Hawaiʻi State Department of Health
Hazard Evaluation and Emergency Response Office

Interim Soil and Water Environmental Action Levels (EALs) for *Perfluoroalkyl and Polyfluoroalkyl Substances* (PFASs)

January 2026

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In reply, please refer to:
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SUBJECT: ***Interim Soil and Water Environmental Action Levels (EALs) for Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs)***

January 2026, Update:

- Text noting the inclusion of the vapor emission pathway to the drinking water action level model for PFEtA^- and PFPrA^- added to Section 6.1.1. Environmental Action Levels for PFEtA^- and PFPrA^- were affected.
- Exposure Time for vapor emission component of tapwater action level model corrected from 24 hrs/day to 4.2 hrs/day to reflect default in HIDOH (2024) EAL guidance (reflects default time spent using showers, washing machines, dishwashers, etc.). Tapwater action levels for PFEtA^- and PFPrA^- were affected.
- Discussion of inhalation Reference Concentrations in Section 4.1 (Human Toxicity) edited for clarity.

A summary of updates to previous editions of this document is provided in Attachment 6.

Information presented in this Hawai‘i Department of Health (HIDOH) update takes precedence over previous versions of the guidance and should be referred to for projects currently underway in the State of Hawai‘i. Additional guidance on “Total PFAS Risk” included in this update incorporates use of “Total Oxidizable Precursors (TOPs)” and “Total Organic Fluorine (TOF)” to identify and assess the risk posed by PFAS-related compounds that are either unreported by standard test methods or otherwise lack toxicity factors. A Fact Sheet (Attachment 4) is provided to summarize the basis of the Total PFAS Risk approach and guide use of the accompanying Excel spreadsheet (Attachment 5). The approach reflects input from a number of PFAS laboratory and risk assessment experts within and outside of the United States.

Environmental Action Levels (EALs) presented in this memorandum represent an addendum to the HIDOH *Environmental Hazard Evaluation* guidance (HIDOH 2024). As is the case for the HIDOH guidance in general, recommendations in this document are primarily intended to help quickly screen out low-risk sites that meet cumulative risk targets, described herein, including sites where PFASs are tested for as part of a larger-scale environmental investigation. This allows limited resources for more in-depth, site-specific assessments of the risk to human health and the environment to be focused on potentially high-risk sites. A more detailed, site-specific risk assessment might be required by HIDOH for high-risk sites on a case-by-case basis.

Please note, comparison of sample data to action levels for individual compounds can be used to rapidly identify specific compounds of interest and associated, potential environmental concerns. Unlike EALs published by HIDOH for other types of contaminants, however, assessment of risk posed by direct exposure to PFASs in soil and drinking water must also include calculation of a cumulative, noncancer Hazard Index for the identified mixture of PFASs as a whole. A description of methods to do so and an accompanying, Excel-based "Total PFAS Risk" calculator are provided in this technical memorandum.

Forthcoming Hazardous Waste regulations for PFASs could also require updates to the guidance. This guidance should be considered interim and will be updated as new information on PFASs and experience in the field is gained. Comments and suggestions are welcome at any time and should be submitted to Weila Li at weila.li@doh.hawaii.gov and John Jacob at john.jacob@doh.hawaii.gov.

Attachment 1: Interim PFAS Guidance (pdf)

Attachment 2: Summary PFAS EALs (pdf)

Attachment 3: Detailed PFAS EALs (Excel)

Attachment 4: Total PFAS Risk Fact Sheet (pdf)

Attachment 5: Total PFASs Risk Calculator (Excel)

Attachment 6: Summary of Previous Updates

Attachment 1

Interim PFAS Guidance
(HIDOH January 2026)

Figures

Tables

Interim Soil and Water Environmental Action Levels (EALs) for Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs)

1.0 Terminology, Chemistry, Manufacture and Use

The compound naming convention for perfluoroalkyl and polyfluoroalkyl substances (PFASs) recommended by Buck et al. (2011) is generally adhered to for the purposes of this memorandum. Both the singular and plural acronyms “PFAS” and “PFASs” are used. A singular term and acronym are appropriate in many cases when the term is used as an adjective, such as “PFAS Environmental Action Level” and “PFAS manufacturing facilities.” The plural form is appropriate when the group of compounds in general is the subject noun, for example “Environmental Action Levels for PFASs” or “Manufacture of PFASs.” Other examples that include use of the singular form as the subject noun will be grammatically correct, for example “The specific, precursor PFAS associated with the presence of 5:3 FTCA in biosolids is unknown.”

PFASs are used in the manufacture of carpets, clothing, fabrics, paper, packaging for food and other materials in order to make them resistant to water as well as grease or stains, among many other uses. PFASs are also used in firefighting products such as aqueous film forming foams (AFFF). Overviews of the chemistry, production and use of these chemicals are accessible on the internet (e.g., Buck et al. 2011; OECD 2013; ATSDR 2018; DEPA 2018; ITRC 2020; USEPA 2020), as are numerous recorded webinars.

PFASs are manufactured by replacing all of the hydrogen atoms bonded to carbon (“perfluoroalkyl”) or some of the hydrogen atoms bonded to carbon (“polyfluoroalkyl”) in a hydrocarbon compound with fluorine (ITRC 2020). Categorization of PFASs in terms of chemistry can become quite complex, with thousands and by some counts millions of potential compounds. While useful for a detailed understanding of fate and transport as well as toxicity, groupings of PFASs specifically for assessment of risk can be simplified to two categories of compounds: 1) Primary Terminal PFAS originally present in a sample and stable under Total Oxidizable Precursors (TOPs) processing and 2) Secondary Terminal PFASs generated by the breakdown of precursor compounds following processing of the sample using TOPs methods. Nomenclatures and abbreviations used in this study for Terminal PFASs with available physiochemical constants and toxicity factors are noted in Table 1. The table notes both the protonated acid form of the compound and the dissociated, anion form more common in the environment. The same abbreviation is often used for both the acid form and the anion form in literature. To denote the difference for the purposes of this technical memorandum, a superscript “$^{-}$” is added to the abbreviation for the anion form.

Physiochemical constants and toxicity factors are lacking for most precursor compounds, as are laboratory methods for directly identifying and quantifying these compounds in environmental samples. As described in this guidance document, this necessitates the use of alternative, indirect laboratory methods to assess the risk posed by precursor PFAS compounds in the environment.

1.1. Primary Terminal PFASs

Terminal PFASs are characterized by a chain of fully fluorinated ("perfluoro-") carbon atoms with a simple carboxylic acid or sulfonic acid function group attached to one end (ITRC 2020). The anion forms of these compounds most commonly found in the environment and where the hydrogen has been removed are referred to as "carboxylates" and "sulfonates."

PFASs are in part named based on the number of linked carbon atoms in the structure, following the procedure used to name aliphatic compounds. A comparison of acid and anion forms of eight-carbon terminal PFASs to the corresponding, eight-carbon aliphatic compound "octane" is depicted in Figure 1. Primary Terminal PFASs used to assess risk are noted in Figure 2. Compounds are further categorized as "long-chain," "short-chain" and "ultrashort-chain" based on the number of linked carbon atoms. Carboxylates are categorized as "long-chain" if the compound contains seven or more linked carbon atoms. Sulfonates are categorized as long-chain if they contain six or more linked carbon atoms. Compounds in both categories are categorized as "ultrashort" if they contain less than four linked carbon atoms. Short-chain compounds capture the middle fraction of this grouping. Although not exact, this is in part done to group compounds in terms of both toxicity and mobility. As discussed below, longer-chain compounds tend to be more toxic and less mobile than shorter chain compounds. Groundwater plumes tend to be increasingly dominated by more mobile but less toxic short- and ultra-short compounds with increasing distance from the source area of a release and in PFAS-contaminated wastewater in general.

The compound 2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate (HFPO-DA), sometimes referred to as "GenX," is grouped with "Primary Terminal PFASs" due the recalcitrance of the compound to Total Oxidizable Precursor (TOPs)" processing and breakdown (Zhang et al. 2019). This likely explains the increased toxicity of HFPO-DA in comparison to the toxicity of hypothetical, ultrashort breakdown products. The TOPs processing methods should not be modified to degrade HFPO-DA into ultrashort organic fluorine components since this could underestimate the toxicity and risk posed by exposure to the original compound. Consideration of the originally reported concentration of HFPO-DA in a sample should be included in assessment of cumulative risk unless otherwise instructed by a PFAS-trained toxicologist.

1.2. Precursor Compounds

Precursor compounds are characterized by partially fluorinated ("polyfluoro-") chain of carbon atoms with typically more complex functional groups added to obtain desired physical properties. These compounds are referred to as "precursors" because they can degrade via natural metabolism or other processes in the environment to Secondary Terminal PFASs. The toxicity invoked by the latter are of most concern for assessment of risk.

The compound 6:2 fluorotelomer thioether amido sulfonic acid (6:2 FtTAoS), used as the dominant PFAS in AFFF since 2005, and its sulfonate anion form (6:2 FtTAoS$^-$) are examples of precursor compounds (Figure 3; SERDP 2017). The compound was manufactured to replace the earlier use of PFOA in AFFF, due to concerns over the latter's potential toxicity. Figure 3 depicts the structure of 6:2 FtTAoS$^-$. Hydrogen has been replaced with fluorine on only six of the eight carbons in comparison to PFOA, thus the designation "6:2" (refer to Figure 3). The functional group thioether amido sulfonic acid has been added to the head of the molecule.

The compound 6:2 FtTAoS might be predicted to be breakdown to PFHpA$^-$ (six fluorinated carbons plus a carboxyl group) following biological or chemical removal of the functional group and the outermost carbon atom. The breakdown of 6:2 FtTAoS has in fact been shown to be more complex (Figure 4; Marjanoic et al. 2015), with a mixture of secondary PFHxA$^-$ and PFPeA$^-$ (four fluorinated carbons) generated, as well as intermediate metabolites that include fluorotelomer sulfonates (e.g., 6:2 FTS$^-$) and carboxylates (e.g., 5:3 FTCA$^-$). These degradation compounds have been identified in contaminated soil and water at AFFF-release sites in Hawai´i, including samples collected as part of an HIDOH field study (HIDOH 2025). The reduction of 6:2 FtTAoS to PFHxA$^-$ (five fluorinated carbons) and PFPeA$^-$ (four fluorinated carbons) implies the additional but undetected presence of one- and two-carbon, ultrashort, organo-fluorine compounds in the media. This issue was investigated in more detail in the HEER Office PFAS Study report (HIDOH 2025).

Fluorotelomer alcohols, used to make paper, clothing, carpeting as well as food containers and wrappers water- and grease-resistant, represent another example of precursor compounds that can degrade to Secondary Terminal PFAS in the environment (Carnero et al. 2021). Figure 5 depicts the microbial degradation of 6:2 FTOH into a complex mixture of metabolites and the secondary terminal endpoint compounds PFBA$^-$, PFPeA$^-$ and PFHxA$^-$ (Tseng et al. 2014). Intermediate metabolites are again characterized by fluorotelomer carboxylates such as 5:3 FTCA$^-$ and related precursor compounds. The reduction of 6:2 FTOH to terminal compounds with less than six fluorinated carbons again implies the presence of ultrashort, organo-fluorine compounds in the media. Similar mixtures of Secondary Terminal PFASs and intermediate metabolites compounds have been identified in samples of influent and biosolids collected from wastewater treatment plants in Hawai´i (HIDOH 2025).

The presence of precursor compounds in soil, water and other PFAS-contaminated media complicates quantification and assessment of the risk posed by the combined exposure to both these compounds and Primary Terminal PFAS already existing in the media (e.g., Nikiforov 2021). This necessitates the development of an approach to quantify and assess the collective toxicity of precursor compound mixtures as well as ultrashort PFAS compounds not routinely reported under standard USEPA and equivalent laboratory methods. An approach for calculation of “Total PFAS Risk” based on the combined use of Total Oxidizable Precursors (TOPs) and Total Organic Fluorine (TOF) methods is described in Section 7.

1.3. Laboratory Reporting of PFASs

Laboratory test methods required to characterize PFAS-contaminated media and assess risk are discussed in Sections 7 and 10. PFASs produced or used by industries are normally present in a salt or acid form. When these compounds are released to soil or water, the hydrogen atom dissociates, leaving the anion form. Anion forms of the compounds are assumed to dominate in contaminated soil and water and are the focus of the Environmental Action Levels (EALs) presented in this memorandum. Current laboratory methods cannot distinguish between the different forms. Sample processing steps instead convert any salt or acid form of a compound present into the anion form prior to testing. The concentration of the anion form of the compound is then reported by the laboratory.

USEPA Standard Operating Procedures for testing of PFASs calls for conversion of anion data to equivalent acid-form concentrations for reporting purposes, even though true acid forms of the compound are unlikely to be found in nature (e.g., USEPA 2020, 2021b, 2021c). This is most likely due to original development of the lab methods to test manufactured product. As discussed in Section 3, modeling the acid form of the compound rather than the anion form that is more likely to be present could introduce significant error into an assessment of the fate and transport of the compounds in the environment (see also ITRC 2020). While the effect on the reported concentration is insignificant (generally <<1%), laboratories should be requested to report environmental data in the original anion form, rather than the acid form. The anion form of the compound should always be used in environmental investigation reports.

2.0 Sources of PFASs in Soil and Groundwater

Contamination of soil and groundwater with PFASs has been associated with the use of PFAS containing foam at firefighting training operations, releases of wastewater and sludge from PFAS manufacturing facilities, releases of leachate from unlined, municipal landfills, use of PFAS containing biosolids from wastewater treatment facilities as a soil amendment and use of treated wastewater for irrigation, among other sources (OECD 2013, SERDP 2017, ITRC 2020). Contamination of groundwater in Hawai´i has to date been identified at only a small number of firefighting training operations. Significant impacts are thus far limited to a single, private well used for drinking and irrigation purposes. Contamination in most cases occurs at airports in coastal areas. These impacts do not threaten a drinking water resource but could pose a concern for nearby shorelines and aquatic habitats. Active landfills in Hawai´i are similarly not located in areas that could threaten a drinking water supply. The risk posed by historical, unlined landfills that overlie drinking water aquifers on the islands is, however, currently under evaluation.

There are no registered PFAS manufacturing facilities in Hawai'i. Effluent from wastewater treatment plants is used for irrigation of golf courses and road medians in some municipalities and potentially small areas of agricultural fields. Biosolids from treatment plants have also reportedly been used as a soil amendment at golf courses and to a lesser degree in fields.

Published studies indicate that PFASs found in soil and groundwater at fire training sites are typically dominated by $PFOS^-$, $PFHxA^-$, $PFOA^-$ and $PFHxS^-$ with lesser amounts of $PFNA^-$. This is based largely on PFASs reported under Method 537 and in the absence of TOPs processing of the samples (Tsitonaki et al. 2014). As noted in Section 1.2, the primary PFAS used in firefighting foam since 2005 is in fact 6:2 FtTAoS. This compound is not routinely reported by laboratories. Methods to assess risk were also lacking prior to publication of the toxicity factors noted in this Technical Memorandum. The presence of this compound in a sample is identifiable, however, if the sample is processed using TOPs. Data for soil samples collected by HIDOH and processed using TOPs had identified concentrations of PFASs hundreds of time higher than indicated by samples tested in the absence of TOPs processing ("pre-TOPs"). This confirms observations in other publications (e.g., Ateia et al. 2023). Impacts to fire training sites based on consideration of only pre-TOPs Primary Terminal PFASs is therefore likely to underestimate actual risk.

The relative proportions of these compounds in contaminated media can vary from site to site, depending on the types of firefighting foam used over time and distance from the initial release area. Testing of water supply wells in California identified nine, primary PFASs, including $PFHxS^-$, $PFOS^-$, $PFOA^-$, $PFBS^-$, $PFHxA^-$, $PFHpA^-$, $PFNA^-$, $PFDA^-$ and $ADONA^-$ (CAEPA 2020). Significant concentrations of "ultrashort" PFASs have also been identified in some samples (personal communication; Wendy Lynk, CAEPA 2023; see also Björnsdotter et al. 2019, Zheng et al. 2023). The occurrence and relative proportions of the compounds varies widely between test sites. In most cases, the source of the PFASs is still under investigation.In most cases, the source of the PFASs is still under investigation.

An informal review of landfill data from California indicated that leachate is dominated by $PFBA^-$, $PFHxA^-$, $PFOA^-$, $PFPeA^-$ and $PFHpA^-$, with a less common but still potentially significant component of $PFBS^-$, $PFOS^-$, $NEtFOSSA^-$ and $PFUnDA^-$ (Keith Roberson, personal communication; based primarily on Method 537 data). More detailed testing of landfill leachate by Lang et al. (2017) suggests, however, that precursor compounds such as the fluorotelomer compounds 5:3 FTCA, 6:2 FTCA and 7:3 FTCA typically make up 30-40+% of PFAS compounds rather than traditionally tested for sulfonates and carboxylates. These compounds can form from the biodegradation of other fluorotelomer compounds, including fluorotelomer alcohols such as 6:2 FTOH (Buck et al. 2011, OECD 2013, ITRC 2020). Data for leachate samples collected from landfills in Hawaii are similar (HIDOH 2025).

Concentrations of PFASs in wastewater treatment plant influent and effluent is higher at facilities that accept industrial wastewater or leachate from landfills (e.g., Kathan 2020). Highly sorptive PFASs tend to be dominant in sludge (ITRC 2020) but the overall PFAS makeup can be highly variable between separate facilities (e.g., Kathan 2020). Landfill leachate can also contain a high proportion of PFAS precursors. Detailed studies of PFASs in contaminated soil and groundwater at AFFF-release sites, landfill leachate, wastewater treatment plant influent, effluent and biosolids currently underway by HIDOH confirm that precursor compounds dominate impacted media in many cases and significantly contribute to potential risk to human health and the environment (HIDOH 2025).

3.0 Physiochemical Constants

Table 2a summarizes physiochemical constants for individually targeted, Primary Terminal PFASs, inclusive of HFPO-DA$^-$. Constants for a short list of precursor compounds for which toxicity factors are available are also noted. The constants are used to predict the fate and transport of the compounds in the environment and develop Environmental Action Levels. References for constants are summarized in Table 2b. Primary sources include:

1. US Environmental Protection Agency, CompTox Chemistry Dashboard (USEPA 2017); and
2. Oak Ridge National Laboratories, Risk Assessment Information System(ORNL 2010).

The majority of the constants were taken from the USEPA CompTox Chemistry Dashboard (USEPA 2017, and updates). The majority of values for the solubility of a compound were predicted from models rather than directly measured. Confidence in the reliability of the values is moderate to low. Although not specifically referenced in the table, Henry's Constants for a number of PFASs are also available from Sander (2015).

Volatility is categorized in terms of both a chemical's Henry's law constant and the molecular weight of the compound. A chemical is considered to be volatile and subject to emission to ambient air if the Henry's constant is greater than 0.00001 atm m^3/mole or the vapor pressure is greater than 1 mm of mercury and the molecular weight is less than 200 (HIDOH 2024a; USEPA 2019b). A chemical is considered to be "semi-volatile" if the Henry's constant or vapor pressure criteria are exceeded but the molecular weight is greater than 200.

Perfluoroethanoate (PFEtA$^-$, aka trifluoroacetate) and perfluoropropanoate (PFPrA$^-$) are the only PFAS compounds currently categorized as "volatile," due to a theoretical vapor pressure greater than 1 mm Hg and a molecular weight under 200 (refer to Table 2). The compounds have thus far been only identified in water. The dissolved-phase, anion forms of PFEtA$^-$ and PFPrA$^-$ in water is expected to be significantly less volatile than the acid form. PFEtA$^-$ and PFPrA$^-$ are not currently considered to be significant contaminant of potential concern for soil or other particulate matter at PFAS-sites in Hawai´i. Preservation of samples of solids using methanol or other methods is therefore not required at this time. Direct testing of soil vapors and/or indoor air will be recommended if potential vapor emission or vapor emission risks from contaminated soil or groundwater are identified in the future.

The compounds PFBA$^-$, PFPeA$^-$, PFHxA$^-$, and 6:2 FTOH$^-$ are classified as semi-volatile due to high vapor pressures and molecular weights greater than 200 (see Table 2). The Henry's constant listed in the CompTox database for PFBA$^-$ also exceeds 0.00001 atm m^3/mole. Samples to be tested for volatile compounds should in practice be placed in methanol in the field immediately after collection (HIDOH TGM Section 4, Appendix I). Samples of soil, biosolids and other particulates to be tested for semi-volatile and should in practice be subsampled prior to air drying in order to prevent potential loss due to volatilization (refer to HIDOH TGM Section 4.2.6.4). Henry's Law constants and vapor pressures noted in Table 2 are largely modeled rather than directly measured, however, decreasing confidence in their accuracy. Vapor pressure can also be estimated based on the chemicals molecular weight, Henry's constant and solubility (after ECHA 2016, Equation r.16-4):

$$\text{Vapor Pressure (mm Hg)} = \left(\frac{\left(\text{Henry's Constant}\left(\frac{\text{atm m}^3}{\text{mole}}\right)\times\left(\frac{760\text{ mm Hg}}{\text{atm}}\right)\times\times\left(\frac{1{,}000\,L}{m^3}\right)\right)\times\left(\text{Solubility}\left(\frac{\text{mg}}{\text{L}}\right)\times\left(\frac{1g}{1{,}000\,mg}\right)\right)}{\text{MW}\left(\frac{\text{g}}{\text{mole}}\right)}\right) \qquad \text{Eq 1.}$$

Using this approach and the values for the noted parameters listed in Table 2a, the predicted vapor pressures of PFPeA$^-$ and PFHxA$^-$ would all fall well below 1 mm Hg, implying that the compounds are unlikely to be even semi-volatile. This suggests that loss during air drying and sieving of soil samples would in fact be minimal and that samples can be processed as normal prior to the collection of analytical subsamples for testing.

