated separately to identify the critical effects and their corresponding doses. This information was used to determine the critical dose levels (TRVs) or concentrations that elicit adverse effects in human or ecological receptors occupying different trophic levels and environments.

This information, along with a review of behaviour and effects in biota, estimations of daily intake by humans, bioaccumulation and bioconcentration potential, and exposure pathway-specific information were used to calculate soil quality guidelines to protect environmental (PFOS) and human (PFOS and PFOA) receptors for four land use scenarios: agricultural, residential/parkland, commercial, and industrial. Three types of exposure pathways were evaluated: required pathways (direct contact, soil ingestion), applicable pathways (soil ingestion by secondary and tertiary environmental receptors) and check mechanisms (off-site migration of contaminated soils). The lowest of these values for both ecological and human health receptors was chosen as the generic SSV. In the case of PFOA, ecological values have not yet been derived, so the generic SSV applies only for humans at this time.

Results and discussion

For human health, toxicolological reference values (TRVs) were derived for effects observed in acute, subchronic and chronic studies using animal models, in vitro assays and epidemiological studies. For PFOS, the critical effect that occurred at the lowest concentrations and for which there was sufficient data to derive a TRV was hepatocellular hypertrophy in rats (0.00006 mg/kg bw/d). This value was considered protective of two other critical effects for PFOS, namely hepatocellular hypertrophy in rats and changes in thyroid hormones in monkeys (HC 2016a; 2017, in press). For PFOA, the TRV (0.000025 mg/kg bw/d) was also based on hepatocellular hypertrophy (HC 2016b; 2017, in press). In order to derive SSVs for human, the most sensitive age group for each land use category is selected to identify the input parameters for the calculations. For the agricultural and residential land uses the toddler is expected to have the highest exposures whereas the adult is the most sensitive receptor at commercial and industrial sites.

Ecological effects are assessed for several different receptors: plants and invertebrates; primary, secondary and tertiary consumers, water used for livestock and irrigation and offsite migration. The most sensitive ecological receptor (i.e. that for which the risks were highest) was the secondary consumer (common shrew) due to its small body size and high ingestion rate of invertebrates, which in turn had the highest bioaccumulation rates for PFOS.

SSVs for each of four land use categories are the lowest of the component (pathway) values and applicable check values calculated for ecological and human receptors. For PFOS the check values include offsite migration of contaminants and protection of groundwater for aquatic life, for PFOA only the offsite migration check could be calculated at this time. For human health, SSVs are calculated by dividing hazard, (as determined by toxicological assessment), by exposure, (which is based on various environmental and receptor-specific parameters). For ecological health, the value is based on ecotoxicology data only. Check values are calculated using different methods. In the case of PFOS, the generic SSVs for the agricultural and residential land uses are based on ecological receptors, while the commercial and industrial land use SSVs are based on the groundwater protection of aquatic life check value, as these are the lowest values and are therefore protective of the other components (receptors, pathways, etc.). SSVs for individual components (pathways) can be applied according to specific needs and applicability. The calculated values for PFOS and PFOA are presented in the tables below.

The health effects of PFOS and PFOA are similar and well documented. Based on recent science (2015), it is apparent that PFOS and PFOA affect the same organ in similar ways. Thus, when PFOS and PFOA are found together in soil, to protect human health it is recommended that both chemicals be considered together when comparing to the SSVs. This is done by adding the ratio of the measured concentration for PFOS to its screening value with the ratio of the measured concentration for PFOA to its screening value. If the result is equal to or below one (1), then the soil is considered acceptable for its land use. Science currently does not justify the use of this approach for other PFAS.

Soil Screening Values for PFOS (mg/kg)

	Land Use			
	Agricultural	Residential/ Parkland	Commercial	Industrial
Final Guideline	0.01	0.01	0.14	0.14
Human health guidelines/check values				

SSV_{HH}[b]	2.1	2.1	3.2	30.5
Direct contact guideline[d]	2.1	2.1	3.2	39.4
Inhalation of indoor air check[e]	NC	NC	NC	NC
Off-site migration check	—	—	30.5	30.5
Groundwater check (drinking water)[f]	NC	NC	NC	NC
Produce, meat, and milk check	NC	NC	—	—
Environmental health guidelines/check values				
SSV_E[c]	0.01	0.01	0.14[g], 0.21[h]	0.14[g], 0.21[h]
Soil contact guideline	11	11	61	61
Soil and food ingestion guideline	0.01	0.01	—	
Nutrient and energy cycling check	NC	NC	NC	NC
Off-site migration check	—	—	0.2	0.2
Groundwater: Livestock watering and irrigation water guideline	12[g], 9[h]	—	—	
Groundwater check (aquatic life)	0.14[g], 0.21[h]	0.14[g], 0.21[h]	0.14[g], 0.21[h]	0.14[h], 0.21[h]

