These investigatory levels are no longer used.

Investigatory Levels for Perfluoroalkyl Substances

Detections of per- and poly-fluorinated alkyl substances (PFAS) in ground water at multiple locations in Washington State have prompted questions regarding whether and how these substances are regulated under MTCA. At present, PFAS are not on the list of substances regulated under MTCA and do not appear in Ecology's Cleanup Levels and Risk Calculations (CLARC) database. This could change if a state or federal drinking water standard is promulgated or if toxicity data become available in the U.S. Environmental Protection Agency's toxicity database, the Integrated Risk Information System.

In the meantime, local agencies in Issaquah who wish to clean up PFAS ground water contamination proactively are looking for guidance to inform their decision-making. Ecology's Northwest Regional Office agreed to assist Headquarters staff by calculating the following Investigatory levels (ILs) for perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA):

- Potable ground water IL applicable to PFOS, PFOA, or the sum of PFOS and PFOA
- Soil ILs for human contact with residential and industrial soil applicable to PFOS, PFOA, or the sum of PFOS and PFOA
- Soil ILs for protection of potable ground water for PFOS and PFOA individually in the vadose zone and the saturated zone.

These ILs were developed to assist the local agencies in Issaquah. The ILs are advisory values only and do not have regulatory status. Based on the chemical and toxicological data available to Ecology at present, meeting the ILs shown in this paper is expected to be protective of human health and the environment.

These ILs focus on protection of drinking water and soil contact. In the future, ILs may need to be developed to address other endpoints (e.g., protection of surface water or environmental receptors). ILs were not developed for other PFAS due to limited data for toxicological and chemical characteristics.

Potable Ground Water IL

EPA's health advisory concentration of 0.07 micrograms of contaminant per liter of water (µg/L) (USEPA 2016 a,b) was determined to be sufficiently protective per WAC 173-340-720(7)(b) using MTCA Equation 720-1 and the reference doses (RfDs) developed by EPA (2016 a,b) for its PFOS and PFOA drinking water health advisories. Thus, the IL for drinking water was established at 0.07 µg/L for PFOS and PFOA individually or combined. The evaluation is shown in Table 1. Based on a preliminary review of the ecological literature currently available, Ecology believes that the IL for drinking water would likely be protective of aquatic receptors if the ground water discharged to surface water. It is not possible to evaluate the protectiveness of the IL for human consumption of fish living in contaminated surface water because we do not currently have fish bioconcentration factors for PFAS.

Soil Contact IL

Soil contact ILs were calculated using MTCA Equation 740-1 for unrestricted land use, MTCA Equation 745-1 for industrial land use, and the reference doses (RfDs) developed by USEPA (USEPA 2016 a,b). The calculations are shown in Table 2. The resulting ILs are 1.6 milligrams of contaminant per kilogram of soil (mg/kg) for unrestricted land use and 70 mg/kg for industrial land use for PFOS and PFOA individually or combined.

Soil Leaching IL

Soil leaching ILs for the vadose and saturated zones were calculated using MTCA Equation 747-1 with the ground water IL of 0.07 μg/L, as discussed above, and the default soil characteristics listed in the equation. Organic carbon-water partitioning coefficients (Koc) and Henry's Law constants (Hcc) for PFOS and PFOA were obtained from EPA (2014). Soil water distribution coefficient (Kd) values were calculated from Koc values using MTCA Equation 747-2. The calculations are shown in Table 3.

The resulting ILs are 8.0×10^{-4} and 4.6×10^{-5} mg/kg for PFOS in the vadose and saturated zones, respectively, and 4.4×10^{-4} and 2.8×10^{-5} mg/kg for PFOA in the vadose and saturated zones, respectively. Based on a preliminary review of the ecological literature currently available, Ecology believes that the ILs for soil leaching to ground water would likely be protective of ecological receptors contacting soil.

Unit Conversions

A log Koc value was converted to a Koc value by raising 10 to the power of the log Koc value. Units of Pascal (Pa) were converted to units of atmospheres (atm) by multiplying by 9.869×10^{-6}. Units of atm-m^3/mol were converted to the unitless form using the following equation:

$$Hcc = \frac{Hcp}{RxT}$$

Where:

Hcc	=	Chemical-specific Henry's law constant (unitless)
Hcp	=	Chemical-specific Henry's law constant (atm-m^3/mol)
R	=	Universal gas constant (0.0821 atm-m^3/mol-K)
T	=	Temperature (286.15°K, equivalent to 25 °C)

Summary of ILs

The soil and ground water ILs are summarized below.