A similar conclusion was reached for PFBA$^-$ and 6:2 FTOH$^-$ following discussions with laboratory chemists familiar with testing for PFASs in soil samples. The applicability of the Henry's law constants and vapor pressures in the CompTox Chemical Dashboard is questionable and significant loss of PFBA$^-$ during air drying is not anticipated. The same is anticipated to be true for fluorotelomer alcohols.

For the purposes of this guidance, soil, sediment and other particulate samples to be tested for PFBA$^-$, PFPeA$^-$, PFHxA$^-$ and 6:2 FTOH$^-$ can therefore be processed in accordance with methods described in the HEER Office TGM for non-volatile chemicals unless otherwise directed. Minor loss of potentially semi-volatile compounds during processing and resulting error in the sample data is expected to be offset by an increase in the representativeness of the subsample collected for analysis. This issue will be re-evaluated in the future as additional research is carried out. Modified sample collection and laboratory methods for volatile and semi-volatile PFASs will be incorporated into future updates of this guidance, as needed.

Physiochemical constants for individual compounds will be updated as new information becomes available and could result in changes to the action levels presented in this technical memorandum. Additional studies of factors that control potential leaching of these compounds from soil and subsequent impacts to groundwater and surface water are also currently underway by HIDOH.

4.0 Toxicity Factors

4.1. Human Toxicity

4.1.1. Selected Toxicity Factors

A summary of toxicity factors compiled for individual PFASs is provided in Table 3a. Final toxicity factors selected to generate EALs are noted in Table 3b. Figure 6 depicts the relative toxicity of PFAS compounds in comparison to other common contaminants. The studies reflect a mix of toxicity associated with protonated acid and anion forms of the compounds (see Table 3a). For the purposes of this document, the toxicity of protonated acid and anion forms of the compounds is assumed to be identical, and the toxicity factors apply to both.

A summary of available evidence of health effects indicated by toxicological studies of PFASs is provided in Table 4. An abbreviated summary is provided in Table J of Attachment 3. Health concerns associated with long-term, chronic exposure to PFASs focus on potential systemic (noncancer) effects to liver function, immune system alterations, developmental effects and metabolic and endocrine dysfunction (e.g., USEPA 2022a,b,c; USEPA 2024b,c,e,f; Zeilmaker 2018; ATSDR 2018; Kirk et al. 2018). Refer to the references provided with Table 2b and Table 3b for additional overviews of toxicological studies.

There is significant debate and uncertainty regarding the long-term human health effects of exposure to these and other PFASs. Human epidemiology studies as well as in vitro and animal toxicology studies have often produced conflicting results, contributing to the uncertainty. Toxicity factors used to develop EALs and health effects associated with individual compounds will be updated as new information becomes available. This could result in a future increase or decrease of the action levels presented in this document.

Primary sources referred to for selection of toxicity factors presented in Table 3a include:

1. ATSDR, 2021, *Toxicological Profile for Perfluoroalkyls*: Agency for Toxic Substances and Disease Registry, May 2021.
2. MIDOE, 2020, *Screening Level Evaluation 6:2 Fluorotelomer Sulfonic Acid*: Michigan Department of Environment, Great Lakes and Energy, Interoffice Communication from Michael Depa, Toxics Unit, Air Quality Division, September 24, 2020. (toxicity factors for 6:2 FTS-).
3. MIDOE, 2021, Response to Public Comments for 6:2 Fluorotelomer Sulfonic Acid: Michigan Department of Environment, Great Lakes and Energy, Air Quality Division, January 24, 2021
4. MNDOH, 2018, *Toxicological Summary for Perfluorobutanoate*: Minnesota Department of Health, August 2018.
5. TXCEQ, 2016, *Toxicity Factor Derivation for Perfluoro Compounds (PFCs) Under the Texas Risk Reduction Program*: Texas Commission on Environmental Quality, January 4, 2016.

6. USEPA, 2018, *Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt* (CASRN 13252-13-6 and CASRN 62037-80-3), Also Known as "GenX Chemicals" (Public Comment Draft): U.S. Environmental Protection Agency, EPA-823-P-18-001, November 2018.
7. USEPA, 2021, *Human Health Toxicity Values for Perfluorobutane Sulfonic Acid* (CASRN 375-73-5) and Related Compound Potassium Perfluorobutane Sulfonate (CASRN 29420-49-3): US Environmental Protection Agency, Office of Research and Development, EPA/600/R-20/345F, April 2021.
8. USEPA, 2021, *Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt* (CASRN 13252-13-6 and CASRN 62037-80-3) Also Known as "GenX Chemicals": US Environmental Protection Agency, Office of Research and Development, EPA Document Number: 822R-21-010, October 2021.
9. USEPA, 2023, *Screening Levels for Chemical Contaminants*: U.S. Environmental Protection Agency, November 2023, prepared by Oak Ridge National Laboratories, http://www.epa.gov/region09/waste/sfund/prg/
10. USEPA, 2024, *Maximum Contaminant Level Goals (MCLGs) for Three Individual Per- and Polyfluoroalkyl Substances (PFAS) and a Mixture of Four PFAS*: US Environmental Protection Agency, Office of Water, EPA-815-R-24-004, April 2024.
11. USEPA, 2024, Human Health Toxicity Assessment for Perfluorooctanoic Acid (PFOA) and Related Salts: US Environmental Protection Agency, Office of Research and Development, 815R24006, April 2024.
12. USEPA, 2024, Human Health Toxicity Assessment for Perfluorooctane Sulfonic Acid (PFOS) and Related Salts: US Environmental Protection Agency, Office of Research and Development, 815R24006, April 2024.
13. WIDHS, 2020, Summary and Scientific Support Documents for Cycle 11 Recommended Groundwater Standards: Wisconsin Department of Health Services, P-02807, November 2020.
14. Zeilmaker, M.J., Fragki, S., Verbruggen, E.M.J. and B.G.H. Bokkers, 2018, Mixture Exposure to PFAS, A Relative Potency Factor Approach: National Institute for Public Health and the Environment, Bilthoven, The Netherlands.

Reference dose (RfD) toxicity factors for oral ingestion were available or could be generated for 25 PFASs. When available, toxicity factors published by the USEPA normally take priority. Toxicity factors for additional PFAS compounds were selected based on the date of the guidance and overall depth of the data reviews. Relative Potency Factors (RFPs) for PFASs published by The Netherlands in 2018 and based on the reference potency of PFOA (acid form) were used to select RfDs for $PFPeS^-$, $PFHpS^-$, $PFDS^-$, $PFPeA^-$, $PFHpA^-$, $PFDA^-$, $PFUnDA^-$, $PFDoDA^-$, $PFTrDA^-$ and $PFTeDA^-$.

Texas was the only entity identified with a published RfD for PFOSA (acid form; TXCEQ 2016) and was used for calculation of $PFOSA^-$ action levels. The Texas guidance also includes inhalation Reference Concentration (RfC) for acid forms of PFBS, PFHxS, PFOS, PFBA, PFNA, PFDA and PFDoDA. Reference Concentrations for volatile compounds are used in the vapor emission and inhalation pathway compartments of tapwater and soil direct-exposure models. Reference Concentrations are required for derivation of indoor action levels in the case of volatile and semi-volatile contaminants and for the dust emission compartment of soil direct-exposure models (refer to Table 3a and Table H in Attachment 3). Route-to-route extrapolation from oral RfD values was utilized if an RfC was not available for semi-volatile PFASs in the original publication. Although less reliable, the referenced studies suggest that health effects posed by these compounds are not route-specific. Inhalation of dust particles was not considered for non-volatile compounds if a published RfC was not available. With the exception of PFBS, consideration of the RfC in calculation of direct-exposure action levels for soil did not significantly affect action levels based on incidental ingestion only.

4.1.2. Cancer Studies

Rodent studies have suggested that long-term exposure to PFOA can lead to an increased cancer risk with a cancer slope factor of 0.07 (mg/kg-day)$^{-1}$ proposed (ATSDR 2021). Risk-based action levels for noncancer health hazards fall within the range of acceptable screening levels associated with an excess cancer risk of 10^{-4} to 10^{-6} (HIDOH 2025). A focus on noncancer hazard and protection of developing children and women of child-bearing age, as utilized in this guidance document, can therefore be assumed to also be protective of cancer risk.

The California EPA has published studies of potential cancer concerns for both perfluorooctanoic acid and perfluorooctane sulfonate (CAEPA 2019a). Significantly more conservative cancer slope factors have been proposed for PFOA (2.93E+04 (mg/kg-day)$^{-1}$) and PFOS (3.95E+01 (mg/kg-day)$^{-1}$) based on reviews of epidemiological studies (USEPA 2024e, 2024f). The carcinogenicity of PFOA extrapolated from rodent as well as epidemiological studies has been challenged by outside experts (Burgoon.et al. 2023; Gibb and O’Leary 2024). The mode of action associated with the development of liver tumors in rodents is considered to be irrelevant for humans. The potential for development of kidney tumors extrapolated from epidemiological studies was not observed in rodent and monkey bioassays that included exposure to very high doses of PFOA.

The uncertainty in cancer slope factors developed from rodent and epidemiological studies precludes utilization in quantitative risk assessments and supports a focus on assessment of health risk based on noncancer, systemic health effects and protection of developing children and women of childbearing age.

4.1.3. Animal versus Epidemiological Studies

Toxicity factors for PFASs have been traditionally based on animal studies, including mice and swine. Epidemiological studies of human populations chronically exposed to low levels of PFASs over many years have more recently been used to derive toxicity factors. Epidemiology-based toxicity factors proposed by USEPA (2024e,f,g; 2025) for PFOA (3.0E-08 mg/kg-day), PFOS (1.0E-07 mg/kg-day), PFDA (2.0E-09 mg/kg-day) and PFHxS (4.0 E-10 mg/kg-day) are more than an order of magnitude lower (more conservative) than correlative toxicity factors based on animal studies.

Theoretical advantages of the epidemiological studies include the ability to compare the health status of large populations exposed to PFASs to populations not exposed to PFASs. Challenges include estimation of long-term, average daily exposure (“dosage”) based on limited measurements of PFASs in blood serum and limited data for PFASs in food and drinking water that the populations consumed. Other challenges on the reliability of the toxicity factors include the clinical significance of observed health effects as well as possible association with other, unrelated and unrecognized environmental factors.

The reliability of epidemiological studies reviewed by USEPA (2024e,f,g, 2025) and used to derive toxicity factors for assessment of both cancer and systemic/noncancer health risks has been challenge by multiple, independent panels of experts (Burgoon et al. 2023; Garvey et al. 2023; Gibb and O'Leary 2024, 2025; Hua et al. 2024; Paustenbach et al. 2024; Richardson 2024). Concerns cited by the reviewers include:

- Exposure and serum level examined at only a single point or two points in time, raising uncertainty about the representativeness of the data for longer-term exposure inferred to have led to the observed health effects;
- Reliance on exposures not significantly different from background;
- Lack of clinical significance of identified health effect;
- Absence of mechanistic data relevant for humans at serum level identified in the general population;
- Inability to control potential confounding factors, including concurrent exposure to multiple PFASs and/or additional contaminants known to cause health effects similar to those identified in the study; and
- Lack of observed adverse health effects at doses 100 to 1,000 times above those associated with proposed drinking water guidelines and standards.

The reviewers noted the advantage of animal-based toxicity studies for control of exposure conditions and the ability to focus on a single PFAS. The reviewers further concluded that available animal toxicity studies provide a comprehensive and adequate dataset for development of toxicity factors and assessment of health risk. A focus on noncancer toxicity factors derived from animal studies and the protection of developing young children and women of child bearing age was therefore adopted for use in this guidance document.

4.1.4. Other Compounds

Perfluoropentane sulfonate ($PFPeS^-$) has been identified in groundwater samples collected in Hawai´i. Published toxicity factors for this compound have not been identified. Zeilmaker et al. (2018) note that based on carbon chain length, the RFP for $PFPeS^-$ is anticipated to be more toxic than $PFBS^-$ and less toxic than $PFHxS^-$. The Danish Ministry of Environment (DMOE 2015) review of the toxicity of short-chain PFASs more narrowly notes that $PFPeS^-$ is anticipated to demonstrate a slight increase toxicity both respect to $PFBS^-$ and $PFPeA^-$. For the purposes of this guidance, an RfD of 0.00016 mg/kg-day, representing the halfway point between $PFBS^-$ (RfD = 0.0003 mg/kg-day) and $PFHxS^-$ (RfD = 0.00002 mg/kg-day) was tentatively assigned to $PFPeS^-$ in order to ensure that the potential risk posed by this compound is considered when identified at a site. The ATSDR (2021) toxicity factor rather than the USEPA (2024b) toxicity factor was referred to for this calculation, given lingering uncertainties in the latter. The RfD for $PFPeS^-$ will be updated in the future as more information becomes available.

Gibb and O'Leary (2023) carried out a review of toxicity studies for 6:2 FtTAoS, 6:2 FTOH and 8:2 FTOH under contract with HIDOH. Toxicity factors generated by the review are noted in Table 3a.

Assessment of the toxicity of PFASs is continually evolving. The U.S. Environmental Protection Agency (USEPA) as well as other government and private entities are currently carrying out targeted research on many of the topics discussed, including the toxicity of less-well-studied, polyfluoroalkyl substances. This Technical Memorandum will be periodically updated to provide new information as it becomes available.

4.2. Ecotoxicity and Food Chain Uptake

HEER Office action levels include consideration of discharges of contaminated groundwater to a surface water body and potential impacts to aquatic flora and fauna (HIDOH 2024a). As a default, contaminants in groundwater should not exceed chronic, aquatic toxicity action levels at the point that the groundwater discharges into a body of surface water. The dilution of contaminated groundwater upon mixing with surface water is not considered. This is intended to be protective of benthic habitats where dilution of groundwater with surface water prior to discharge could be minimal. A less conservative requirement to meet acute, aquatic toxicity action levels prior to discharge is generally acceptable for highly developed harbors and similar areas where the aquatic habitat has otherwise already been significantly disrupted. Natural seepage of groundwater into stormwater sewers or intentional discharge into storm sewers during construction activities must also be considered.

Toxicity to terrestrial flora and fauna is not addressed in the HEER Office EALs and must be evaluated on a case-by-case basis, as appropriate for the site. Uptake into edible produce is anticipated to take precedence to actual toxicity to the plant in most cases. Additional guidance on this issue will be provided in the future as it becomes available and is applicable to Hawai´i.

Groundwater and aquatic toxicity action levels do not consider the uptake of PFASs into benthic and aquatic organisms and potential risk to human health. The uptake and bioaccumulation of PFASs into benthic organisms and other aquatic flora and fauna and propagation up the food chain could require investigation at sites where PFAS-impacted sediment or surface water is identified. Reliable methods to assess these concerns are still in development. Soil EALs presented in this memorandum likewise do not address potential uptake of PFASs into food crops from agricultural land potentially impacted by the use of WWTP biosolids as a soil amendment or the use of WWTP effluent for irrigation. The need for additional evaluation of the uptake of PFASs into aquatic organisms or food crops should be discussed with the HEER Office on a case-by-case basis. Detailed guidance on the latter topic is under preparation by outside research institutes in coordination with HIDOH and anticipated to be available in 2026.

5.0 Environmental Fate and Transport

An in-dept review of the fate and transport of PFASs in the environment is beyond the scope of this Technical Memorandum. Refer to Guelfo et al. (2019) and ITRC (2020), among other sources for additional information. A summary but still incomplete overview of basic fate and transport considerations is provided below.

The mobility of PFASs in the environment is governed by each chemical's solubility, volatility and tendency to sorb to organic carbon and clay. These processes are still not well understood for PFASs. The breakdown and transformation of PFASs in the environment can similarly be very complex (see ITRC 2020). Basic information on the degradation and fate and transport of precursor compounds is provided in Section 1.2. Research on this topic is ongoing and will be incorporated into HEER Office guidance in the future as available and pertinent to projects in Hawai´i.

The potential for a compound to leach from soil and contaminate underlying groundwater is traditionally evaluated in terms of the chemical's solubility and "sorption coefficient (Koc)," (McCall et al. 1981; refer also to HIDOH 2024a). The solubility of PFASs can be dependent on site-specific conditions that promote degradation and transformation into other compounds. This complicates accurate modeling of leaching potential. The sorption coefficient, expressed in units of cm^3/g, reflects the ratio of the mass of the chemical that will sorb to organic carbon to the mass of the chemical that will dissolve in water under ambient, equilibrium conditions. Chemicals with a Koc value of less than approximately 50 cm^3/g are considered to be highly mobile (see HIDOH 2024a). Chemicals with a Koc value greater than 500 cm^3/g are considered to have low mobility. Chemicals with Koc values greater than 5,000 cm^3/g are considered to be essentially immobile, or not significantly leachable from soil.

Incorporation of the default solubility, Henry's Constant and sorption coefficient into a simple contaminant partitioning model (USEPA 1996) and default, soil parameters used in the USEPA RSL and HIDOH EAL models allows prediction of the initial fate of a PFAS when released to soil (Figure 7). This simple exercise predicts that PFASs with a relatively low sorption coefficient and a high solubility like $PFHxA^-$ will more easily dissolve into infiltrating water and pose a greater leaching threat than chemicals with relatively high sorption coefficients, such as $PFOS^-$.

Such models are likely to overpredict the mobility of aged releases of PFASs in vadose-zone soil. Published sorption coefficients are based on the energy required to physically sorb the chemical to organic carbon. Like sticking a Velcro-covered ping pong ball to an opposing sheet of Velcro, however, much more energy is often required to *desorb* the chemical from the carbon. Soil action levels for leaching concerns based on Koc *sorption* values can therefore significantly overestimate the potential mobility of the PFASs and potential, adverse impacts to groundwater. Electrostatic binding of polar, PFAS compounds to charged particles in the soil over time or diffusion of compounds into clay particles can further inhibit leachability. As discussed below, laboratory testing of leachability and determination of soil-specific "desorption" coefficients will be necessary when action levels are exceeded (HIDOH 2024a).

A similar separation of PFASs in groundwater plumes migrating away from a source area is also predicted, with lower mobility compounds such as $PFOS^-$ remaining concentrated in the source area and compounds such as PFEtA$^-$, PFPrA$^-$, PFHxA$^-$, PFPeA$^-$ and PFBS$^-$ characterizing the forward, leading edge of the plume (Figure 8). This in part likely explains the identification of the latter compounds in groundwater in absence of significant PFOS$^-$ and PFOA$^-$ and highlights the need for risk-based, drinking water action levels for more than just these two compounds.

Figure 9 compares the hypothetical mobility of individual PFASs in terms of the sorption coefficient to the compound's toxicity. This could be useful to predict highly toxic and recalcitrant compounds that could remain trapped in soil or taken up in the food chain and pose similar risk to PCBs. Less mobile PFASs are anticipated to accumulate in soil and biosolids. More mobile compounds could drive risk for uptake into food crops or livestock feed or impacts to groundwater. As noted in Figure 9, the least sorptive compounds that pose the greatest leaching risk to groundwater, such as PFBS$^-$ and PFHxA$^-$, are fortunately also of relatively lower toxicity.

6.0 Environmental Action Levels for Individually Targeted PFASs

Interim soil and water action levels for PFASs are provided in Tables A and B in Attachment 2. Detailed tables for derivation of the EALs are provided in Attachment 3. These tables represent an addendum to the 2024 *Environmental Hazard Evaluation* (EHE) guidance document (HIDOH 2024a) and are presented in the same format. A separate, Excel-based "EAL Surfer" of electronic lookup tables specific to PFASs is available for download from the HEER Office EHE guidance webpage (refer to weblink in below reference). The action levels represent an addendum to the 2024 EHE guidance and will be incorporated into that guidance in the future. The list of PFAS-related compounds with action levels will be expanded as toxicity factors and physiochemical constants for additional compounds become available.

6.1. Potential Environmental Concerns

Methods used to derive EALs for specific, environmental concerns are discussed in Volume 1 and Volume 2, Appendix 1 of the HEER Office EHE guidance (HIDOH 2024a). Action levels were generated for the following environmental concerns:

Environmental Concern	Action Level Generated?	Notes
Soil		
Direct Exposure	X	All PFASs with available toxicity factors
[1]Vapor Intrusion	X	Currently $PFEtA^-$ and $PFPrA^-$ only
[2]Leaching to Groundwater	X	All PFASs with available toxicity factors
[3]Gross Contamination	-	Odor thresholds not identified
Groundwater		
Drinking Water Ingestion	X	All PFASs with available toxicity factors
[1]Vapor Intrusion	-	Currently $PFEtA^-$ and $PFPrA^-$ only
Aquatic Toxicity	X	Limited; drinking water action levels applied for initial screening if aquatic toxicity action levels not available
[3]Gross Contamination	-	Taste and odor thresholds not identified
Ambient Air and Subslab Vapor		
[1]Vapor Intrusion	-	Currently $PFEtA^-$ and $PFPrA^-$ only

1. Vapor intrusion risk posted by volatile PFASs under review. Methods for development of groundwater action levels for potential vapor intrusion concerns are not currently available. Soil vapor samples recommended for site-specific assessment if a potentially high-risk concern is identified, with a focus on subslab Large Volume Purge (LVP) sampling methods (refer to HIDOH Technical Guidance Manual, Section 7 (HIDOH 2023). Model-based soil and groundwater action levels considered to be unreliable due to complexity of PFAS fate and transport.