Soil Screening Values for PFOA (mg/kg)

	Land Use			
	Agricultural	Residential/ Parkland	Commercial	Industrial
Interim Guideline[a]	0.85	0.85	1.28	12.1
Human health guidelines/check values				
SSV_{HH}[b]	0.85	0.85	1.28	12.1
Direct contact guideline[d]	0.85	0.85	1.28	12.1
Inhalation of indoor air check[e]	NC	NC	NC	NC
Off-site migration check	—	—	12.1	12.1
Groundwater check (drinking water)[f]	NC	NC	NC	NC
Produce, meat, and milk check	NC	NC	—	—
Environmental health guidelines/check values[i]	NC	NC	NC	NC

Notes: NC = not calculated; ND = not determined; SSV_E = Soil Screening Value for Environmental Health; SSV_{HH} = Soil Screening Value for Human Health. The dash indicates a guideline/check value that is not part of the exposure scenario for this land use and therefore is not calculated.

[a] The guideline is only based on the SQG_{HH} as no SQG_E was available at the time the present document was edited.

[b] The SSV_{HH} is the lowest of the human health guidelines and check values.

[c] The SSV_E is the lowest of the environmental health guidelines and check values.

[d] The direct human health-based Soil Screening Value is based on direct exposure to soil *via* ingestion, dermal contact, and particulate inhalation.

[e] The inhalation of indoor air check applies to volatile organic compounds. PFOS and PFOA are essentially non-volatile.

[f] Could not be estimated. Concerns about PFOS or PFOA in groundwater used as drinking water should be addressed on a site specific basis.

[g] Coarse-grained soil is soil which contains more than 50% by mass particles larger than 75 µm mean diameter (D_{50}>75 µm).

[h] Fine-grained soils are soils which contain more than 50% by mass particles smaller than 75 µm mean diameter (D_{50}<75 µm).

[i] SSVs for ecological receptors could not be calculated for PFOA at this time due to insufficient data.

SSVs follow the CCME protocol for the derivation of Soil Quality Guidelines (SQGs) but undergo a less intensive peer review. Health Canada may sometimes develop SSVs depending on the needs of federal government and the availability of resources and data. They are published exclusively to federal departments in Canada whereas SQGs are reviewed and adopted by all provinces and territories in Canada and available publicly via the CCME website. The TRVs used to derive the SSVs to protect human health are the same as those used to develop the Canadian drinking water maximum allowable concentrations (MAC) (HC 2017a; b. in press).

For PFOS, Environment and Climate Change Canada has developed Federal Environmental Quality Guidelines to address additional ecological receptors (freshwater aquatic species, fish tissues, wildlife diet (mammalian and avian), and bird eggs). These are currently undergoing peer review and will be published for the Canadian federal community. Additional ecotoxicological studies are being conducted to complete the dataset necessary to derive ecological SQGs for PFOA.

Considering that PFAS generally exist as mixtures, and in an effort to help federal government departments manage sites with PFAS, Health Canada is currently developing SSVs for PFAS beyond PFOS and PFOA. While insufficient data exist to derive new TRVs for many of the other PFAS commonly measured in environmental samples, SSVs for seven additional PFAS are being derived based either on chemical-specific TRVs (PFBA, PFBS, PFHpA and PFNA) or using the TRVs for PFOS or PFOA as surrogates (PFPeA, PFHxS, PFHxA). These values will be published as SSVs for the Canadian federal community.

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References

1. CCME. 2006. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines. Winnipeg, MB.
2. Environment and Climate Change Canada (ECCC). 2017 (in press). Federal Environmental Quality Guidelines, Perluorooctane Sulfonate (PFOS). Gatineau, QC.
3. Health Canada. 2016a. Perfluorooctane Sulfonate in Drinking Water; Document for Public Consultation. Ottawa, ON.
4. Health Canada. 2016b. Perfluorooctanoic Acid in Drinking Water, Document for Public Consultation. Ottawa, ON.
5. Sanexen. 2015a. Canadian Soil Quality Guidelines for Perfluorooctanoic Acid (PFOA): Protection of Human Health, Scientific Criteria Document. Contractor report under contract to Health Canada, Contaminated Sites Division, Safe Environments Directorate. Ottawa, ON. pp. 167.
6. Sanexen. 2015b. Canadian Soil Quality Guidelines for Perfluorooctane Sulfonate (PFOS): Protection of Human Health, Scientific Criteria Document. Contractor report under contract to Health Canada, Contaminated Sites Division, Safe Environments Directorate. Ottawa, ON. pp. 166.
7. SLR global environmental solutions. 2017. Toxicological Literature Review and Soil Screening Values for Perfluoroalkylated Substances (PFAS) – "C4" to "C7 & C9" Compounds. Contractor report under contract to Health Canada, Contaminated Sites Division, Safe Environments Directorate. Ottawa, ON. pp. 87.