Medium	Scenario	PFOS IL	PFOA IL	Units
Ground water	Potable	0.07		μg/L
Soil	Unrestricted (residential) contact	1.6		mg/kg
	Industrial contact	70		
	Leaching from vadose zone	8.0×10^{-4}	4.4×10^{-4}	
	Leaching from saturated zone	4.6×10^{-5}	2.8×10^{-5}	

The final soil IL is the minimum of the relevant pathway-specific ILs; in most cases, the minimum relevant pathway will be leaching. If the soil IL for the leaching pathway is lower than the practical quantitation limit (PQL), the soil IL should be adjusted up to the best achievable PQL.

In the future, if cleanup levels are published in CLARC, they could differ from the ILs presented here for any of the following reasons:

- The RfDs published in EPA's toxicity database, Integrated Risk Information System, differ from the RfDs used to calculate the health advisories
- EPA develops a cancer slope factor(s)
- EPA's maximum contaminant levels differ from the health advisories
- The State Department of Health establishes health advisory levels or drinking water standards that differ from EPA's health advisories
- The Koc or Hcc values that Ecology publishes in CLARC differ from those in EPA's fact sheet.

Comparison of Draft ILs with Other States and Countries

The ILs developed for this paper are within the range of regulatory and guidance levels from other states and countries. The levels for other states and countries were taken from Ecology's September 2017 internal draft Chemical Action Plan for PFAS and state web sites.

Ground water regulatory and guidance levels reported for other states and countries range from 0.013 μg/L (New Jersey cleanup level under consideration for PFOS) to 1 μg/L (United Kingdom Tier 3 value for PFOA) (Table 4).

Direct contact soil regulatory and guidance levels reported for other states and countries range from 1.6 mg/kg (Alaska cleanup level for both PFOS and PFOA) to 16 mg/kg (EPA screening level for PFOA) (Table 5). Most states do not provide regulatory or guidance levels for the leaching pathway. Alaska's leaching cleanup levels are slightly higher than the ILs presented here because Alaska's ground water cleanup levels are higher.

References

Ecology. 2017. September 2017 draft per- and poly-fluorinated alkyl substances chemical action plan (PFAS CAP).

USEPA. 2014. Emerging contaminants – perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), emerging contaminants fact sheet. U.S. Environmental Protection Agency, Office of Water, Washington DC.

USEPA. 2016a. Drinking water health advisory for perfluorooctane sulfonate (PFOS). EPA 822-R-16-004. U.S. Environmental Protection Agency, Office of Water, Washington DC.

USEPA. 2016b. Drinking water health advisory for perfluorooctanoic acid (PFOA). EPA 822-R-16-005. U.S. Environmental Protection Agency, Office of Water, Washington DC.

Table 1. Ground Water Investigatory Level for PFOS and PFOA in Potable Water

Table 1a. Parameter Values and MTCA Equation 720-1 Value

Parameter	Abbrev.	Value	Units	Source
Reference dose	RfD	2E-05	mg/kg-day	USEPA health advisories for PFOS and PFOA
Average body weight	ABW	16	kg	MTCA default
Unit conversion factor	UCF	1E+03	µg/mg	MTCA default
Hazard quotient	HQ	1	unitless	MTCA default
Averaging time	AT	6	years	MTCA default
Drinking water ingestion rate	DWIR	1	L/day	MTCA default
Inhalation correction factor	INH	1	unitless	MTCA default for nonvolatile chemicals
Drinking water fraction	DWF	1	unitless	MTCA default
Exposure duration	ED	6	years	MTCA default
Ground water equation value	GW-Eq	0.32	µg/L	MTCA Equation 720-1

Table 1b. Evaluation of USEPA Health Advisory Level as an ARAR

Parameter	Value	Units	Comment
USEPA health advisory levels	0.07	µg/L	--
Noncancer hazard associated with health advisory	0.22	unitless	Calculated as health advisory level / GW-Eq
Ground water IL for PFOS+PFOA	**0.07**	**µg/L**	Based on health advisory levels as ARARs

ARAR = applicable or relevant and appropriate requirement
IL = investigatory level
MTCA Equation 720-1: GW-Eq = RfD x ABW x UCF x HQ x AT / (DWIR x INH x DWF x ED)
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonic acid