2. Confidence in leaching model used is low; corresponding soil levels predicted to be excessively conservative. Use of laboratory leaching methods (e.g., SPLP and/or Method 1314 soil column) recommended if action levels exceeded (see text).

3. "Gross Contamination" includes short-term risks associated with temporary but high emissions of vapors from disturbed soil or groundwater, sheens in runoff, explosion and fire hazards, etc. (HIDOH 2024a). Action levels

currently not available for PFAS compounds and anticipated to be significantly higher than action levels based on direct exposure risks.

Additional information on each of the targeted concerns is provided in the following sections. The primary route of exposure to PFASs is considered to be ingestion of contaminated food and drinking water (NIEHS 2023). Default, USEPA exposure assumptions regarding daily soil ingestion and water consumption as well as the number of days per year and years of exposure were used to calculate the action levels.

Organization of the EAL lookup tables is discussed in Volume 1, Section 2.4 of the EHE guidance. The "Tier 1" action levels for soil listed in Tables A and B are intended to allow unrestricted current and future use of a property. This includes use of the property for residences, schools, medical facilities, day-care centers, and other sensitive purposes with no restrictions regarding regular contact with the soil. Alternative and potentially less stringent soil action levels for sites that will be restricted to commercial/industrial land use only can be considered on a case-by-case basis, as discussed in Section 3 of the EHE guidance.

Groundwater utility is determined based on the location of the site with respect to the Underground Injection Control (UIC) Line and the state Aquifer Identification and Classification technical reports prepared by the University of Hawai‘i (Figure 10). Groundwater situated mauka (inland) of the UIC line is classified in most cases as a current or potential source of drinking water. Soil and groundwater action levels applicable to drinking water impact scenarios apply to these areas (Scenarios A-1 and A-2 in Figure 10). Exceptions are discussed in Section 2.4.3 of the EHE guidance.

First-encountered groundwater in areas situated makai (oceanward) of the UIC line is, by regulation, not considered to be a potential source of drinking water. Environmental Action Levels for nondrinking water scenarios apply to both soil and groundwater situated in these areas (Scenarios B-1 and B-2 in Figure 10). Groundwater action levels focus on the protection of aquatic habitats associated with natural or intentional discharges of groundwater to surface water. Action levels based on aquatic toxicity are in most cases less stringent than action levels based on drinking water toxicity. As discussed below, aquatic toxicity action levels are only currently available for 11 of the 25 PFAS compounds discussed. Drinking water action levels are applied as a substitute in the interim. Groundwater action levels presented in Table A (drinking water resource) and Table B (non-drinking water resource) are therefore identical.

Groundwater action levels should be compared to dissolved-phase chemical concentrations unless instructed by the overseeing regulatory agency. This may require filtering of turbid samples prior to analysis (refer to Section 6 of the HEER Office *Technical Guidance Manual*).

6.1.1. Drinking Water Direct Exposure

Cancer Risk

Cancer-based drinking water action levels are not currently included in the HIDOH PFAS guidance. Cancer Slope Factors presented for both PFOA and PFOS in the USEPA MCL documents discussed in Section 4.1 are currently under review by HIDOH. Previous USEPA documents have concluded that noncancer hazard outweighed cancer risk and that risk-based levels based strictly on protection of the former would be protective of the latter (USEPA 2022a,b). This assumption will be re-visited following HIDOH's review of the studies used to develop the USEPA cancer slope factors.

Noncancer Hazard
The USEPA Regional Screening Levels (RSL) "Tapwater" model used to generate drinking water action levels in HIDOH EAL guidance includes components for three exposure pathways: 1) Direct ingestion of tapwater; 2) Dermal absorption and 3) Inhalation of vapors of during water use. The latter only applies to volatile chemicals (refer to Section 3.0). Refer to the RSL User's Guide for the full equations used to calculate tapwater RSLs (provided in Attachment 2 of the HIDOH EAL guidance document; HIDOH 2024).

Several alternative but similar models have been used to calculate screening levels and standards for PFASs that focus on the ingestion pathway. The method used by the USEPA to derive noncancer-based, MCLGs was adopted for calculation of the ingestion component of noncancer-based drinking water action levels (USEPA 2024b):

$$\text{Health Advisory } (\mu\text{g/L}) = \text{THQ} \times \left(\frac{\text{RfD (mg/kg day)}}{\text{DWIR}-\text{BW (L/kg day)}}\right) \times \frac{1000\mu\text{g}}{\text{mg}} \times \text{RSC} \qquad \text{Eq 2}$$

where:
THQ = Target Hazard Quotient (default 1);
RfD: Chronic, oral Reference Dose (chemical specific);
DWIR-BW: Drinking water ingestion rate per kilogram of body weight of targeted sensitive population of concern (chemical specific); and
RSC: Relative Source Concentration (default 0.2).

A default RSC of 20% was retained for calculation of HIDOH PFAS EALs.

An identical approach was used to derive earlier USEPA Drinking Water Advisory Levels (USEPA 2022a,b). A Target Hazard Quotient of "1" is inferred in those documents but not specifically stated. The USEPA models used to derive MCLGs and Drinking Water Advisories are similar to the approach used to derive ingestion-based, Tapwater Regional Screening Levels (RSLs) for PFASs published by the USEPA Superfund office (USEPA 202):

$$\text{RSL}_{ing}\ (\mu\text{g/L}) = \frac{\text{THQ}\times\text{AT}_{\text{res}-\text{c}}\times\text{BW}_{\text{res}-\text{c}}\times\frac{1000\mu\text{g}}{\text{mg}}}{\text{EF}_{\text{res}-\text{c}}\times\text{ED}_{\text{res}-\text{c}}\times\frac{1}{\text{RfD}}\times\text{IRW}_{\text{res}-\text{c}}} \qquad \text{Eq 4}$$

where:
RSL_{ing}: Tapwater Regional Screening Level based on ingestion-only pathway;
THQ: Target Hazard Quotient (default = 1.0);
AT: Averaging Time (default = 365 days/year x 6 years);
$\text{BW}_{\text{res-c}}$: Resident Child Body Weight (default = 15 kg);
EF: Resident Child Exposure Frequency (default = 350 days/year);
ED: Resident Child Exposure Duration (default = 6 years);
RfD: Chronic, Oral Reference Dose (chemical specific);
IRW: Resident Child Ingestion Rate Water (default = 0.78 L/day).

The RSL model includes an Exposure Frequency parameter that allows the final screening level to be adjusted upwards to reflect a reduced number of exposure days per year. The default of 350 days/year reflects an assumption that residents will be away from their home for 15 days of the year and not exposed to contaminants potentially present in the tapwater.

Consideration of a reduced number of days of exposure per year is not included in the USEPA drinking water advisory models, in effect assuming an Exposure Frequency to 365 days/year. Assumption of an Exposure Frequency of 365 days/year was therefore retained for calculation of tapwater EALs for PFASs. Note that this differs from use of the default USEPA RSL Exposure Frequency of 350 days/year in HIDOH tapwater EALs for other types of contaminants (HIDOH 2024a).

Additional uptake through the skin during bathing or through contact with contaminated soil is possible but considered to be insignificant in comparison to ingestion (e.g., <10% of total exposure; refer to USEPA 2004). Dermal exposure is considered in the model used to calculate soil action levels. Methods to assess dermal uptake from tapwater while bathing are more complex, however, and are not yet fully developed. This pathway will be added to future updates of the action level as this information becomes available. Significant changes in tapwater action levels based only on the ingestion route only are not anticipated.

The vapor emission and inhalation exposure pathway component of the USEPA RSL Tapwater model is included in the calculation of drinking water action levels for $PFEtA^-$ and $PFPrA^-$. Both compounds are classifiable as “volatile” based on physiochemical constants posted in the USEPA CompTox database (refer to Section 3 and Table 2a. Exposure is assumed to occur by volatilization of the compounds into indoor air during tapwater during bathing and use of dishwashers and washing machines. The default Exposure Time of 4.2 hours/day for bathing and use of dishwashers and washing machines was retained. Refer to HIDOH (2024a) for additional discussion of this topic.

Default Target Hazard Quotient
A target Hazard Quotient of “1” is used to derive HIDOH action levels for individual PFASs in drinking water. Calculation of a Hazard Index based on *the full suite of PFAS identified* is required in Section 7 of this Technical Memorandum for groundwater that serves as a source of drinking water as well as other exposure media, including in soil. This recognizes the oftentimes complex mixture of PFASs present in the environment allows for a more complete assessment of Total PFAS Risk.

A Hazard Quotient of “1” is also used to derive drinking water action levels for compounds listed in the general HIDOH Environmental Action Levels guidance (HIDOH 2024a). Calculation of cumulative risk is required if more than one contaminant is present. The number of cases in Hawai’i where calculation of cumulative risk is necessary is low, however, due to the relatively simple nature of the contaminants released.

Default Drinking Water Ingestion Rates
A summary of DWIR-BW rates utilized for calculation of drinking water action levels is provided in Table 5. DWIR-BW rates based on targeted exposure populations and incorporated into MCLGs for PFHxS, PFNA, PFBS and HFPO DA were retained for use in this guidance (USEPA 2024b; refer to footnotes to Table 5). DWI-BW rates applied to calculation of USEPA Drinking Water Advisories for PFOA and PFOS were also retained (USEPA 2022a,c). A DWIR-BW rate based on the default, average drinking water ingestion rate and body weight of 0- to 6-year-old children used for calculation of USEPA Tapwater RSLs was applied to all other PFASs (USEPA 2023; refer to footnotes to Table 5).

Default Relative Source Contribution
The 2022 USEPA Health Advisories only consider exposure to the chemical via drinking water. Exposure to the same chemical in food, indoor dust, contaminated soil and even personal care products could also occur. Compounded exposure to a chemical is addressed through application of a "Relative Source Contribution (RFC)" for exposure to a particular media (see USEPA 2024b,d). The extent of exposure to PFASs in media other than drinking water is still under review. As a precautionary measure, USEPA Health Advisories for PFOA and PFOS as well as final MCLGs for other PFASs allocate an RSC of 20% for exposure to PFASs in drinking water (USEPA 2024b). For example, the RfD for $PFBA^-$ is 0.0038 mg per kilogram of body weight per day (mg/kg-day) or 3.8 µg/kg-day (see Table 5). Of this maximum daily exposure, 20% or 0.76 µg/kg-day is allotted to exposure to $PFBA^-$ in drinking water.

USEPA MCLGs and MCLs
Promulgated MCLGs and MCLs for PFASs are incorporated into Summary Table A and Table D-3a in Attachment 3 (USEPA 2024a). Table D-3b in Attachment 3 presents risk-based action levels for the same compounds that were calculated using the methods described above.

Risk-based MCLGs are presented for perfluorobutane sulfonic acid (PFBS), perfluorohexane sulfonic acid (PFHxS), perfluorononanoic acid (PFNA) and hexafluoropropylene oxide dimer acid (HFPO DA). The MCLGs apply to both acid and anionic forms of the compounds. Derivation of the MCLGs, including final toxicity factors assigned to each compound, is described in USEPA (2024b). The MCLGs for these compounds closely align with similar, risk-based drinking water action levels calculated by HDOH and presented in this Technical Memorandum. The MCLGs were rounded to one significant digit and are referred to in final summary tables (see Table A in main text and Table D-3a in Attachment 3).

MCLGs for perfluorooctanoic acid (PFOA) and perfluoro octane sulfonic acid (PFOS) were set to "zero" due to suspected carcinogenicity (USEPA 2024c, e, f). Final MCGs for PFOA and PFOS were in turn set to a default, laboratory Method Reporting Level of 4 ng/L, reflecting USEPA MCL policy for chemicals that are known or suspected carcinogens (USEPA 2024a). Use of a Maximum Reporting Level of 4 ng/L was based on consideration of economic cost versus health benefits for municipalities (USEPA 2024g). The MCLs of 4 ng/L for PFOA and PFOS apply to treatment requirements for drinking water systems impacted by PFASs.

Application of MCLGs for PFBS, PFHxS, PFNA and HFPO DA MCLGs to drinking water systems requires calculation of cumulative risk and a maximum-allowable "Hazard Index" of "1" (USEPA 2024a). Consideration of PFOA and PFOS is excluded, with reported concentrations of these compounds directly compared to MCLs of 4 ng/L, as noted above. Consideration of other PFAS compounds detected in the drinking water system is also currently excluded, under a current premise that the six targeted compounds comprise the majority of the health risk likely to be posed by PFAS-related contamination. The methodology to be used for calculation of a Hazard Index for PFBS, PFHxS, PFNA and HFPO DA in a drinking water system is described in USEPA (2024d).

A similar approach for assessment of cumulative risk posed by PFASs identified in soil and groundwater is described in the Total PFAS Risk section of this Technical Memorandum (Section 7). Consideration of the *entire suite of PFASs present* in contaminated media is, however, required for assessment of cumulative risk (hazard) associated with PFAS-contaminated groundwater, soil and other media. This includes consideration of risk-based drinking water action levels for PFOA and PFOS noted in Table D-3b of Attachment 3 and included in the accompanying Total PFAS Risk spreadsheet.

Toxicity factors also used to generate the MCLGs are also utilized for derivation of direct-exposure action levels for soil (see Tables I-1, I-2 and I-3 in Attachment 3). Calculation of direct-exposure for soil is discussed in Section 6.1.3.

6.1.2. Aquatic Toxicity

Chronic aquatic-toxicity action levels are used under HIDOH guidance to screen groundwater within 150 meters of a surface water body or groundwater that could enter a storm drain and quickly impact an aquatic habitat (see Figure 10; HIDOH 2024a). Acute, aquatic toxicity action levels are applied to groundwater situated >150m from a surface water body that does not pose a near-term risk to an aquatic habitat.

Chronic and acute toxicity levels compiled and reviewed by the Washington Department of Ecology served as the primary reference for use in this technical memorandum (refer to Table D-4e of Attachment 3; WADOE 2020). Aquatic toxicity screening levels published by Divine et al (2020) were referred to when levels were not included in the WADOE document. Additional publications with aquatic and/or terrestrial ecological toxicity screening levels for PFASs include Grippo et al. (2021) and Conder et al (2020).

Action levels were available for 11 of the 20 targeted PFASs. The action levels are intended to represent concentrations of the noted compound that did not result in an adverse effect on the health and propagation of fish, invertebrates and other aquatic life. Aquatic toxicity levels are presented for the anion form of sulfur-based PFASs in the WADOE document and the acid form for nonsulfur-based compounds. The reason for the latter is unclear, since the carboxylate form of the compound should be present in water, rather than the carboxylic acids form. Aquatic toxicity levels presented for the acid forms are assumed to be applicable to the anion forms for the purposes of this technical memorandum.

Chronic aquatic toxicity action levels for compounds are applied to acute toxicity if data for the latter were not presented in the Washington document. Studies for freshwater were applied to the marine environment when action levels for the latter were not available, and vice versa. Note that WADOE opted to apply No Observed Effects Concentration data for acute studies to select chronic action levels when supported by other studies for the latter (e.g., $PFBS^-$ marine, $PFDA^-$ freshwater).

The Washington document is currently under final review for development of formal, surface water standards in that state. The aquatic toxicity action levels selected will be updated as additional information becomes available. The action levels do not take into account bioaccumulation and uptake in the food chain, including potential risk to humans and wildlife that use aquatic organisms as a source of food. Other references include the Australia Cooperative Research Centre (ACRC 2018), Giesy et al. (2010) and the European Chemical Agency (ECHA 2018).

Acute aquatic toxicity action levels for $PFOS^-$ and $PFOA^-$ in Table 4e of Attachment 3 are based on guidance published by the Australia Cooperative Research Centre (ACRC 2018). Guidelines presented for 80% species protection are intended to protect 80% of exposed organisms from a 10% decrease in a chronic, sub-lethal endpoint. These values were selected as surrogates for "acute" aquatic toxicity. As was the case for the WADOE guidance, the Australia document presents aquatic toxicity levels for perfluorooctane sulfonate, the anion form of the compound, but then somewhat confusingly presents levels for the non-sulfur containing equivalent in terms of perfluorooctanoic acid. Aquatic toxicity levels presented for the latter are again assumed to be applicable to the perfluorooctanoate anion form of the compound.

Acute aquatic toxicity action levels for $PFHxA^-$ were derived from a summary of studies published by the European Chemical Agency (ECHA 2018). The document notes that the compound will be present in the anion form when dissolved in water. The acute action level of 48,000 µg/L for freshwater (also applied to marine habitats) is based on 50% of an LC50 concentration derived for daphnia. This reflects recommendations for development of aquatic toxicity action levels in the USEPA Great Lakes water quality initiative guidance (USEPA 1995; refer to Section 5.3.2 in Volume 2 of the EHE guidance).

Aquatic toxicity action levels could not be identified for the remaining PFASs (see Table D-4b and Table D-4c in Attachment 3). HEER Office guidance calls for the use of toxicity-based, drinking water action levels when aquatic toxicity action levels are not available (HIDOH 2024a). This is intended to ensure that contaminants in groundwater that could pose a threat to surface water habitats are not inadvertently overlooked due to the absence of published action levels. As a result, the final action level for groundwater that is not a source of drinking water (Table B) is identical to the action level for groundwater that is a source of drinking water (Table A).

Drinking water action levels will be replaced with aquatic toxicity action levels as the latter become available in the future. Use of the drinking water action levels as surrogates for aquatic toxicity and decisions regarding the need for remedial actions for PFAS contaminated groundwater is likely to be excessively conservative, based on a comparison of action levels for compounds where both are available. Drinking water action levels for $PFOS^-$, $PFOA^-$, $PFBS^-$, $PFHxS^-$ and $PFHxA^-$ are significantly lower than chronic, aquatic toxicity action levels for these chemicals. Additional evaluation, including a review of published research and/or laboratory bioassay tests of aquatic toxicity, should be carried out when groundwater with PFASs in excess of the interim action levels is identified and could potentially discharge into an aquatic habitat (refer to HIDOH 2023). This should include the use of laboratory bioassay tests in addition to reviews of published literature.

Confidence in the aquatic toxicity action levels presented varies from low to medium (refer to WADOE 2020). Whole effluent toxicity methods are recommended for site-specific assessment of aquatic toxicity (e.g., WADOE 1993). Test methods and use of resulting data for decision making should be discussed with the HEER Office project manager on a site-by-site basis.

Action levels selected for screening of potential PFAS aquatic toxicity concerns in groundwater were not carried forward for screening of surface water. Surface water action levels are anticipated to be driven in part by bioaccumulation and food chain risks. Action levels for bioaccumulation risk are currently only available for $PFOA^-$ and $PFOS^-$ (e.g., 99% species protection levels presented in ACRC 2018). Additional action levels and guidance on PFAS contamination of surface water will be included in future updates of the HEER Office guidance as available. Until such time, the detection of PFASs in surface water should be discussed with the HIDOH Clean Water Branch and HEER Office on a case-by-case basis.

6.1.3. Soil Direct Exposure

For use in this document, the term "soil" refers to any unconsolidated, particulate matter found in the subsurface, including actual soil, saprolite, sediment, biosolids, fill material, etc. (HIDOH 2024a). Soil data should be reported on dry-weight basis (refer to Volume 2, Appendix 1, Section 7.3 of the EHE guidance).

HEER Office action levels for direct exposure to contaminants in soil are based on models presented in the USEPA Regional Screening Level (RSL) guidance (USEPA 2019b). Equations, default exposure assumptions and target risks utilized in the models are presented in Appendix 1 and Appendix 2 of the HEER Office EHE guidance (HIDOH 2024a). Default exposure assumptions and target risks used to develop direct exposure action levels for the targeted PFASs are summarized in Table 6. Modifications include consideration of a Relative Source Contribution of 20% and a target, noncancer Hazard Quotient of “1,” similar to the approach used to develop risk-based action levels for drinking water.

Use of a target Hazard Quotient of 1 to generate soil and drinking water action levels for direct exposure requires calculation of cumulative noncancer hazard (“Hazard Index”) for all sites where PFAS contamination is identified. Methods to calculate a Hazard Index are described in Section 7. Automatic calculation of a Hazard Index based on input sample data included in Total PFAS Risk spreadsheet accompanying this Technical Memorandum.

6.1.4. Soil Leaching

An algorithm based on a combined use of the computer applications SESOIL (vadose-zone migration of contaminants) and AT123D (mixing of leachate with groundwater) was used to generate action levels for potential leaching of PFASs from soil and impacts on groundwater (discussed in Appendix 1 of the EHE guidance; HIDOH 2024a):

$$C_{soil} = DAF \text{ x } C_{gw} \text{ x } 0.001 \text{ mg/}\mu\text{g} \qquad \text{Eq 7}$$

$$DAF = (6207 \text{ x } H) + (0.166 \text{ x } Koc) \qquad \text{Eq 8}$$

where: DAF = SESOIL-based dilution/attenuation factor;
H = Henry's Law Constant (atm-m^3/mol);
Koc = Organic carbon partition coefficient (cm^3/g);
C_{soil} = Leaching based soil concentration (mg/kg);
C_{gw} = Target groundwater action level (µg/L).

The term DAF is defined for the purposes of the model as the concentration of the contaminant in soil (in mg/kg) divided by the concentration of the contaminant in groundwater (in mg/L).

The algorithm reflects modeling of an assumed annual rainfall of 1,100 mm (approximately 43 inches). A total of 720 mm (28 inches) of the total rainfall is assumed to infiltrate the ground surface and reach groundwater. This is considered to be adequately conservative for the majority of developed areas in Hawai‘i. The model incorporates a three-meter-thick vadose zone characterized by one meter of impacted soil sandwiched between two, one-meter-thick layers of clean soil. The lower layer immediately overlies groundwater. All vadose-zone soil is conservatively assumed to be very permeable sand that freely allows the migration of leachate to groundwater. The organic carbon content of the soil is assumed to be 0.1%.

Leaching based soil action levels are lower than action levels based on direct-exposure concerns for most of the PFASs listed in cases where underlying groundwater is a source of drinking water (refer to Attachment 3, Table A-1, A-2). This was therefore selected as the final soil action level for those chemicals in Summary Table A, following the approach used in the general HIDOH EAL guidance (HIDOH 2024a). Leaching based action levels are lower than direct exposure action levels for only a few of the PFASs in cases where underlying groundwater is not a source of drinking water and the latter was in turn selected as the final, soil action level (Summary Table B; refer to Attachment 3, B-1 and B-2). This reflects the significantly higher groundwater action levels for non-drinking water that are based instead on toxicity to aquatic organisms (refer to above discussion).

Synthetic Precipitation Leaching Procedure (SPLP) laboratory tests should be carried out on soil samples that exceed these action levels. Refer to the HEER Office guidance document *Use of Laboratory Batch Tests to Evaluate Potential Leaching of Contaminants from Soil* (HIDOH 2024b) for additional information on the use of SPLP data to assess leaching risk. Soil column leaching tests such as LEAF Method 1314 might also prove very useful in assessing leaching tests (USEPA 2019c). Modified Method 1314 protocols more suitable to the collection of Multi Increment soil samples and investigation questions specific to leaching of PFASs from soil are currently under development.

Aged compounds in soil can be significantly more sorptive than predicted by published, sorption coefficients for the compounds (HIDOH 2024a). In-house reviews of SPLP batch sample data for soil samples collected in Hawaii suggest that the model *over predicts* the mobility and leaching risk posed by contaminants present in soil in general at very low concentrations. This could be due in part to sorption of PFASs to clays or diffusion into clay lattices, which is not considered in the model. Combined with target groundwater action levels in the parts-per-trillion, resulting leaching based action levels for several PFASs are likely to be lower than laboratory detection limits.

In order to partially address this issue, leaching based action levels for chemicals with Koc values greater than 5,000 cm^3/g, are based on the theoretical soil saturation level ("sat") rather than the SESOIL-ATM123 leaching models, if higher. Examples include $PFDS^-$ (see Table E-1 in Attachment 3). Soil saturation levels were calculated using the saturation equation presented in USEPA Regional Screening Levels guidance (USEPA 2019; see Appendix 2 of HIDOH EHE guidance).

The SESOIL model scenario assumes that the depth to groundwater from the base of the impacted layer of soil is only one meter. This might seem overly conservative. The thickness of the clean layer of soil between the base of the impacted layer and the top of groundwater does not, however, significantly affect the concentration of the contaminant in leachate as it migrates through the vadose zone unless the contaminant is highly volatile or highly biodegradable. Neither is true for the targeted PFASs. Temporary sorption to organic carbon in the soil will retard the rate that the contaminants migrate through vadose but in theory will not significantly reduce the concentration of the contaminants within the leachate itself.

Site-specific modeling of leaching impacts using SESOIL or similar models is therefore unlikely to generate significantly different soil action levels, even for cases where the depth to groundwater is very deep. The time it takes for the contaminants to reach groundwater will simply increase. In practice, however, diffusion of PFASs into clays in the soil and essential immobilization could significantly reduce contaminant concentrations in leachate by the point that the leachate reaches the water table. This factor, which is not taken into consideration in the models, should be assessed on a site-specific basis as necessary.

6.1.5. Vapor Intrusion

Vapors emitted from soil or groundwater contaminated with volatile compounds can pose a potential vapor intrusion risk to existing or future overlying buildings (HIDOH 2024a). Perfluoroethanoate (PFEtA$^-$, aka trifluoroacetate) and perfluoropropanoate (PFPrA$^-$) are currently the only PFAS compound categorized as "volatile" (refer to Table 2). The compound has thus far been only identified in water and in areas that do not pose a vapor intrusion risk to nearby buildings. Potential vapor intrusion concerns have also been raised for fluorotelomer alcohols, in particular where these compounds are manufactured or in association with vapors released from landfills (e.g., Roth 2019). No manufacturing facilities are located in Hawai´i. Potential offsite vapor intrusion risks associated with municipal landfills is not anticipated due to the typical separation distance of these facilities from offsite residential or commercial areas.

Assessment of potential vapor intrusion concerns associated with PFASs is not required at this time but could be required in the future on a case-by-case basis. Future assessment of vapor intrusion concerns associated with PFASs will likely rely on the direct collection of soil vapor and/or indoor air samples rather than comparison of soil or groundwater data to HIDOH action levels. Methods for the collection and testing of vapor-phase PFASs still under development and not widely available.

6.1.6. Uptake into Food Crops and Livestock Feed

The use of PFAS containing biosolids and/or treated wastewater poses potential concerns for uptake of these compounds into food crops and livestock feed (Ghisi et al. 2019; Blaine et al. 2013, 2014). Laboratory-based studies using spiked water indicate a potential accumulation of long-chain PFASs in root crops and uptake of more mobile, short-chain (and likely ultrashort-chain) PFASs into other portions of a plant (e.g., Higgins 2017). A field study of the uptake of PFASs into food crops is anticipated to be initiated by the HIDOH HEER Office in 2026.

Assessment of risk will likely necessitate case-by-case reviews due to variability in anticipated controlling factors such as soil characteristics (organic carbon and clay content, pH, soil microbiome, etc.), plant type; use of roots, stems or fruit; industrial versus domestic source of biosolids amendments and treated irrigation water; use of fertilizers, etc. Action levels developed for soil and treated wastewater to prevent adverse accumulation of PFASs in targeted crops and feed will similarly likely be site-specific, although some general trends might become apparent. Assessment will also require development of risk-based action levels for individual and/or combined groupings of crops and feed.

7.0 Assessment of Total PFAS Risk

A Fact Sheet that summarizes the approach for assessment of Total PFAS Risk is provided in Attachment 4. A three-step approach is presented: 1) Comparison of data for Primary Terminal PFASs originally present in a sample to risk-based action levels ("Pre-TOPs PFASs"), 2) Comparison of additional Secondary Terminal PFASs generated by oxidation of the sample and assumed related to precursor compounds in the sample to the same action levels ("Post-TOPs Precursor PFASs") and 3) Estimation of the concentration of additional PFASs present based on Total Organic Fluorine (TOF) data and comparison to a default action level ("Excess Fluorine PFASs"). A Total PFAS Risk spreadsheet that accompanies this Technical Memorandum allows rapid calculation of the cumulative risk posed by each group of compounds.

Primary Terminal PFASs initially present in a sample can be identified and quantified using standard laboratory methods (see Section 10). Retesting of samples using Total Oxidizable Precursors (TOPs) will identify additional "precursor" PFAS compounds not reported by standard laboratory methods or compounds that lack toxicity factors (Houtz and Sedlak 2012, Ateia 2023, Pelch 2023). Assessment of risk could in practice be carried out based solely on post-TOPs data, since Primary Terminal Endpoint compounds originally present in the sample would, in theory, be unaffected still be present. Inclusion of pre-TOPs data is useful to understand the overall makeup of the original PFAS mixture, however, as well as necessary for comparison to USEPA and HIDOH drinking water Maximum Contaminant Levels (MCLs).

The risk assessment approach presented in this guidance document focuses the development of toxicity factors and action levels for assessment of potential noncancer health hazards and the protection of young children (i.e., ingestion and dermal absorption Reference Doses and inhalation Reference Concentrations). This is assumed to take precedence over potential cancer-related risks posed to older adults. This assumption will be reviewed as additional information on the carcinogenicity of PFAS compounds evolves.

7.1. Step 1: Primary (Pre-TOPs) PFASs

Calculate and sum noncancer Hazard Quotients for each Primary Terminal PFAS compound reported in pre-TOPs data. A Hazard Quotients is calculated as the ratio of the reported concentration of the compound divided by the corresponding, risk-based action level listed in Attachment 3 to this document. Soil data are compared to Direct Exposure action levels presented in Table I-1 (Unrestricted/Residential), Table I-2 (Commercial/Industrial) and/or Table I-3 (Construction-Trench Workers), depending on current or anticipated future use of the site. Data for groundwater or surface water that is a current or potential source of drinking water are compared to toxicity-based drinking water action levels presented in Table D-3a. Both the soil and water action levels are based on an HQ of "1." The sum of the Hazard Quotients is referred to as the "Hazard Index" (USEPA 2024b,d; refer also to HIDOH 2024a, Volume 2, Section 1.4).

7.2. Step 2: Secondary (Post-TOPs) PFASs

Initial testing of the sample for PFASs is followed by processing and retesting of the sample using Total Oxidizable Precursors (TOPs) method (e.g., Houtz and Sedlak 2012). The sample is heated with an oxidizing agent under alkaline conditions. Primary Terminal PFASs originally in the sample are assumed to have been preserved largely unchanged in the post-TOPs data. Much like pruning branches from a tree to exposure the underlying trunk, functional groups are stripped from any "precursor" PFAS compounds present, exposing the underlying, Terminal PFASs that forms the backbone of the compounds and generating an additional group of Secondary Terminal PFASs. The method indirectly mimics end products generated by natural metabolism of the compounds (refer to Tseng et al. 2014; Marjanoic et al. 2015).

Reported concentrations of Primary Terminal PFASs are subtracted from the post-TOPs data in order to determine the concentrations of Secondary Terminal PFASs associated with the breakdown of precursor compounds. Separate Hazard Quotients and a cumulative Hazard Index are then calculated for this group of compounds in the same manner as described for Primary Terminal PFASs noted above.

7.3. Step 3: Excess (Organic) Fluorine PFAS

The final step involves the use of "Total Organic Fluorine" (TOF) data to determine the presence of additional, PFAS-related compounds not captured by the post-TOPs data. Excess organic fluorine (EOF) in a sample is calculated as the difference between measured TOF and predicted TOF based on concentrations of Primary and Secondary Terminal PFASs. For example:

$$Excess\ Organic\ Fluorine\ \left(\frac{ng}{L}\right) = Measured\ TOF - Predicted\ TOF; \qquad \text{Eq.1}$$

$$Predicted\ Total\ Organic\ Fluorine\ \left(\frac{ng}{L}\right) = (Predicted\ Primary\ Teminal\ PFAS\ \ TOF + Predicted\ Secondary\ Termnal\ PFAS\ TOF). \qquad \text{Eq.2}$$

The predicted concentration of Total Organic Fluorine associated with pre-TOPs sample data for Primary Terminal PFASs and post-TOPs data for precursor-related, Secondary Terminal PFASs is calculated as:

$$\begin{aligned} Predicted\ TOF &= \left(Conc._{PFAS\#1} \times \frac{(AM_{Fluorine} \times \#Fluorine\ Atoms)}{MW_{PFAS\#1}}\right) \\ &+ \left(Conc._{PFAS\#2} \times \frac{(AM_{Fluorine} \times \#Fluorine\ Atoms)}{MW_{PFAS\#2}}\right) \\ &+ \left(Conc._{PFAS\#3} \times \frac{(AM_{Fluorine} \times \#Fluorine\ Atoms)}{MW_{PFAS\#3}}\right) + etc. \end{aligned} \qquad \text{Eq.3}$$

where "$AM_{Fluorine}$" is the atomic mass of fluorine (18.998 u) and "MW_{PFAS}" is the molecular weight (mass) of the specific PFAS compound. The molecular weight of individually targeted PFAS compounds is included in Table 2.

In previous versions of this guidance document, predicted TOF estimations only considered post-TOPs data. Both iterations will yield approximately the same result, since post-TOPs data in theory will reflect both Primary Terminal PFASs and precursor-related, Secondary Terminal PFASs. Nevertheless, the updates presented here (eq 2 and 3) allow for input of data for compounds that are not reported in TOPs data and more directly relates to the three groups of PFASs defined for use in estimation of Total PFAS Risk.

Measured TOF is tested and reported by the laboratory as Absorbable Organic Fluorine (AOF) for liquids and Extractable Organic Fluorine (EOF) for solids. The sum of the predicted concentration of organic fluorine is compared to measured TOF reported for the sample to identify any additional, organic fluorine in the sample. Subtraction of the predicted TOF from the measured TOF yields the concentration of "Excess Organic Fluorine."

The excess organic fluorine is assumed to be attributable to additional, terminal endpoint PFAS compounds in the sample that were not identified by pre-TOPs analysis. Non-Targeted Analysis (NTA) testing of water samples collected by HIDOH as part of an ongoing field study of PFAS at WWTPs and AFFF-release sites (HIDOH, 2025) as well as unpublished drinking water data collected by California (personal communication, Wendy Lynk 2023) indicates that the majority of excess organic fluorine is attributable to terminal ultrashort PFAS compounds such as $PFEtA^-$, $PFPrA^-$ and perfluoropropane sulfonate ($PFPrS^-$). The origin of these compounds is uncertain but is presumably attributable to an original presence in the product released and/or to natural degradation of longer-chain compounds (Björnsdotter et al. 2019, Zheng et al. 2023). Precursor compounds identified by NTA can provide additional information on the source of a PFAS release.

For the purposes of this Technical Memorandum, the weighted toxicity of Excess Fluorine-related compounds in a sample is assumed to be equal to the toxicity of $PFPrA^-$, the most toxic of the two ultrashorts with available toxicity factors ($PFEtA^-$ and $PFPrA^-$; refer to Table 3b). The need to re-evaluate this assumption based on sample-specific NTA data can be determined on a case-by-case basis, either at the option of the Responsible Party or as requested by HIDOH. Corresponding, alternative action levels for Excess Fluorine PFASs can be input into the accompanying Total PFAS Risk calculator (see Section 7.4). Technical supporting documentation must be provided to HIDOH for review and approval.

The calculated concentration of excess organic fluorine in a sample is converted to an equivalent concentration of PFPrA- using similar stoichiometry as described above, except in reverse:

$$Conc. EFPs = Conc. Excess\ Organic\ Fluorine \times \frac{MW\ \mathrm{PFPrA}^-}{\#F \times AM_{Fluorine}} \qquad \text{Eq. 4}$$

where "Conc. EFPs" is the concentration of "Excess Fluorine PFASs", "MW $PFPrA^-$" is the molecular weight (mass) of $PFPrA^-$ (164 g/mol), "#F" is the number of fluorine atoms in $PFPrA^-$ (5 atoms) and "$AM_{Fluorine}$" is again the atomic mass of fluorine (18.998 u). This simplifies to:

$$Conc.\ EFPs = Conc.\ of\ Excess\ Fluorine \times 1.73. \qquad \text{Eq. 5.}$$

A Hazard Quotient for this group of compounds is generated by division of the resulting estimated concentration of Excess Fluorine PFASs by the corresponding drinking water or soil action level for $PFPrA^-$. The result could conceivably be referred to as a "Hazard Index," since the value most likely reflects an unknown mixture of PFAS ultrashort compounds in the sample.

While inexact, this allows approximation of both the concentration and weighted toxicity of additional PFAS compounds in a sample not captured in either the pre-TOPs or post-TOPs data, as well as the potential health risks posed by these compounds. These assumptions can be evaluated on a site-specific basis as needed based on more detailed sample data or reference to related information.

7.4. Step 4. Calculation of Total PFAS Risk

Total PFAS Risk is calculated by summing the Hazard Indices calculated for Primary Terminal PFAS and Secondary Terminal PFASs as described above and the Hazard Quotient calculated for Excess Fluorine PFASs. The final Hazard Index is rounded to a single, significant digit for decision making (USEPA 1989, HIDOH 2024a). An exceedance of a Hazard Index of “1” indicates a need for additional action to assess exposure and health risk.

Health risks posed by terminal PFASs identified in samples outside of those specifically discussed in this guidance should be individually assessed and, as appropriate, included with calculation of cumulative health risk. This includes ether acids similar in recalcitrance to TOPs processing as HFPO-DA$^-$ and not expected to metabolize into potentially lower-toxicity compounds following exposure (e.g., refer to Zhang et al. 2019).

These calculations are automatically carried out in the accompanying Total PFAS Risk Excel spreadsheet based on input site data (Attachment 5, separate Excel file). Use of the spreadsheet for reports submitted to HIDOH for review is strongly recommended. Cancer risk is assessed based on individually targeted compounds, such as PFOA$^-$. Protection of young children against noncancer-related health hazards as described in this guidance is currently assumed to also be protective of future cancer risks to older children and adults. This assumption will be reviewed as additional information on the health effects posed by PFASs is obtained.

8.0 Sample Collection and Processing

8.1. General

Investigations of PFASs-contaminated soil and groundwater should adhere to sampling protocols presented in the HEER Office *Technical Guidance Manual* (TGM; HIDOH 2023). This includes the collection of Multi Increment samples for testing of soil, sediment and biosolids (TGM Sections 3-5). Discrete soil or other particulate matter sample data are not acceptable for final decision making (refer to TGM Section 3). The collection of Multi Increment-type samples should also be considered for testing of surface water (TGM Section 6). This might include, for example, the continuous collection of a sample during purges of large, risk-based volumes of water from a single well, referred to as "Large Volume Purge (LVP)" sampling methods, rather than the collection of traditional, small-volume, "discrete" waters samples.

Guidance documents published by the USEPA and other states caution against the use of specific equipment and materials that could result in inadvertent contamination of samples with PFASs (e.g., USEPA 2019, CAEPA 2019b,c, 2020a,b; MADEP 2019; MIDEQ 2019). Note that statements made in early regulatory guidance regarding the potential presence of PFAS in sampling equipment, sample bags, sunscreen and other field material have in some cases proven to be incorrect. Research has not, for example, indicated significant cross contamination of environmental samples with equipment and material typically used to collect samples (Denly et al. 2019; Kaminski 2019; Rodowa et al. 2020). This includes the lack of PFASs in the manufacturing of low-density polyethylene bags (LPDE) recommended in the HEER TGM for the collection of soil, sediment and other particulate media. [The lack of PFASs in their food storage bags was confirmed by representatives of SC Johnson, the maker of Ziplock® storage bags (Cataldo 2020) as well as the makers of Hydrosleeve® samplers (Ciomek 2020) and Snap Samplers (QED 2019), used for the collection of groundwater samples. The lack of PFASs in Banana Boat sunscreen was similarly confirmed by representatives of that company.]

Contact the makers of specific sampling equipment and other field supplies to determine the potential use or inadvertent presence of PFAS containing compounds of interest in these materials. It is not the intent of the HEER Office to require the use of or avoidance of tools, containers, personal protective equipment and other products that might come into contact with samples, particularly as formulations may change over time. Field and laboratory workers should be aware of and take into consideration a products formulation that could lead to inadvertent contamination of samples with PFASs. Material that is specifically identified as waterproof, water resistant or stain-resistant and might come into contact with a sample should be avoided or tested for the potential presence of PFASs. The use of material that contains fluoropolymers is acceptable provided that the material does not introduce targeted PFASs or related precursor compounds into the samples.

Inadvertent contamination of properly collected soil samples is highly unlikely if proper Multi Increment sampling methods are used and simple precautions are taken to avoid cross contamination. Equipment blanks for soil samples are therefore not necessary or recommended. The use of equipment blanks is highly recommended, however, for the collection of water samples.

8.2. Collection and Processing of Liquid Samples

"Ultra-clean" collection methods are especially warranted for the collection of water samples in order to minimize inadvertent, secondary contamination of samples due to the potential presence of PFASs in clothing, cosmetics and other material taken into the field. Refer to the guidance documents noted above and related information for specific details. The collection of equipment blanks is recommended to assess and document potential cross contamination of samples.

Action levels for drinking water and aquatic toxicity are based on the dissolved-phase concentrations of PFAS compounds. Turbid samples should be filtered prior to testing in order to more accurately assess these concerns. Filtering should be carried out at the laboratory. Data for unfiltered samples might be required if the objective of the study is to assess total, mass loading associated, for example, with discharge of wastewater to a surface water body. These issues should be evaluated and tied to recommended sample collection and processing methods as part of the systematic planning process and discussed in the sampling and analysis plan (refer to Section 3 of the HEER TGM).

8.3. Collection and Processing of Particulate Media Samples

Decision Unit and Multi Increment Sample (DU-MIS) investigation methods must be used for the collection of soil, sediment, biosolids and other particulate matter (refer to Section 4 of the TGM). This includes preparation of a minimum 1-2kg sample composed of at least 50 increments collected in a systematic, random manner within the targeted DU area. Discrete sample data are not acceptable for decision making purposes, including the presence or absence of targeted compounds of concern.

The use of new, heavy-duty, low-density or high-density polyethylene (HDPE, LDPE) freezer bags (e.g., Ziplock® bags) to collect Multi Increment soil, sediment and other particulate samples as recommended in Section 4 of the HEER Office TGM is recommended for the collection of samples to be tested for PFASs. PFASs are not used in the production of these bags, contrary to statements in some early sampling guidance (Cataldo 2022). Significant, cross contamination of large, Multi Increment samples from equipment or containers that inadvertently contain trace levels of PFASs is furthermore unlikely given the mass of the sample prepared. Sampling equipment should be cleaned in accordance with guidance in Section 5.9 of the TGM. As noted in that section, the collection of equipment rinsate samples is not necessary.

As a default, **the <2 mm diameter particle size fraction should be targeted for testing of particulate matter such as soil, sediment and biosolids** and for comparison to the HEER EALs (refer to Section 4.2.6 of the HEER TGM, HIDOH 2023). The analytical subsample (aliquot) should be collected following MI sample processing methods discussed in Section 4.2.6.2 of the HEER TGM. The targeted PFAS anions are not anticipated to be significantly volatile (refer to following section). Standard laboratory protocols for processing of Multi Increment soil samples should therefore be followed, including air drying, sieving to < 2mm particle size and the use of Multi Increment-type methods for collection of subsamples for analysis (refer to Section 4.2.6 of the HEER Office TGM; HIDOH 2023).