Table 2. Investigatory Levels for Direct Contact with PFOS and PFOA in Soil

Parameter	Abbrev.	Unrestricted (Eq. 740-1)	Industrial (Eq. 745-1)	Units	Source
Reference dose	RfD	2E-05	2E-05	mg/kg-day	USEPA health advisories for PFOS and PFOA
Average body weight	ABW	16	70	kg	MTCA default
Unit conversion factor	UCF	1E+06	1E+06	mg/kg	MTCA default
Hazard quotient	HQ	1	1	unitless	MTCA default
Averaging time	AT	6	20	years	MTCA default
Soil ingestion rate	SIR	200	50	mg/day	MTCA default
Gastrointestinal absorption fraction	AB1	1	1	unitless	MTCA default
Exposure frequency	EF	1	0.4	unitless	MTCA default
Exposure duration	ED	6	20	years	MTCA default
Soil contact ILs for PFOS+PFOA	**SC-ILs**	**1.6**	**70**	**mg/kg**	MTCA Equations 740-1 and 745-1

MTCA Equations 740-1 and 745-1: SC-IL = RfD x ABW x UCF x HQ x AT / (SIR x AB1 x EF x ED)

IL = investigatory level

PFOA = perfluorooctanoic acid

PFOS = perfluorooctane sulfonic acid

Table 3. Investigatory Levels for Soil Leaching of PFOS and PFOA to Potable Ground Water

Table 3a. Chemical Properties

Parameter	Abbrev.	PFOS	PFOA	Units	Source
Ground water investigatory level	GW-IL	0.07	0.07	μg/L	Health advisory levels as ARARs (Table 1)
Henry's law constant	Hcc	1.3E-10	0.0E+00	unitless	USEPA (2014) fact sheet
Soil organic carbon-water partitioning coefficient	Koc	371	115	ml/g	USEPA (2014) fact sheet
Soil fraction of organic carbon	foc	0.001	0.001	g/g	MTCA default
Distribution coefficient	Kd	0.37	0.12	L/kg	MTCA Equation 747-2

Table 3b. Soil Properties and Investigatory Levels

Parameter	Abbrev.	Vadose Zone	Saturated Zone	Units	Source
Unit conversion factor	UCF	1E-03	1E-03	mg/μg	MTCA default
Dilution factor	DF	20	1	unitless	MTCA default
Water-filled soil porosity	θw	0.3	0.43	ml/ml	MTCA default
Air-filled soil porosity	θa	0.13	0	ml/ml	MTCA default
Dry soil bulk density	ρb	1.5	1.5	kg/L	MTCA default
Soil leaching IL for PFOS	**SL-IL**	**8.0E-04**	**4.6E-05**	**mg/kg**	MTCA Equation 747-1
Soil leaching IL for PFOA	**SL-IL**	**4.4E-04**	**2.8E-05**	**mg/kg**	MTCA Equation 747-1

ARAR = applicable or relevant and appropriate requirement
IL = investigatory level
MTCA Equation 747-1: SL-IL = GW-IL x UCF x DF [Kd + (θw + θa x Hcc) / ρb]
MTCA Equation 747-2: Kd = Koc x foc
nm = not measurable
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonic acid

Table 4. Drinking Water Regulatory and Guidance Levels for PFOS and PFOA (μg/L)

State/Country	PFOS	PFOA	Notes
Washington	0.07		IL for protection of drinking water, individual or combined
Alaska	0.4	0.4	Ground water cleanup levels
Minnesota	0.3	0.3	Risk limits
New Hampshire	0.07		Ambient ground water quality standard, individual or combined
New Jersey	0.013	0.014	PFOS value is under consideration
USEPA	0.07		Health advisories, individual or combined
Canada	0.3	0.7	Drinking water guidance values
European Union	0.1 - 0.5	--	Water Framework Directive
United Kingdom	0.3	1	PFOS value is Tier 2; PFOA value is Tier 3

IL = investigatory level
PFAS = poly- and per-fluoroalkyl substances
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonic acid

Table 5. Soil Regulatory and Guidance Levels for PFOS and PFOA (mg/kg)

State/Country	Pathway	PFOS	PFOA	Notes
Washington ILs	Human contact - unrestricted	1.6		Individual or combined
	Human contact - industrial	70		Individual or combined
	Leaching - vadose zone	8.0E-04	4.4E-04	--
	Leaching - saturated zone	4.6E-05	2.8E-05	--
Alaska	Soil contact	1.6	1.6	--
	Migration to ground water	3.0E-03	1.7E-03	--
New Hampshire	Soil contact	0.5	0.5	--
Minnesota	Soil contact	2.1	2.1	--
USEPA CERCLA	--	6	16	Soil screening level

IL = investigatory level
Koc = soil organic carbon-water partitioning coefficient
PFAS = poly- and per-fluoroalkyl substances
PFOA = perfluorooctanoic acid
PFOS = perfluorooctane sulfonic acid
RfD = reference dose for noncancer health effects