Extraction and testing of a minimum, ten-gram analytical subsample is required in order to ensure that the subsample is representative of the sample. A default, 10-gram subsample mass for the <2mm particle-size fraction is recommended in the HEER Office TGM. Discussions with laboratories indicate that this might be cost- and labor-prohibitive at this time. Testing of a

5-gram subsample is acceptable provided that replicate (triplicate) subsamples are collected and tested from 20% of the samples submitted for a given project (minimum two samples if more than one sample to be tested for PFASs). Laboratories might need to modify standard test methods to achieve a five-gram subsample mass or conduct multiple small subsample extractions and combine them for analysis. This might also increase the standard analytical fee. Some labs, for example, only test 0.5 grams of soil as a default analytical subsample mass for PFASs. The potential error in estimation of a mean contaminant concentration for the sample as a whole is, however, unacceptable. Alternative methods should be discussed with the HEER Office and justified in the sampling and analysis plan.

Particulate samples to be tested for potentially volatile PFAS, including some fluorotelomer alcohols, should be collected in accordance with guidance presented in Section 4 of the HEER Office *Technical Guidance Manual* (HIDOH 2023). Guidance specific to the collection of soil samples to be tested for volatile PFASs has not been identified. The use of methanol to preserve a sample should be discussed with the laboratory prior to collection in the field, since this could increase method reporting limits. Alternative sample preservation approaches are discussed in the TGM. Discrete samples are not allowed under HIDOH guidance (HIDOH 2023). Consider the collection and testing of soil vapor samples for PFASs as an alternative and a more direct way to assess potential vapor intrusion risk.

9.0 Laboratory Test Methods

Methods for testing of PFASs in water and other media are still evolving (USEPA 2019d, 2021a). The most common methods currently in use include:

- Method 537M (USEPA 2020; 40+ PFAS compounds);
- Method 1633 (USEPA 2021c; 40+ PFAS compounds; includes additional sample cleanup procedures; SGS equivalent MLA110); and
- Method 1621 (USEPA 2024i; Total Organic Fluorine’ SGS equivalent MLA119).

Other USEPA lab methods that report a short list of individual PFASs include Method 533 (USEPA 2019a) for drinking water and Method 8327 for groundwater, surface water and wastewater (USEPA 2021b). These methods have largely been replaced by modifications to Method 537 by commercial laboratories to manage the large load of samples submitted while providing the degree of data quality required for a project. Modifications to Method 537M and Method 1633 include expansion to report ultrashort compounds (SGS equivalent MLA120). The joint Department of Defense and Department of Energy *Quality Systems Manual* includes a test method for a combined and extended list of PFASs, referred to as DoD QSM 5.3 in Table 7 (DOD-DOE 2019; refer to Table B-15 and Table C-44 in manual). Commercial laboratories have developed similar, propriety methods to improve identification and quantification of PFAS-related compounds.

Ensure that the laboratory selected for testing of samples is able to process samples using Total Oxidizable Precursors (TOPs) methods. Current methods utilized by laboratories are proprietary but in general follow the approaches described in published literature (e.g., Houtz and Sedlak 2012). The USEPA is working with commercial laboratories to develop a Standard Operating Procedure (SOP) procedure.

Select a method most appropriate for the release scenario of interest. Testing for PFASs reportable under both Method 537.1 and Method 533 or separately under DoD QSM 5.3 or an equivalent laboratory method is recommended in order to obtain data for all PFASs for which toxicity factors are available. Method 1633 tests for a much broader scope of PFAS compounds and can be useful for initial investigation and identification of key contaminants of concern. Less extensive and less costly methods can normally be adequate for followup testing.

Total Organic Fluorine is reported as Absorbable Organic Fluorine (AOF) for liquids and Extractable Organic Fluorine (EOF) for solids. **CAUTION! Ensure that fluorine-free filters are used by the laboratory to filter water samples that will be tested for Absorbable Organic Fluorine.** Laboratories have reported high levels of organic fluorine in some types of filters. This could lead to an erroneous conclusion of significant, unidentified PFASs in a sample due to the apparent presence of high levels of organic fluorine in exceedance of that predicted by data reported for individually identified compounds.

Current USEPA laboratory methods for PFASs might require modification for testing of soil, turbid water or other types of media. Discuss collection and processing requirements with the laboratory prior to submittal of samples for analysis.

10.0 Limitations

An understanding of the fate and transport and toxicity of PFASs is continually evolving. Physiochemical constants and toxicity factors used to generate action levels in this guidance will be updated as new information is obtained. HEER Office guidance on more reliable, laboratory-based leaching methods as an alternative to the use of default soil action levels is anticipated to be published in 2026.

TOPs methods discussed in this guidance are also continually evolving and being standardized. Guidance on preferred methods published by the USEPA and other entities will be incorporated into this document as they become available. Use of TOPs data to assess risk assumes the full oxidation of precursor compounds to Secondary Terminal PFASs in the human body. Some researchers have suggested that partial oxidation is more likely and that this assumption could be overly conservative. Other researchers have suggested that partially oxidized metabolites could in fact be more toxic than the parent compounds. A more in-depth review of this issue will be incorporated into future updates of the guidance document and related HIDOH research. A more in-depth review of these issues can be evaluated in a site-specific risk assessment, if needed.

The guidance currently does not address potential risk posed the uptake of PFASs into food crops. This is a potential concern for agricultural fields where biosolids have been applied as a soil amendment or treated wastewater used for irrigation. Biosolids and wastewater from industries that manufacture or heavily use PFASs are currently assumed to pose the primary risk. Concentrations of PFASs in biosolids and wastewater associated with domestic wastewater treatment plants tend to be significantly lower and the PFASs present of lower toxicity. Research on these issues is ongoing. The results of a field studies of PFASs in domestic biosolids and wastewater in Hawai´i are included in HIDOH (2024b).

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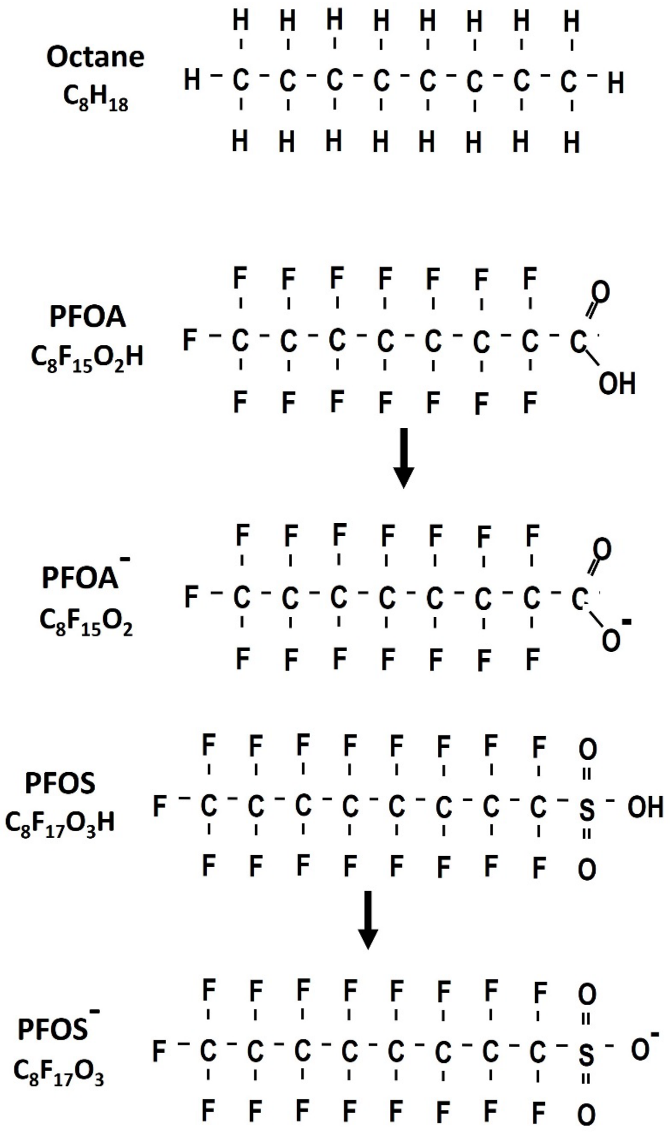
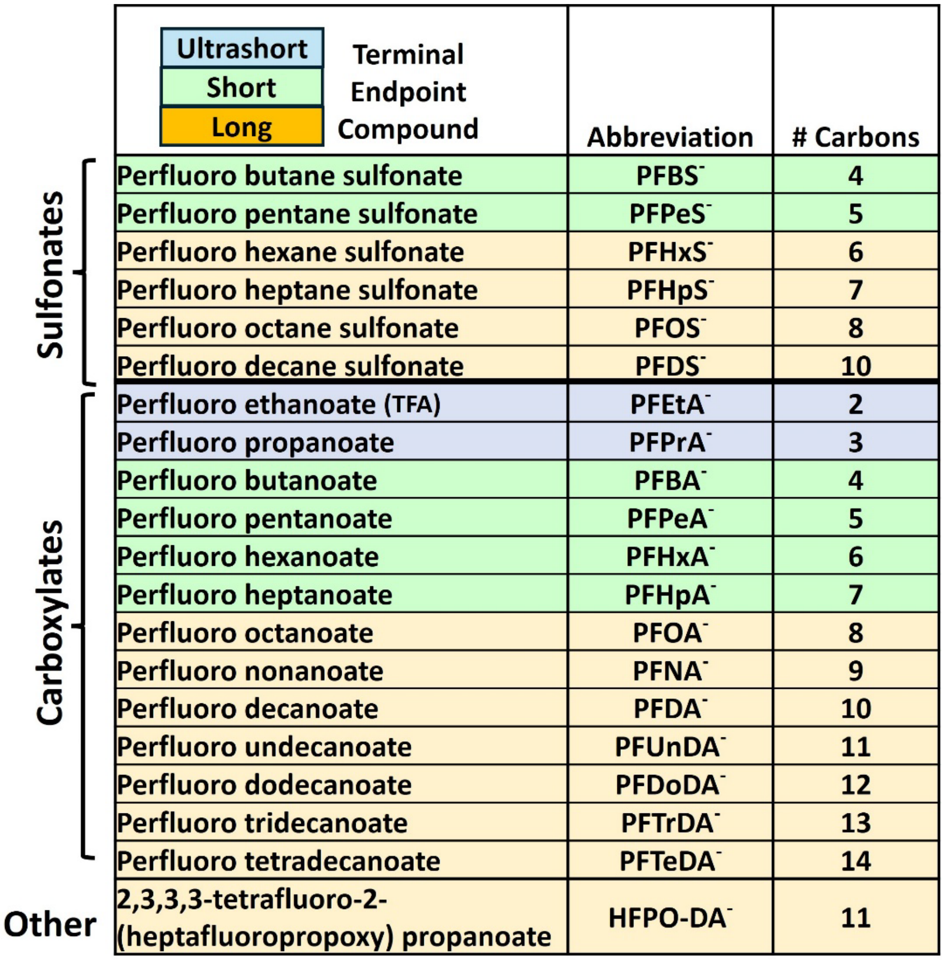


Figure 1. Structure of octane compared to perfluorooctane sulfonic acid and its anion form perfluorooctane sulfonate and perfluorooctanoic acid and its anion form perfluorooctanoate. Anion forms are more common in contaminated soil, sediment and water.



Ultrashort
Short
Long

	Terminal Endpoint Compound	Abbreviation	# Carbons
Sulfonates	Perfluoro butane sulfonate	PFBS^{-}	4
	Perfluoro pentane sulfonate	PFPeS^{-}	5
	Perfluoro hexane sulfonate	PFHxS^{-}	6
	Perfluoro heptane sulfonate	PFHpS^{-}	7
	Perfluoro octane sulfonate	PFOS^{-}	8
	Perfluoro decane sulfonate	PFDS^{-}	10
Carboxylates	Perfluoro ethanoate (TFA)	PFEtA^{-}	2
	Perfluoro propanoate	PFPrA^{-}	3
	Perfluoro butanoate	PFBA^{-}	4
	Perfluoro pentanoate	PFPeA^{-}	5
	Perfluoro hexanoate	PFHxA^{-}	6
	Perfluoro heptanoate	PFHpA^{-}	7
	Perfluoro octanoate	PFOA^{-}	8
	Perfluoro nonanoate	PFNA^{-}	9
	Perfluoro decanoate	PFDA^{-}	10
	Perfluoro undecanoate	PFUnDA^{-}	11
	Perfluoro dodecanoate	PFDoDA^{-}	12
	Perfluoro tridecanoate	PFTrDA^{-}	13
	Perfluoro tetradecanoate	PFTeDA^{-}	14
Other	2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate	HFPO-DA^{-}	11

Figure 2. Terminal PFAS compounds with available physiochemical constants and toxicity factors; used to Total PFAS Risk associated with complex mixtures of compounds. Perfluoroethanoate is more commonly referred to as trifluoroacetate (TFA). HFPO-DA is considered a Terminal PFAS due to its recalcitrance to breakdown in the environment and TOPs processing.

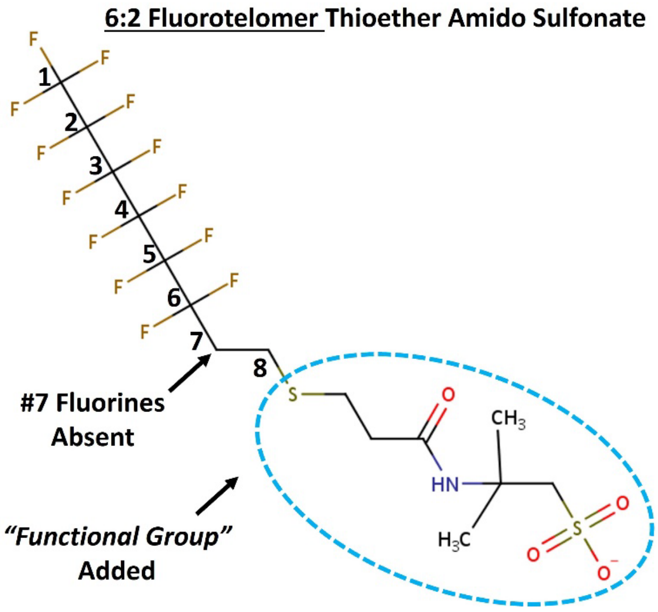


Figure 3. Structure of 6:2 FtTAoS$^-$ (compare to structure of PFOA depicted in Figure 1).

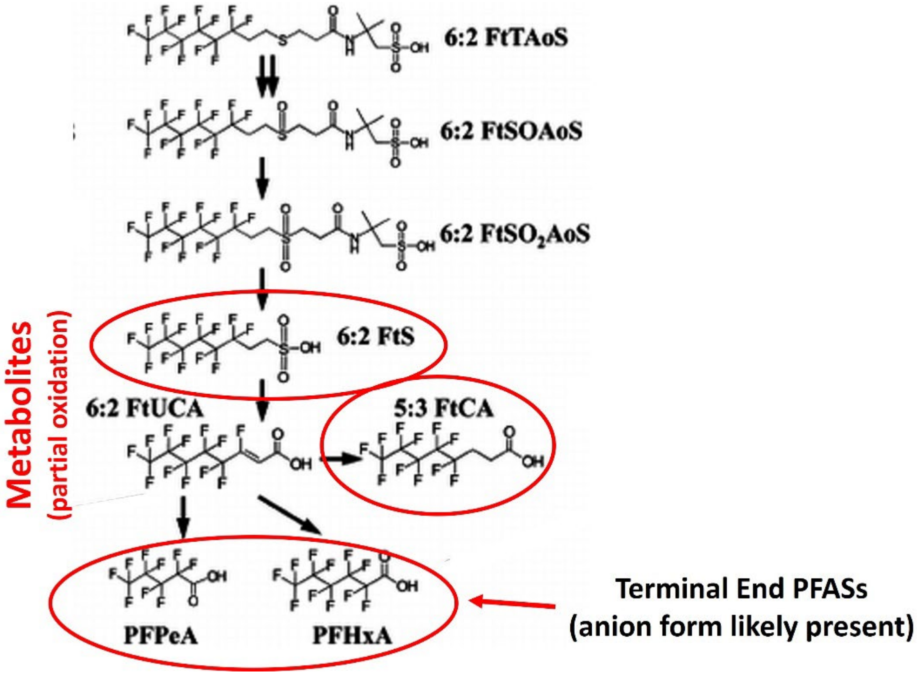


Figure 4. Example biological degradation of 6:2 FtTAoS$^-$ into flurotelomer sulfonates and carboxylates before ultimately degrading to the Secondary Terminal PFAS compounds PFPeA$^-$ and PFHxA$^-$ (after Marjanoic et al. 2015). Structures should be in anion forms rather than acid forms, as depicted (hydrogen removed from hydroxyl group).

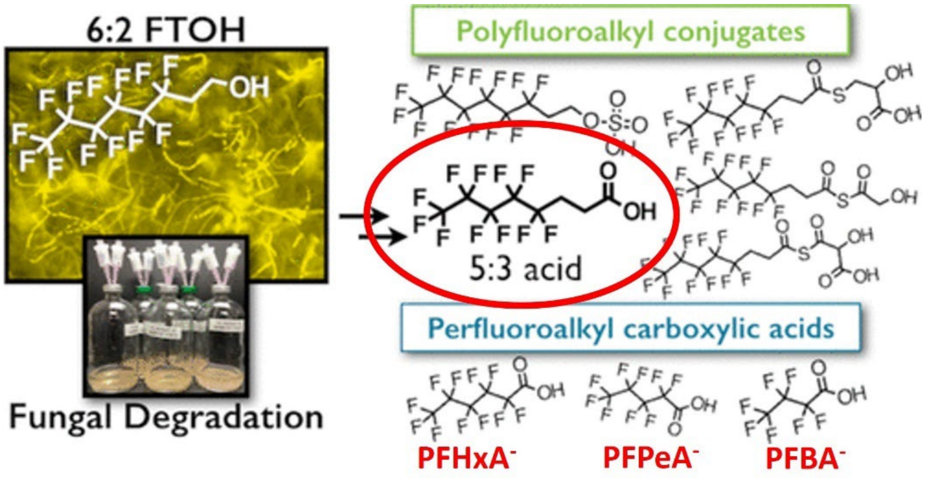


Figure 5. Example biological degradation of 6:2 FTOH$^-$ into carboxylates before ultimately degrading to the short-chain Secondary Terminal PFAS compounds PFHxA$^-$, PFPeA$^-$ and PFBA$^-$ (after Tseng et al. 2014). Structures should be in anion forms rather than acid forms, as depicted (hydrogen removed from hydroxyl group).

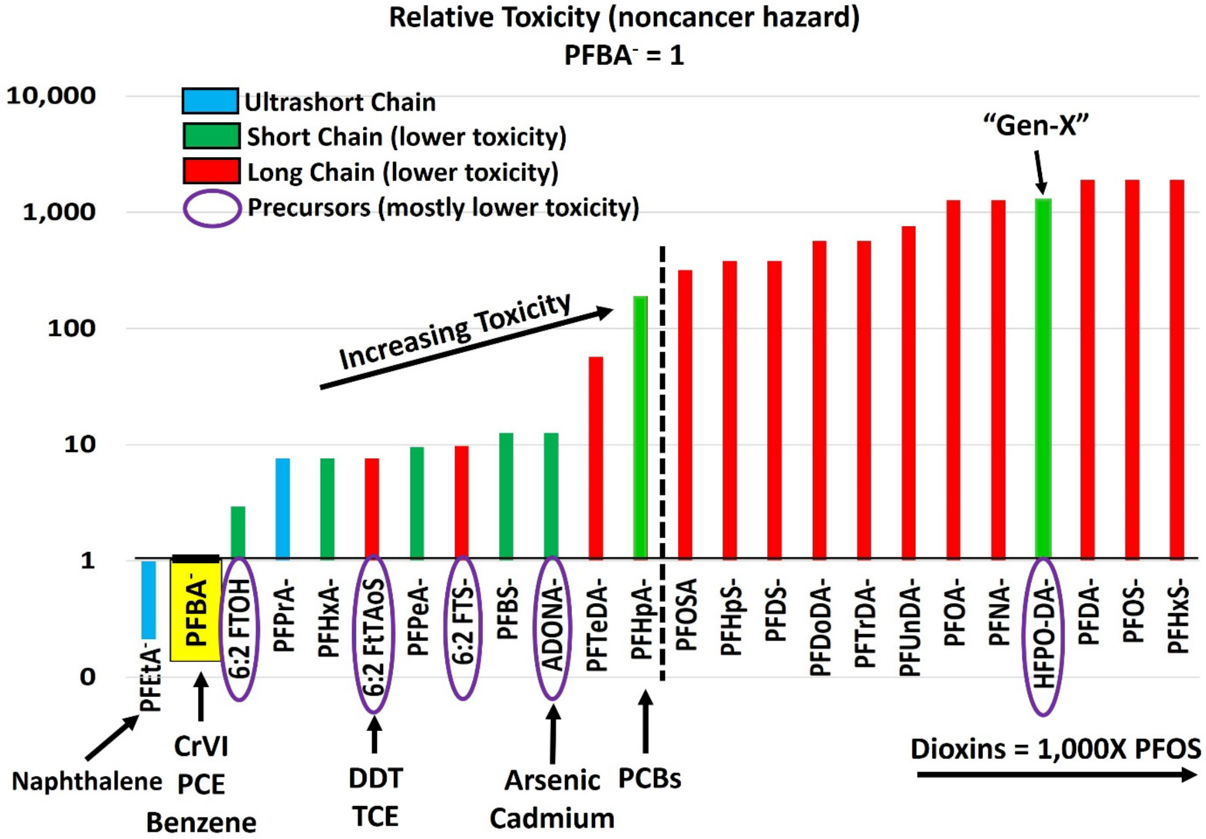


Figure 6. Relative toxicity of PFASs in comparison to other common environmental contaminants.

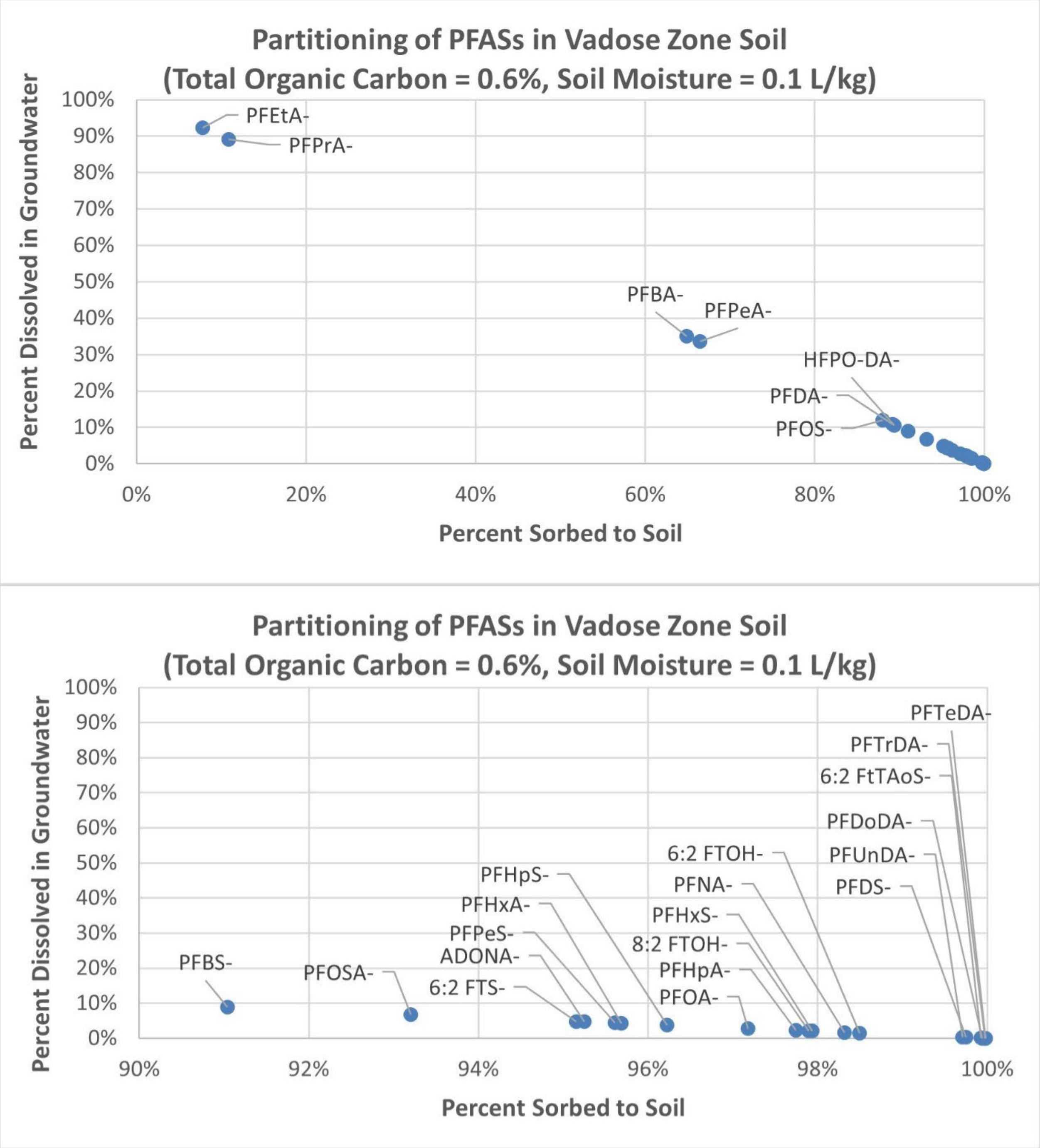
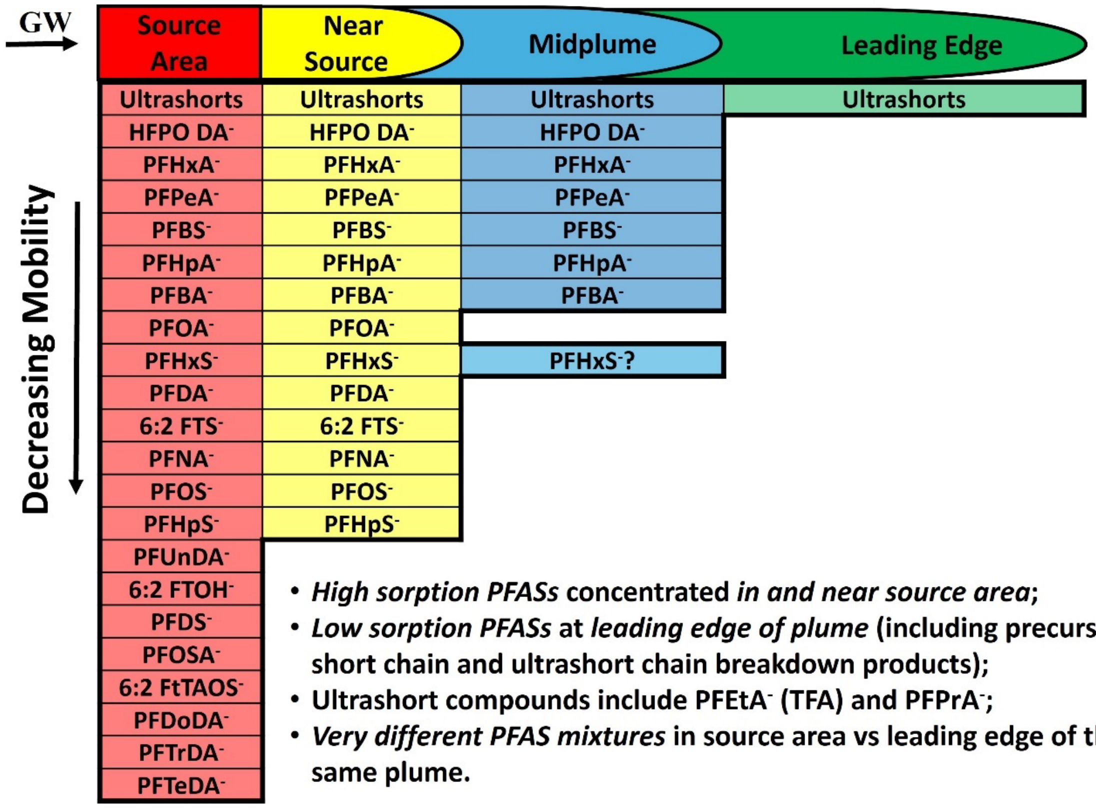


Figure 7. Predicted partitioning of PFASs upon initial release to vadose zone soil based on the chemical's solubility, sorption coefficient and volatility and default soil parameter values used in HIDOH EAL models.



- ***High sorption PFASs*** **concentrated** ***in and near source area*****;**
- ***Low sorption PFASs*** **at** ***leading edge of plume*** **(including precursor short chain and ultrashort chain breakdown products);**
- **Ultrashort compounds include PFEtA$^-$ (TFA) and PFPrA$^-$;**
- ***Very different PFAS mixtures*** **in source area vs leading edge of the same plume.**

Figure 8. Hypothetical PFASs groundwater plume separation based on sorption coefficients for individual compounds. Widespread occurrence of PFHxS$^-$ in groundwater suggests greater mobility than predicted by published sorption coefficients.

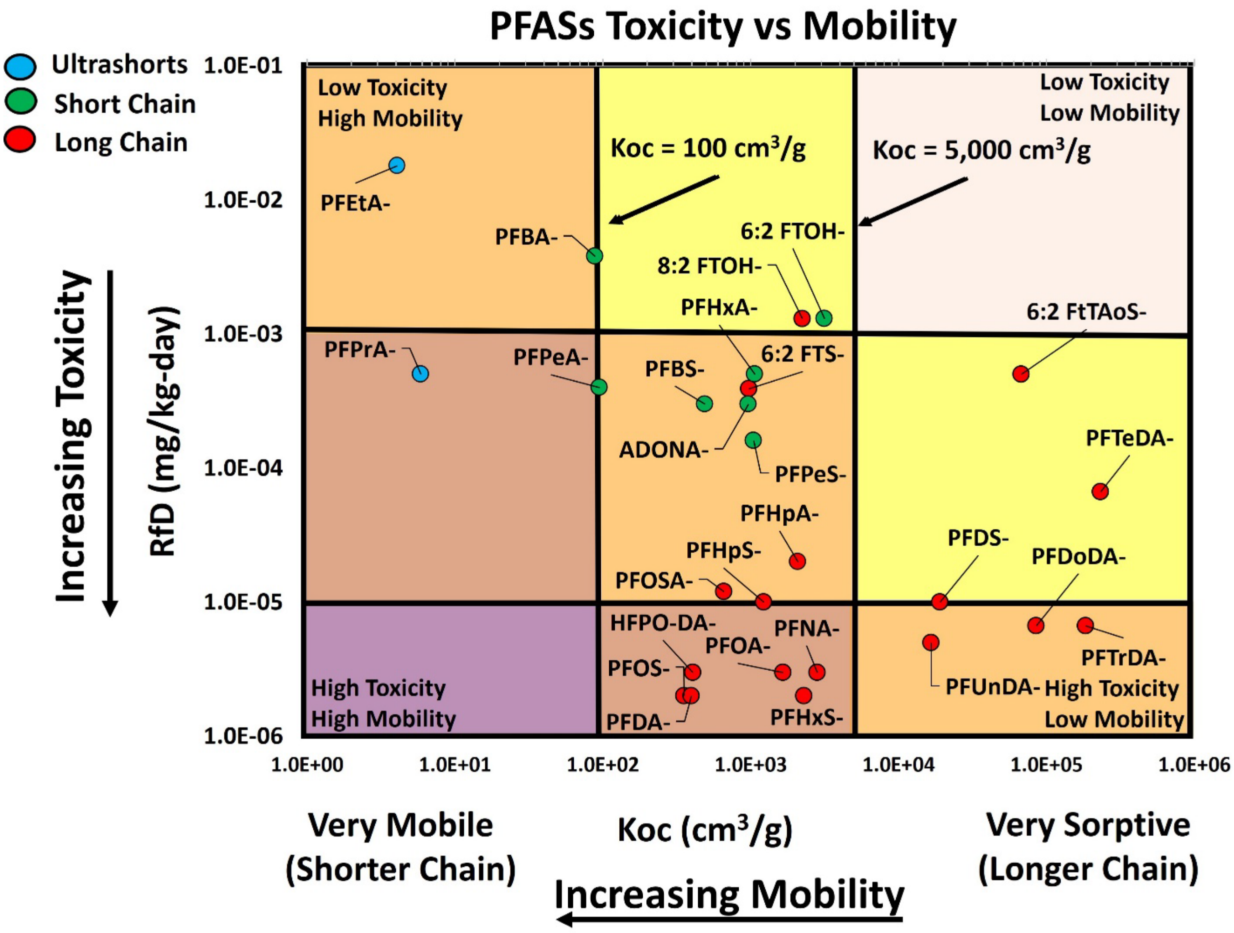


Figure 9. Predicted PFASs mobility versus toxicity.

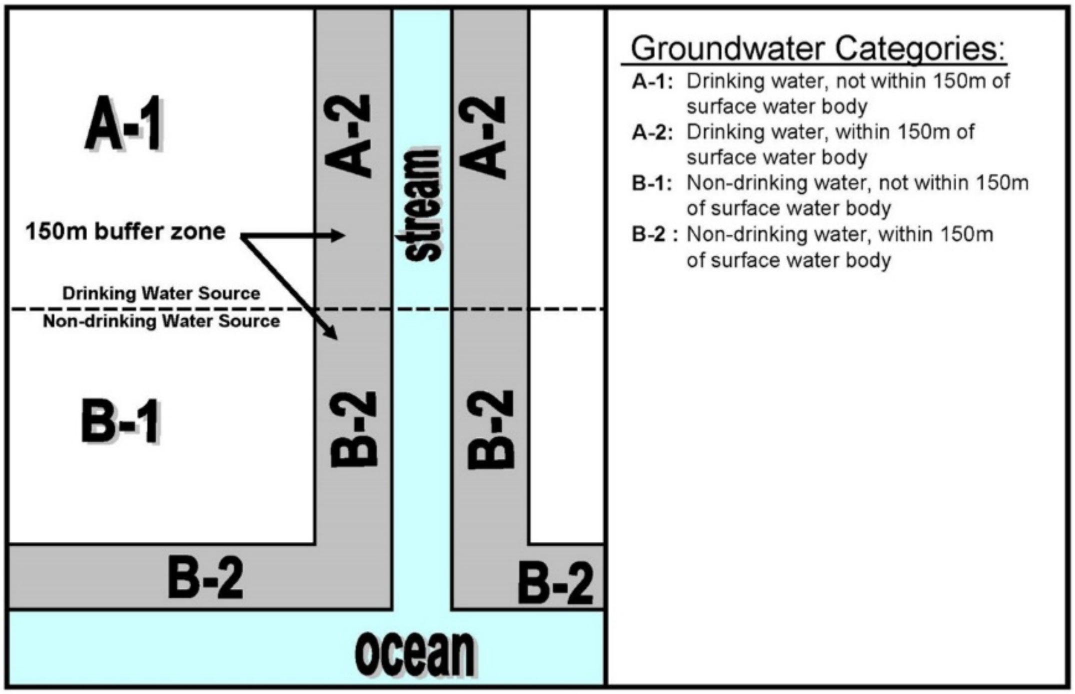


Figure 10. Groundwater categories used to develop the Tier 1 EAL lookup tables (HIDOH 2024).

Table 1. Nomenclature and abbreviations for per- and polyfluoroalkyl substances with physiochemical constants and toxicity factors.

Group	Protonated Acid Form	CAS #	Abbreviation	Anion Form Found in the Environment	CAS #	[1]Abbreviation
Perfluoroalkyl Sulfonic Acids and Sulfonates	Perfluorobutane sulfonic acid	375-73-5	PFBS	Perfluorobutane sulfonate	45187-15-3	PFBS$^-$
	Perfluoropentane sulfonic acid	1035556	PFPeS	Perfluoropentane sulfonate	175905-36-9	PFPeS$^-$
	Perfluorohexane sulfonic acid	355-46-4	PFHxS	Perfluorohexane sulfonate	108427-53-8	PFHxS$^-$
	Perfluoroheptane sulfonic acid	375-92-8	PFHpS	Perfluoroheptane sulfonate	146689-46-5	PFHpS$^-$
	Perfluorooctane sulfonic acid	1763-23-1	PFOS	Perfluorooctane sulfonate	45298-90-6	PFOS$^-$
	Perfluorodecane sulfonic acid	335-77-3	PFDS	Perfluorodecane sulfonate	126105-34-8	PFDS$^-$
Perfluoroalkyl Carbonic Acids and Carboxylates	[2]Perfluoro ethanoic acid	76-05-1	PFEtA	[2]Perfluoro ethanoate	44864-55-3	[2]PFEtA$^-$
	Perfluoro propanoic acid	422-64-0	PFPrA	Perfluoro propanoate	14477-72-6	PFPrA$^-$
	Perfluoro butanoic acid	375-22-4	PFBA	Perfluoro butanoate	45048-62-2	PFBA$^-$
	Perfluoro pentanoic acid	2706-90-3	PFPeA	Perfluoro pentanoate	45167-47-3	PFPeA$^-$
	Perfluoro hexanoic acid	307-24-4	PFHxA	Perfluoro hexanoate	92612-52-7	PFHxA$^-$
	Perfluoro heptanoic acid	375-85-9	PFHpA	Perfluoro heptanoate	120885-29-2	PFHpA$^-$
	Perfluoro octanoic acid	335-67-1	PFOA	Perfluoro octanoate	45285-51-6	PFOA$^-$
	Perfluoro nonanoic acid	375-95-1	PFNA	Perfluoro nonanoate	72007-68-2	PFNA$^-$
	Perfluoro decanoic acid	335-76-2	PFDA	Perfluoro decanoate	73829-36-4	PFDA$^-$
	Perfluoro undecanoic acid	2058-94-8	PFUnDA	Perfluoro undecanoate	196859-54-8	PFUnDA$^-$
	Perfluoro dodecanoic acid	307-55-1	PFDoDA	Perfluoro dodecanoate	171978-95-3	PFDoDA$^-$
	Perfluoro tridecanoic acid	72629-94-8	PFTrDA	Perfluoro tridecanoate	862374-87-6	PFTrDA$^-$
	Perfluoro tetradecanoic acid	376-06-7	PFTeDA	Perfluoro tetradecanoate	365971-87-5	PFTeDA$^-$
Other	Perfluoro octane sulfonamide	754-91-6	PFOSA	Perfluoro octane sulfonate	45298-90-6	PFOSA$^-$
	Hexafluoro propylene oxide dimer acid (GenX)	13252-13-6	HFPO-DA	Perfluoro (2-propoxypropanoate)	122499-17-6	HFPO-DA$^-$
	6:2 Fluorotelomer Sulfonic Acid	27619-97-2	6:2 FTS	6:2 Fluorotelomer sulfonate	27619-97-2	6:2 FTS$^-$
	4,8-Dioxa-3H-perfluorononanoic acid	919005-14-4	DONA	Ammonium 4,8-Dioxa-3H-perfluoro nonanoate	958445-44-8	[3]ADONA$^-$
	6:2 Fluorotelomer alcohol	647-42-7	6:2 FTOH	6:2 Fluorotelomer alcohol	647-42-7	6:2 FTOH$^-$
	8:2 Fluorotelomer alcohol	678-39-7	8:2 FTOH	8:2 Fluorotelomer alcohol	678-39-7	8:2 FTOH$^-$
	6:2 Fluorotelomer Thioether Amido Sulfonic Acid	62880-95-9	6:2 FtTAoS	6:2 Fluorotelomer Thioether Amido Sulfonate	88992-47-6	6:2 FtTAoS$^-$

Table 1 (cont.). Acid vs anion nomenclature for Per- and Polyfluoroalkyl substances with available physiochemical constants and toxicity factors.

Notes:
1. Superscript “-” after abbreviation of anion form of compound to distinguish with protonated acid form.
2. More commonly referred to as trifluoroacetic acid and trifluoroacetate; aliphatic-based term (ethane) utilized for consistency with nomenclature of other compounds.
3. CAS # for ADONA noted (example anion salt of DONA)
4. Aliphatic-based term (ethane) for trifluoroacetic acid and trifluoroacetate utilized for consistency with nomenclature of other compounds
.

Table 2a. PFAS physiochemical constants and absorption factors used in EAL Models.

				Molecular Weight	Organic Carbon Partition coefficient,	Diffusivity in Air	Diffusivity in Water	Pure Component Solubility in Water	[4]Vapor Pressure	Henry's Law Constant	Henry's Law Constant	GI Tract Absorption Factor	Skin Absorption Factor
					K_{oc}	D_a	D_w	S	VP	H	H'	GIABS	ABS
[1]PFAS	[1]CAS #	[2]Physical State		MW	(cm^3/g)	(cm^2/s)	(cm^2/s)	(mg/L)	(mm Hg)	($atm\text{-}m^3/mol$)	(unitless)	(unitless)	(unitless)
PFBS$^-$	45187-15-3	NV	S	299	4.90E+02	2.70E-02	7.17E-06	2.17E+03	1.15E-08	2.95E-10	1.21E-08	1.00E+00	1.00E-01
PFPeS$^-$	175905-36-9	NV	S	349	1.05E+03			1.31E+05	2.82E-07	2.14E-10	8.75E-09	1.00E+00	1.00E-01
PFHxS$^-$	108427-53-8	NV	S	399	2.29E+03	3.50E-02	4.09E-06	1.70E+05	8.13E-09	1.94E-10	7.93E-09	1.00E+00	1.00E-01
PFHpS$^-$	146689-46-5	NV	S	449	1.23E+03			3.53E+05	3.31E-07	1.79E-10	7.32E-09	1.00E+00	1.00E-01
PFOS$^-$	45298-90-6	NV	S	499	3.55E+02	2.07E-02	5.26E-06	5.64E+05	2.45E-06	1.80E-11	7.36E-10	1.00E+00	1.00E-01
PFDS$^-$	126105-34-8	NV	S	599	1.91E+04			1.00E+06	8.13E-06	3.31E-10	1.35E-08	1.00E+00	1.00E-01
PFEtA$^-$	14477-72-6	V	L	114	4.07E+00	5.07E-02	9.30E-06	9.93E+05	1.08E+02	3.31E-03	1.35E-01	1.00E+00	1.00E-01
PFPrA$^-$	44864-55-3	V	L	164	5.89E+00	5.07E-02	9.30E-06	2.44E+04	2.30E+01	3.63E-06	1.48E-04	1.00E+00	1.00E-01
PFBA$^-$	45048-62-2	SV	L	213	8.91E+01			1.46E+05	2.18E+01	5.01E-05	2.05E-03	1.00E+00	1.00E-01
PFPeA$^-$	45167-47-3	NV	L	263	9.55E+01			2.43E+05	7.27E+00	2.97E-10	1.21E-08	1.00E+00	1.00E-01
PFHxA$^-$	92612-52-7	NV	L	313	1.07E+03			3.44E+05	2.00E+00	2.35E-10	9.61E-09	1.00E+00	1.00E-01
PFHpA$^-$	120885-29-2	NV	S	363	2.09E+03			5.30E+05	3.03E-01	2.09E-10	8.54E-09	1.00E+00	1.00E-01
PFOA$^-$	45285-51-6	NV	S	413	1.66E+03			6.24E+05	1.92E-01	1.92E-10	7.85E-09	1.00E+00	1.00E-01
PFNA$^-$	72007-68-2	NV	S	463	2.82E+03			7.78E+05	8.98E-02	1.18E-09	4.82E-08	1.00E+00	1.00E-01
PFDA$^-$	73829-36-4	NV	S	513	3.98E+02			9.54E+05	2.39E-02	1.50E-10	6.13E-09	1.00E+00	1.00E-01
PFUnDA$^-$	196859-54-8	NV	S	563	1.66E+04			1.00E+06	1.27E-02	3.34E-10	1.37E-08	1.00E+00	1.00E-01
PFDoDA$^-$	171978-95-3	NV	S	613	8.54E+04			1.00E+06	4.72E-03	3.40E-10	1.39E-08	1.00E+00	1.00E-01
PFTrDA$^-$	862374-87-6	NV	S	663	1.84E+05			1.00E+06	2.13E-03	3.48E-10	1.42E-08	1.00E+00	1.00E-01
PFTeDA$^-$	365971-87-5	NV	S	713	2.33E+05			1.00E+06	1.20E-03	3.55E-10	1.45E-08	1.00E+00	1.00E-01
PFOSA	754-91-6	NV	S	499	6.61E+02	3.02E-02	3.53E-06	1.00E+06	2.48E-01	2.24E-10	9.16E-09	1.00E+00	1.00E-01
HFPO-DA$^-$	122499-17-6	NV	S	329	4.07E+02			1.00E+06	2.40E-01	4.06E-06	1.66E-04	1.00E+00	1.00E-01
6:2 FTS$^-$	425670-75-3	NV	S	427	9.47E+02			5.72E+05	8.24E-07	1.83E-10	7.48E-09	1.00E+00	1.00E-01
ADONA$^-$	958445-44-8	NV	S	395	9.67E+02			2.17E+05	1.32E-02	1.80E-10	7.36E-09	1.00E+00	1.00E-01
6:2 FTOH$^-$	647-42-7	SV	L	364	3.16E+03			1.76E+01	1.70E+00	2.60E-10	1.06E-08	1.00E+00	1.00E-01
8:2 FTOH$^-$	678-39-7	NV	S	464	2.24E+03			1.98E-01	2.09E-01	2.09E-10	8.54E-09	1.00E+00	1.00E-01
6:2 FtTAoS$^-$	88992-47-6	NV	S	586	6.76E+04			1.92E+02	2.57E-09	8.91E-10	3.64E-08	1.00E+00	1.00E-01

Table 2a (cont.). PFAS physiochemical constants and absorption factors used in EAL Models.

Notes:

Values in Red reflect updates to April 2024 guidance.

1. Abbreviations refer to anion form of compound, assumed to be dominant in environmental samples (noted by "-" sign after abbreviation; refer to Table 1a in November 2020 Technical Memorandum).

2. Physical state of chemical at ambient conditions (V - volatile, NV - nonvolatile, SV-semivolatile, S - solid, L - liquid, G - gas). *Chemical considered to be "volatile" if Henry's number (atm m^3/mole) >0.00001 and molecular weight <200, and "semi-volatile" if molecular weight >200.

3. Volatility determined based on Molecular Weight and Henry's Constant (see Table 3a).

4. Dimensionless Henry's Law constant calculated based on Sander (2015) assuming a temperature of 25°C.

5. Confidence in modeled vapor pressures is low; not considered in determination of a compound as volatile or semivolatile.

6. Diffusivity constants for PFEtA$^-$ not currently available. Constants for PFPrA$^-$ used as interim surrogates and assumed similar.

Table 2b. References for PFAS physiochemical constants.

^{1}PFAS	^{1}CAS #	^{1}Physical State		Molecular Weight	Organic Carbon Partition Coefficient	Diffusivity in Air	Diffusivity in Water	Pure Component Solubility in Water	Henry's Law Constant	^{2}Henry's Law Constant	GI Tract Absorption Factor	Skin Absorption Factor
				MW	K_{oc} (cm^3/g)	D_a (cm^2/s)	D_w (cm^2/s)	S (mg/L)	H (atm-m^3/mol)	H' (unitless)	GIABS (unitless)	ABS (unitless)
PFBS$^-$	45187-15-3	*	1	1	1	2	2	1	1	1 (calc)	2	2
PFPeS$^-$	175905-36-9	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFHxS$^-$	108427-53-8	*	1	1	1	2	2	1	1	1 (calc)	2	2
PFHpS$^-$	146689-46-5	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFOS$^-$	45298-90-6	*	1	1	1	2	2	1	1	1 (calc)	2	2
PFDS$^-$	126105-34-8	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFEtA$^-$	14477-72-6	*	1	1	1	(=PFPrA$^-$)	(=PFPrA$^-$)	1	1	1 (calc)	after 2	*after 2*
PFPrA$^-$	44864-55-3	*	1	1	1	2	2	1	1	1 (calc)	after 2	*after 2*
PFBA$^-$	45048-62-2	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFPeA$^-$	45167-47-3	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFHxA$^-$	92612-52-7	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFHpA$^-$	120885-29-2	*	1	1	1	-	-	1	1	1 (calc)	2	2
PFOA$^-$	45285-51-6	*	1	1	1	-	-	1	1	1 (calc)	2	2
PFNA$^-$	72007-68-2	*	1	1	1	-	-	1	1	1 (calc)	2	2
PFDA$^-$	73829-36-4	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFUnDA$^-$	196859-54-8	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFDoDA$^-$	171978-95-3	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFTrDA$^-$	862374-87-6	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFTeDA$^-$	365971-87-5	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
PFOSA	754-91-6	*	1	1	1	2	2	1	1	1 (calc)	after 2	*after 2*
HFPO-DA$^-$	122499-17-6	*	1	1	1	-	-	1	1	4 (calc)	after 2	*after 2*
6:2 FTS$^-$	425670-75-3	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
ADONA$^-$	958445-44-8	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
6:2 FTOH$^-$	647-42-7	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
8:2 FTOH$^-$	678-39-7	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*
6:2 FtTAoS$^-$	88992-47-6	*	1	1	1	-	-	1	1	1 (calc)	after 2	*after 2*

Table 2b (cont.). References for PFAS physiochemical constants.

References

1. USEPA, 2017, The CompTox Chemistry Dashboard: US Environmental Protection Agency. Journal of Cheminformatics, Vol. 9, Article No: 61 (2017). Accessed 5/11/20. https://comptox.epa.gov/dashboard (values selected in order of preference: Experimental Median Value, Predicted Median Value, Experimental Average Value, Predicted Average Value)
2. ORNL, 2020, Risk Assessment Information System: Oak Ridge National Laboratories, Office of Environmental Management, accessed 5/5/20. https://rais.ornl.gov/
.

Table 3a. PFASs toxicity factors with multiple sources.

[1]PFAS	[1]CAS	USEPA RfDo		ATSDR (2021) Minimum Risk Level		Michigan SAW (2019) DEGLE (2020) Chronic RfDo		[3]Zeilmaker et al. (2018) Equivalent Chronic RfDo			Texas CEQ (2016) Chronic RfDo		Minnesota DEQ (2017-2019) Chronic RfD	
		RfD (mg/kg-d)	[2]Primary Study Form	RfD (mg/kg-d)	[2]Primary Study Form	RfD (mg/kg-d)	[2]Primary Study Form	RPF	RfD (mg/kg-d)	[2]Primary Study Form	RfD (mg/kg-d)	[2]Primary Study Form	RfD	[2]Primary Study Form
PFBS$^-$	45187-15-3	3.00E-04	H+ Acid			3.00E-04	Anion	0.001	2.00E-02	Anion	1.40E-03	Anion	1.30E-03	Anion
PFPeS$^-$	175905-36-9							0.6	3.30E-05	H+ Acid				
PFHxS$^-$	108427-53-8	2.00E-06	H+ Acid	2.00E-05	H+ Acid	9.70E-06	Anion	0.6	3.30E-05	Anion	3.80E-06	Anion	9.70E-06	Anion
PFHpS$^-$	146689-46-5							2	1.00E-05	H+ Acid				
PFOS$^-$	45298-90-6	7.90E-09		2.00E-06	H+ Acid	2.89E-06	Anion	2	1.00E-05	Anion	2.30E-05	Anion	3.10E-06	Anion
PFDS$^-$	126105-34-8							2	1.00E-05	H+ Acid	1.20E-05	Anion		
PFPrA$^-$	44864-55-3	5.00E-04	H+ Acid											
PFBA$^-$	45048-62-2							0.05	4.00E-04	Anion	2.90E-03	H+ Acid	3.80E-03	Anion
PFPeA$^-$	45167-47-3							0.05	4.00E-04	H+ Acid	3.80E-06	H+ Acid		
PFHxA$^-$	92612-52-7	5.0E-04	H+ Acid			8.30E+00	H+ Acid	0.01	2.00E-03	Anion	3.80E-06	H+ Acid		
PFHpA$^-$	120885-29-2							1	2.00E-05	H+ Acid	2.30E-05	H+ Acid		
PFOA$^-$	45285-51-6	1.50E-09		3,00E-06	H+ Acid	3.90E-06	H+ Acid	1	2.00E-05	H+ Acid	1.20E-05	H+ Acid	1.80E-05	Anion
PFNA$^-$	72007-68-2			3.00E-06	H+ Acid	2.20E-06	H+ Acid	10	2.00E-06	H+ Acid	1.20E-05	H+ Acid		
PFDA$^-$	73829-36-4							10	2.00E-06	H+ Acid	1.50E-05	H+ Acid		
PFUnDA$^-$	196859-54-8							4	5.00E-06	H+ Acid	1.20E-05	H+ Acid		
PFDoDA$^-$	171978-95-3							3	6.70E-06	H+ Acid	1.20E-05	H+ Acid		
PFTrDA$^-$	862374-87-6							3	6.70E-06	H+ Acid	1.20E-05	H+ Acid		
PFTeDA$^-$	365971-87-5							0.3	6.70E-05	H+ Acid	1.20E-05	H+ Acid		
PFOSA	754-91-6										1.20E-05	H+ Acid		
HFPO DA$^-$	13252-13-6	3.00E-06	H+ Acid	7.70E-05	H+ Acid									
6:2 FTS$^-$	425670-75-3			3.90E-04	H+ Acid									
ADONA-	958445-44-8													
6:2 FTOH-	647-42-7													
8:2 FTOH-	678-39-7													
6:2 FtTAoS-	88992-47-6													

Table 3a (cont.). Selection of PFASs toxicity factors.

Notes:
1. CAS number reflects anion form. Negative sign added to abbreviation to avoid confusion with H+ acid form.
2. Anion versus protonated (H+) acid form of compound that served as primary basis for the stated RfD noted, based on information provided in the noted references.
3. Reference Doses calculated based on the Zeilmaker et al. 2018 Relative Potency Factor multiplied by the RfD selected for PFOA.
5. NJDEP has published an RfD for PFNA of 7.4E-07 (see 2015 PFNA document).

References:

ATSDR, 2021, Toxicological Profile for Perfluoroalkyls: Agency for Toxic Substances and Disease Registry, May 2021.

MISAW, 2019, Health Based Drinking Water Values for PFAS in Michigan: Michigan Science Advisory, Workgroup Lansing, Michigan, June 27, 2019. (all listed toxicity factors except 6:2 FTS$^-$).

MIDOE, 2020, Screening Level Evaluation 6:2 Fluorotelomer Sulfonic Acid: Michigan Department of Environment, Great Lakes and Energy, Interoffice Communication from Michael Depa, Toxics Unit, Air Quality Division, September 24, 2020. (toxicity factors for 6:2 FTS$^-$).

MIDOE, 2021, Response to Public Comments for 6:2 Fluorotelomer Sulfonic Acid: Michigan Department of Environment, Great Lakes and Energy, Air Quality Division, January 24, 2021.

MNDOH, 2017, Toxicological Summary for: Perfluorobutane sulfonate: Minnesota Department of Health, December 2017.

MNDOH, 2018, Toxicological Summary for Perfluorobutanoate: Minnesota Department of Health, August 2018.

TXCEQ, 2016, Toxicity Factor Derivation for Perfluoro Compounds (PFCs) Under the Texas Risk Reduction Program: Texas Commission on Environmental Quality, January 4, 2016.

USEPA, 2021a, Human Health Toxicity Values for Perfluorobutane Sulfonic Acid (CASRN 375-73-5) and Related Compound Potassium Perfluorobutane Sulfonate (CASRN 29420-49-3): US Environmental Protection Agency, Office of Research and Development, EPA/600/R-20/345F, April 2021.

USEPA, 2021b, Human Health Toxicity Values for Hexafluoropropylene Oxide (HFPO) Dimer Acid and Its Ammonium Salt (CASRN 13252-13-6 and CASRN 62037-80-3) Also Known as “GenX Chemicals”: US Environmental Protection Agency, Office of Research and Development, EPA Document Number: 822R-21-010, October 2021.

USEPA, 2023, *Toxicological Review of Perfluorohexanoic Acid [CASRN 307244] and Related Salts*: US Environmental Protection Agency, Office of Research and Development, EPA/635/R-23/027Fa, April 2023.

USEPA, 2022a, *Drinking Water Health Advisory: Perfluorooctanoic Acid (PFOA) CASRN 335-67-1*: U.S. Environmental Protection Agency, Office of Water, EPA/822/R-22/003. June 2022.

USEPA, 2022b, *Interim Drinking Water Health Advisory: Perfluorooctane Sulfonic Acid (PFOS) CASRN 1763-23-1*: U.S. Environmental Protection Agency, Office of Water, EPA/822/R-22/004. June 2022.

Zeilmaker, M.J., Fragki, S., Verbruggen, E.M.J. and B.G.H. Bokkers, 2018, Mixture Exposure to PFAS, A Relative Potency Factor Approach: National Institute for Public Health and the Environment, Bilthoven, The Netherlands.

Table 3b. Final noncancer toxicity factors used for development of action levels and assessment of risk.

PFAS	[1]CAS	[2]Selected Reference Dose (RfD) mg/kg-day	Reference	[2]Selected Reference Concentration (RfC) mg/m^3	Reference
PFBS$^-$	45187-15-3	3.00E-04	USEPA 2021a	4.90E-03	TXCEQ (2015)
[3]PFPeS$^-$	175905-36-9	1.60E-04	after DMOE (2015)		
PFHxS$^-$	108427-53-8	2.00E-06	USEPA (2024)	1.30E-05	TXCEQ (2015)
PFHpS$^-$	146689-46-5	1.00E-05	Zeilmaker et al. (2018)		
[4]PFOS$^-$	45298-90-6	2.00E-06	ATSDR (2021)	8.10E-05	TXCEQ (2015)
PFDS$^-$	126105-34-8	1.00E-05	Zeilmaker et al. (2018)		
PFEtA$^-$	14477-72-6	1.80E-02	Gibb and O'Leary (2024)	6.30E-02	Gibb and O'Leary (2024)
PFPrA$^-$	44864-55-3	5.00E-04	USEPA (2023a)	1.75E-03	(extrapolated from RfD)
PFBA$^-$	45048-62-2	3.80E-03	MNDOH (2018)	1.00E-02	TXCEQ (2015)
PFPeA$^-$	45167-47-3	4.00E-04	Zeilmaker et al. (2018)	1.40E-03	(extrapolated from RfD)
PFHxA$^-$	92612-52-7	5.00E-04	USEPA (2023b)	1.75E-03	(extrapolated from RfD)
PFHpA$^-$	120885-29-2	2.00E-05	Zeilmaker et al. (2018)		
[4]PFOA$^-$	45285-51-6	3.00E-06	ATSDR (2021)	4.10E-06	
PFNA$^-$	72007-68-2	3.00E-06	ATSDR (2021)	2.80E-05	TXCEQ (2015)
PFDA$^-$	73829-36-4	2.00E-06	Zeilmaker et al. (2018)	5.30E-05	TXCEQ (2015)
PFUnDA$^-$	196859-54-8	5.00E-06	Zeilmaker et al. (2018)		
PFDoDA$^-$	171978-95-3	6.70E-06	Zeilmaker et al. (2018)	4.20E-05	TXCEQ (2015)
PFTrDA$^-$	862374-87-6	6.70E-06	Zeilmaker et al. (2018)		
PFTeDA$^-$	365971-87-5	6.70E-05	Zeilmaker et al. (2018)		
PFOSA	754-91-6	1.20E-05	Texas CEQ (2016)		
HFPO DA$^-$	13252-13-6	3.00E-06	USEPA 2021b		
6:2 FTS$^-$	425670-75-3	3.90E-04	MIDOE (2020, 2021)	1.00E-03	MIDOE (2020, 2021)
DONA$^-$	958445-44-8	3.00E-04	WIDHS (2020)		
6:2 FTOH$^-$	647-42-7	1.30E-03	Gibb and O'Leary (2023)	4.55E-03	Gibb and O'Leary (2023)
8:2 FTOH$^-$	678-39-7	1.10E-03	Gibb and O'Leary (2023)	3.85E-03	Gibb and O'Leary (2023)
6:2 FtTAoS$^-$	88992-47-6	5.00E-04	Gibb and O'Leary (2023)		

Table 3b (cont.). Final noncancer toxicity factors used for development of action levels and assessment of risk.

Notes:

1. CAS numbers reflects anion form when available. Negative sign added to abbreviation to avoid confusion with H+ acid form. Laboratory data should be presented in unadjusted, anion form of targeted compounds for comparison to action levels and assessment of risk and fate and transport.
2. See text for order of preference of references noted for toxicity factors.
3. After DMOE (2015): "Toxicity data on PFPeS have not been available. Considering the conclusions on chain length and presence of functional groups of PFAS, it can be expected that PFPeS shows *slightly increased* toxicity compared to PFBS (0.0003 mg/kg-d), as well as increased toxicity compared to PFPeA (0.0004 mg/kg-d)." Selected interim PFPeS$^-$ RfD 0.00016 mg/kg-day = Halfway between PFBS- (0.0003 mg/kg-d) and ATSDR (2021) RfD for PFHxS$^-$ (0.00002 mg/kg-d).
4. ATSDR (2021) RfDs for PFOS and PFOA referenced pending HIDOH review of toxicity factors presented in USEPA MCLG documents (USEPA 2024d,e).

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Table 4. [1]Chronic health effects of PFASs (refer to Attachment 3, Table J for additional information).

CHEMICAL PARAMETER	**Carcinogen**	**Metabolic**	**Hepatic**	**Cardiovascular**	**Developmental**	**Endocrine**	**Hematologic**	**Immune**	**Kidney**	**Nervous**	**Reproductive**	**Respiratory**	**Other**
Perfluorobutane sulfonate (PFBS-)					15^{A}	15^{A}			15^{A}				
Perfluoropentane sulfonate (PFPeS-)													
Perfluorohexane sulfonate (PFHxS-)			$1^{H},4^{A}$		$1^{A},9^{H}$	4^{A}		$1^{H},2^{H},9^{H}$		11^{A}	10^{H}		5^{H}
Perfluoroheptane sulfonate (PFHpS-)													
Perfluorooctane sulfonate (PFOS-)	13^{A},17	$1^{H},2^{H}$	$1^{H}1^{A},5^{H}$	1^{H}	$1^{H}1^{A},9^{H}$	1^{H}		$1^{H}1^{A},2^{H}$, $9^{H},13^{A}$	$2^{H},5^{H}$	11^{A}	$1^{H},10^{H}$		5^{H}
Perfluorodecane sulfonate (PFDS-)													
[4]Perfluoro ethanoate (PFEtA-)			24^{A}										
Perfluoro propanoate (PFPrA-)		22^{A}	22^{A}				22^{A}		22^{A}				
Perfluoro butanoate (PFBA-)			3^{A}		$1^{A},3^{A}$	3^{A}	3^{A}						
Perfluoro pentanoate (PFPeA-)													
Perfluoro hexanoate (PFHxA-)			1^{A}, 21^{A}	1^{H}	1^{A}, 21^{A}	1^{A}	1^{A}, 21^{A}		1^{A}				
Perfluoro heptanoate (PFHpA-)			1^{A}										
Perfluoro octanoate (PFOA-)	$6^{H},7^{H,}13^{A}$, 16,18	$1^{H},2^{H},6^{H}$, 7^{H}	$1^{H}1^{A},5^{H}$, 6^{H}	$1^{H},5^{H},6^{H}$, 7^{H}	$1^{H}1^{A},5^{H},6^{H}$	$1^{H},5^{H},7^{H}$	8^{A}	$1^{H}1^{A},2^{H},5^{H}$, 6^{H},7H,9^{H}, 13^{A}	$2^{H},5^{H},6^{H}$	$11^{A},5^{H}$	$1^{H}1^{A},8^{A}$, 10^{H}	1^{H}	5^{H}
Perfluoro nonanoate (PFNA-)		$1^{H,}10^{H}$			1^{A}								5^{H}
Perfluoro decanoate (PFDA-)		1^{H}			1^{A}			$1^{H},2^{H}$					
Perfluoro undecanoate (PFUnDA-)					1^{A}								
Perfluoro dodecanoate (PFDoDA-)													
Perfluoro tridecanoate (PFTrDA-)													
Perfluoro tetradecanoate (PFTeDA-)													
Perfluroroctane sulfonamide (PFOSA)													
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate (HFPO DA-)	14^{A}		14^{A}		14^{A}		14^{A}	14^{A}					
6:2 Fluorotelomer sulfonate (6:2 FTS-)			19^{A}, 20^{A}	19^{A}					20^{A}				20^{A}
Ammonium 4,8-Dioxa-3H-perfluoro nonanoate (ADONA-)		12^{A}			12^{A}		12^{A}						
6:2 Fluorotelomer alcohol (6:2 FTOH-)			23^{A}		23^{A}	23^{A}							23^{A}
8:2 Fluorotelomer alcohol (8:2 FTOH-)			23^{A}		23^{A}				23^{A}				
6:2 Fluorotelomer thioether amido sulfonate (6:2 FTTAoS-)					23^{A}			23^{A}					

Table 4 (cont.). [1]Chronic health effects of PFASs (refer to Attachment 3, Table J for additional information).

Notes

1. For general reference only. "A" = Animal study; "H" = Human epidemiological study. Primary health risk long-May not be adequately comprehensive for some chemicals. Specific form of compound used in studies can vary. Some effects may be clinically insignificant. Presence of effect in animal studies may not translate to effect in humans. Refer to original reference documents for more information.
2. Cancer slope factors (CSFs) and Reference Doses presented in the MCLG documents for PFOA and PFOS are currently under review by HIDOH for potential incorporation into the EAL guidance (USEPA 2024e,f).
3. Compilation of chronic health effects incomplete; assumed similar to PFOA and PFOS (see Zeilmaker et al. 2018).

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18: IARC 2016 Monograph 110: PFOA (https://monographs.iarc.fr/wp-content/uploads/2018/06/mono110-01.pdf)
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20^{A}: NASF, 6:2 FluorotelomerSulfonate (6:2 FTS), Toxicology at a Glance: National Association for Surface Finishing, March 2019
21^{A}: USEPA Toxicological Review of Perfluorohexanoic Acid and Related Salts April 2023
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Table 5. Summary of Drinking Water Ingestion Rates relative to body weight utilized for calculation of drinking water action levels.

PFAS	CAS	DWIR-BW (L/kg bw-day)	Targeted Exposure Population	^{1,2,3}Reference
PFBS^{-}	45187-15-3	0.0354	Women of child-bearing age	USEPA 2024b
PFHxS^{-}	108427-53-8	0.0340	General adults	USEPA 2024b
PFHpS^{-}	146689-46-5	0.0520	Young children (0-6 yrs)	USEPA 2023
PFOS^{-}	45298-90-6	0.0701	Young children (0-<5yrs)	USEPA 2022b
PFDS^{-}	126105-34-8	0.0520	Young children (0-6 yrs)	USEPA 2023
PFEtA-	14477-72-6	0.0520	Young children (0-6 yrs)	USEPA 2023
PFPrA-	44864-55-3	0.0520	Young children (0-6 yrs)	USEPA 2023
PFBA^{-}	45048-62-2	0.0520	Young children (0-6 yrs)	USEPA 2023
PFPeA^{-}	45167-47-3	0.0520	Young children (0-6 yrs)	USEPA 2023
PFHxA^{-}	92612-52-7	0.0520	Young children (0-6 yrs)	USEPA 2023
PFHpA^{-}	120885-29-2	0.0520	Young children (0-6 yrs)	USEPA 2023
PFOA^{-}	45285-51-6	0.0701	Young children (0-<5yrs)	USEPA 2022a
PFNA^{-}	72007-68-2	0.0469	Lactating women	USEPA 2024b
PFDA^{-}	73829-36-4	0.0520	Young children (0-6 yrs)	USEPA 2023
PFUnDA^{-}	196859-54-8	0.0520	Young children (0-6 yrs)	USEPA 2023
PFDoDA^{-}	171978-95-3	0.0520	Young children (0-6 yrs)	USEPA 2023
PFTrDA^{-}	862374-87-6	0.0520	Young children (0-6 yrs)	USEPA 2023
PFTeDA^{-}	365971-87-5	0.0520	Young children (0-6 yrs)	USEPA 2023
PFOSA	754-91-6	0.0520	Young children (0-6 yrs)	USEPA 2023
HFPO DA^{-}	13252-13-6	0.0469	Lactating women	USEPA 2024b
6:2 FTS^{-}	425670-75-3	0.0520	Young children (0-6 yrs)	USEPA 2023
ADONA^{-}	958445-44-8	0.0520	Young children (0-6 yrs)	USEPA 2023

Notes

1. PFOA^{-} and PFOS^{-}: DWI-BW of 0.0701 L/kg-day used in 2022 USEPA PFOA and PFOS Drinking Water Advisories, based on exposure of 0 to <5 yr old children. Default DWIR-BW rates not stated in MCLG documents for PFOA and PFOS (USEPA 2024c).

2. PFBS^{-}, PFHxS^{-}, PFNA^{-}, HFPO DA^{-}: DWIR-BW values as presented in USEPA MCLGs for noted chemicals (USEPA 2024b).

3. All Other PFASs: DWIR-BW value calculated based on default, average drinking water ingestion rate and body weight of 0-6 year-old children utilized in USEPA Regional Screening Levels for tapwater. DWIR-BW = (0.78 L/day)/15 kg = 0.0520 L/kg-day.

Table 6. Default exposure parameter values used to generate toxicity-based action levels for drinking water and direct- exposure action levels for soil (refer to Appendix 1 and Appendix 2 in HIDOH 2024).

Symbol	Definition (units)	Default	References
CSFo	Cancer slope factor oral $(mg/kg\text{-}d)^{-1}$	--	Chemical specific – Table 4
CSFi	Cancer slope factor inhaled $(mg/kg\text{-}d)^{-1}$	--	Chemical specific – Table 4
RfDo	Reference dose oral (mg/kg-d)	--	Chemical specific – Table 4
RfDi	Reference dose inhaled (mg/kg-d)	--	Chemical specific – Table 4
[2]THQs	Target hazard quotient (soil)	1.0	(refer to memorandum text)
[2]THQdw	Target hazard quotient (drinking water)	1.0	(refer to memorandum text)
RSCdw	Relative Source Contribution (drinking water)	0.2	(refer to memorandum text)
BWa	Body weight, adult (kg) (soil exposure)	55	HIDOH
BWc	Body weight, child (kg)	15	USEPA 2023
ATc	Average time – carcinogens (days)	25,550	USEPA 2023
ATn	Average time – noncarcinogens (days)	EDx365	USEPA 2023
SAar	Exposed surface area, adult res. (cm^2/day)	6,032	USEPA 2023
SAaw	Exposed surface area, adult occ. (cm^2/day)	2,373	USEPA 2023
SAc	Exposed surface area, child (cm^2/day)	3,527	USEPA 2023
AFar	Adherence factor, adult res. (mg/cm^2)	0.07	USEPA 2023
AFaw	Adherence factor, occupational (mg/cm^2)	0.12	USEPA 2023
AFctw	Adherence factor, construction/trench worker (mg/cm^2)	0.30	USEPA 2023
AFc	Adherence factor, child (mg/cm^2)	0.20	USEPA 2023
ABS	Skin absorption (unitless): chemical specific	--	USEPA 2023
IRAa	Inhalation rate – adult (m^3/day)	20	USEPA 2023
IRAc	Inhalation rate – child (m^3/day)	10	USEPA 2023
IRActw	Inhalation rate – construction/trench worker (m^3/day)	20	USEPA 2011b
IRWa	Drinking water ingestion – adult (L/day)	-	Chemical specific (see Table 5)
IRWc	Drinking water ingestion – child (L/day)	-	Chemical specific (see Table 5)
IRSa	Soil ingestion – adult (mg/day)	100	USEPA 2023
IRSc	Soil ingestion – child (mg/day)	200	USEPA 2023
IRSo	Soil ingestion – occupational (mg/day)	100	USEPA 2023
IRSctw	Soil ingestion–construction/trench worker (mg/day)	330	USEPA 2002
EFr_{DW}	Exposure frequency (Drinking Water; d/y)	365	USEPA 2023
EFr_{soil}	Exposure frequency (Soil, Residential; d/y)	350	USEPA 2023
EFo	Exposure frequency (Soil, Occupational; d/y)	250	USEPA 2023
EFctw	Exposure frequency – construction/trench worker (d/y)	20	Massachusetts DEP (1994)
EDr	Exposure duration – residential (years)	26	USEPA 2023
EDc	Exposure duration – child (years)	6	USEPA 2023
EDo	Exposure duration – occupational (years)	25	USEPA 2023
EDctw	Exposure duration – construction/trench worker (years)	7	modified from Massachusetts DEP (1994)

Attachment 2

Summary PFAS EALs
(HIDOH January 2026)

TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water

CHEMICAL PARAMETER	>150m to Surface Water Body		≤150m to Surface Water Body	
	[1]Soil (mg/kg)	[2]Groundwater (ug/L)	[1]Soil (mg/kg)	[2]Groundwater (ug/L)
Perfluorobutane sulfonate (PFBS-)	1.6E-01	2.0E+00	1.6E-01	2.0E+00
Perfluoropentane sulfonate (PFPeS-)	1.0E-01	5.8E-01	1.0E-01	5.8E-01
Perfluorohexane sulfonate (PFHxS-)	3.8E-03	1.0E-02	3.8E-03	1.0E-02
Perfluoroheptane sulfonate (PFHpS-)	7.9E-03	3.8E-02	7.9E-03	3.8E-02
Perfluorooctane sulfonate (PFOS-)	2.4E-04	4.0E-03	2.4E-04	4.0E-03
Perfluorodecane sulfonate (PFDS-)	1.3E-01	3.8E-02	1.3E-01	3.8E-02
Perfluoro ethanoate (PFEtA-) (Trifluoroacetate)	3.9E-01	4.7E+01	3.9E-01	4.7E+01
Perfluoro propanoate (PFPrA-)	5.1E-04	1.3E+00	5.1E-04	1.3E+00
Perfluoro butanoate (PFBA-)	2.2E-01	1.5E+01	2.2E-01	1.5E+01
Perfluoro pentanoate (PFPeA-)	2.4E-02	1.5E+00	2.4E-02	1.5E+00
Perfluoro hexanoate (PFHxA-)	3.4E-01	1.9E+00	3.4E-01	1.9E+00
Perfluoro heptanoate (PFHpA-)	2.7E-02	7.7E-02	2.7E-02	7.7E-02
Perfluoro octanoate (PFOA-)	1.1E-03	4.0E-03	1.1E-03	4.0E-03
Perfluoro nonanoate (PFNA-)	4.7E-03	1.0E-02	4.7E-03	1.0E-02
Perfluoro decanoate (PFDA-)	5.1E-04	7.7E-03	5.1E-04	7.7E-03
Perfluoro undecanoate (PFUnDA-)	6.3E-02	1.9E-02	6.3E-02	1.9E-02
Perfluoro dodecanoate (PFDoDA-)	8.5E-02	2.6E-02	8.5E-02	2.6E-02
Perfluoro tridecanoate (PFTrDA-)	8.5E-02	2.6E-02	8.5E-02	2.6E-02
Perfluoro tetradecanoate (PFTeDA-)	8.5E-01	2.6E-01	8.5E-01	2.6E-01
Perfluroroctane sulfonamide (PFOSA)	5.1E-03	4.6E-02	5.1E-03	4.6E-02
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate (HFPO DA-)	6.8E-04	1.0E-02	6.8E-04	1.0E-02
6:2 Fluorotelomer sulfonate (6:2 FTS-)	2.4E-01	1.5E+00	2.4E-01	1.5E+00
Ammonium 4,8-Dioxa-3H-perfluoro nonanoate (ADONA-)	1.9E-01	1.2E+00	1.9E-01	1.2E+00
6:2 Fluorotelomer alcohol (6:2 FTOH-)	2.6E+00	5.0E+00	2.6E+00	5.0E+00
8:2 Fluorotelomer alcohol (8:2 FTOH-)	1.6E+00	4.2E+00	1.6E+00	4.2E+00
6:2 Fluorotelomer thioether amido sulfonate (6:2 FTTAoS-)	6.3E+00	1.9E+00	6.3E+00	1.9E+00

Notes:

1. Based on unrestricted current or future land use. Considered adequate for residential housing, schools, medical facilities, day-care centers, parks and other sensitive uses.
2. Assumes potential impacts to drinking water source and discharge of groundwater into a freshwater, marine or estuary surface water system. Compare to *dissolved-phase* concentration.

Source of Soil Action Levels: Refer to Appendix 1, Tables A-1 and A-2.

Source of Groundwater Action Levels: Appendix 1, Table D-1a (≤150m to Surface Water Body) and Table D-1b (>150m to Surface Water Body).

Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).

Soil Action Levels intended to address direct-exposure, groundwater protection (leaching) and gross contamination hazards. The need for a site-specific, ecological risk assessment should be evaluated if sensitive, terrestrial or aquatic habitats are within or nearby areas of contaminated soil. Groundwater Action Levels intended to address impacts to drinking water resources, discharge to surface water and aquatic toxicity, and gross contamination hazards. Action levels include USEPA (2024) MCLs and MCLGs (refer to Table D-3a). Drinking water action levels currently take precedence for all PFAS compounds.

Groundwater action levels should be compared to dissolved-phase chemical concentrations unless otherwise instructed by HDOH.

Groundwater ALs >150m to Surface Water Body: Groundwater screened with respect to acute aquatic toxicity action levels (See Table D-1b).

Groundwater ALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic aquatic toxicity action levels (see Table D-1a).

TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water

	>150m to Surface Water Body		≤150m to Surface Water Body	
CHEMICAL PARAMETER	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**	**[1]Soil (mg/kg)**	**[2]Groundwater (ug/L)**
Perfluorobutane sulfonate (PFBS-)	3.8E+00	5.0E+04	3.8E+00	5.0E+04
Perfluoropentane sulfonate (PFPeS-)	1.0E-01	5.8E-01	1.0E-01	5.8E-01
Perfluorohexane sulfonate (PFHxS-)	2.5E-02	1.0E+01	2.5E-02	1.0E+01
Perfluoroheptane sulfonate (PFHpS-)	7.9E-03	3.8E-02	7.9E-03	3.8E-02
Perfluorooctane sulfonate (PFOS-)	2.5E-02	3.1E+01	2.5E-02	1.1E+00
Perfluorodecane sulfonate (PFDS-)	1.3E-01	3.8E-02	1.3E-01	3.8E-02
Perfluoro ethanoate (PFEtA-) (Trifluoroacetate)	2.1E+00	1.0E+02	2.1E+00	1.0E+02
Perfluoro propanoate (PFPrA-)	5.1E-04	1.3E+00	5.1E-04	1.3E+00
Perfluoro butanoate (PFBA-)	4.8E+01	4.2E+03	1.3E+01	8.3E+02
Perfluoro pentanoate (PFPeA-)	2.4E-02	1.5E+00	2.4E-02	1.5E+00
Perfluoro hexanoate (PFHxA-)	6.3E+00	4.8E+04	6.3E+00	6.3E+03
Perfluoro heptanoate (PFHpA-)	2.7E-02	7.7E-02	2.7E-02	7.7E-02
Perfluoro octanoate (PFOA-)	3.8E-02	1.2E+02	3.8E-02	8.3E+00
Perfluoro nonanoate (PFNA-)	3.8E-02	1.0E+01	3.8E-02	8.0E+00
Perfluoro decanoate (PFDA-)	2.5E-02	1.0E+01	2.5E-02	1.0E+01
Perfluoro undecanoate (PFUnDA-)	6.3E-02	4.4E+02	6.3E-02	1.0E+01
Perfluoro dodecanoate (PFDoDA-)	8.5E-02	6.4E+02	8.5E-02	2.0E+01
Perfluoro tridecanoate (PFTrDA-)	8.5E-02	2.6E-02	8.5E-02	2.6E-02
Perfluoro tetradecanoate (PFTeDA-)	8.5E-01	2.6E-01	8.5E-01	2.6E-01
Perfluroroctane sulfonamide (PFOSA)	5.1E-03	4.6E-02	5.1E-03	4.6E-02
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate (HFPO DA-)	6.8E-04	1.0E-02	6.8E-04	1.0E-02
6:2 Fluorotelomer sulfonate (6:2 FTS-)	4.9E+00	1.1E+04	4.9E+00	2.6E+02
Ammonium 4,8-Dioxa-3H-perfluoro nonanoate (ADONA-)	3.8E+00	1.0E+04	3.8E+00	1.0E+04
6:2 Fluorotelomer alcohol (6:2 FTOH-)	2.6E+00	5.0E+00	2.6E+00	5.0E+00
8:2 Fluorotelomer alcohol (8:2 FTOH-)	1.6E+00	4.2E+00	1.6E+00	4.2E+00
6:2 Fluorotelomer thioether amido sulfonate (6:2 FTTAoS-)	6.3E+00	1.9E+00	6.3E+00	1.9E+00

1. Based on unrestricted current or future land use. Considered adequate for residential housing, schools, medical facilities, day-care centers, parks and other sensitive uses.
2. Assumes potential discharge of groundwater into a freshwater, marine or estuary surface water system. Compare to *dissolved-phase* concentration.

Source of Soil Action Levels: Refer to Appendix 1, Tables B-1 and B-2.

Source of Groundwater Action Levels: Appendix 1, Table D-1c (≤150m to Surface Water Body) and Table D-1d (>150m to Surface Water Body). Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).

Soil Action Levels intended to address direct-exposure, groundwater protection (leaching) and gross contamination hazards. The need for a site-specific, ecological risk assessment should be evaluated if sensitive, terrestrial or aquatic habitats are within or nearby areas of contaminated soil. Groundwater Action Levels intended to address discharge to surface water and aquatic toxicity and gross contamination hazards. Availability of aquatic toxicity action levels for PFAS compounds limited. Drinking water action level used for screening in interim (refer to Table D-4b and Table D-4c).

Groundwater action levels should be compared to dissolved-phase chemical concentrations unless otherwise instructed by HDOH.

Groundwater ALs >150m to Surface Water Body: Groundwater screened with respect to acute aquatic toxicity action levels (See Table D-1d).

Groundwater ALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic aquatic toxicity action levels (see Table D-1c). Groundwater action levels for PFBS- base on "Gross Contamination" upper limit of 50,000 µg/L (Appendix 1, Table G-2). Identical groundwater action levels for >150m and <150m indicate gross contamination cutoff or the lack of one or both chronic and acute action levels (refer to Appendix 1, Table D-3a).

TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Vapor
([1]Vapor Intrusion Hazards)

			INDOOR AIR ACTION LEVELS		SHALLOW SOIL VAPOR ACTION LEVELS	
CHEMICAL PARAMETER	**Physical State**		**Residential (ug/m3)**	**Commercial/ Industrial (ug/m^3)**	**Residential (ug/m3)**	**Commercial/ Industrial (ug/m^3)**
Perfluorobutane sulfonate (PFBS-)	NV	S	-	-	-	-
Perfluoropentane sulfonate (PFPeS-)	NV	S	-	-	-	-
Perfluorohexane sulfonate (PFHxS-)	NV	S	-	-	-	-
Perfluoroheptane sulfonate (PFHpS-)	NV	S	-	-	-	-
Perfluorooctane sulfonate (PFOS-)	NV	S	-	-	-	-
Perfluorodecane sulfonate (PFDS-)	NV	S	-	-	-	-
Perfluoro ethanoate (PFEtA-) (Trifluoroacetate)	V	L	6.6E+01	2.8E+02	1.3E+05	1.1E+06
Perfluoro propanoate (PFPrA-)	V	L	1.8E+00	7.7E+00	3.7E+03	3.1E+04
Perfluoro butanoate (PFBA-)	SV	L	1.0E+01	4.4E+01	-	-
Perfluoro pentanoate (PFPeA-)	SV	L	1.5E+00	6.1E+00	-	-
Perfluoro hexanoate (PFHxA-)	SV	L	1.8E+00	7.7E+00	-	-
Perfluoro heptanoate (PFHpA-)	NV	S	-	-	-	-
Perfluoro octanoate (PFOA-)	NV	S	-	-	-	-
Perfluoro nonanoate (PFNA-)	NV	S	-	-	-	-
Perfluoro decanoate (PFDA-)	NV	S	-	-	-	-
Perfluoro undecanoate (PFUnDA-)	NV	S	-	-	-	-
Perfluoro dodecanoate (PFDoDA-)	NV	S	-	-	-	-
Perfluoro tridecanoate (PFTrDA-)	NV	S	-	-	-	-
Perfluoro tetradecanoate (PFTeDA-)	NV	S	-	-	-	-
Perfluroroctane sulfonamide (PFOSA)	NV	S	-	-	-	-
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate (HFPO DA-)	NV	S	-	-	-	-
6:2 Fluorotelomer sulfonate (6:2 FTS-)	NV	S	-	-	-	-
Ammonium 4,8-Dioxa-3H-perfluoro nonanoate (ADONA-)	NV	S	-	-	-	-
6:2 Fluorotelomer alcohol (6:2 FTOH-)	SV	L	4.7E+00	2.0E+01	-	-
8:2 Fluorotelomer alcohol (8:2 FTOH-)	NV	S	-	-	-	-
6:2 Fluorotelomer thioether amido sulfonate (6:2 FTTAoS-)	NV	S	-	-	-	-

Notes:

1. Targeted PFASs not significantly volatile. Vapor intrusion risks from contaminated soil and groundwater assumed to be insignificant.

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)
[1]Surface Water Bodies

CHEMICAL PARAMETER	[1]SURFACE WATER ACTION LEVELS [2]Freshwater (ug/L)	[3]Marine (ug/L)	[4]Estuarine (ug/L)
Perfluorobutane sulfonate (PFBS-)	-	-	-
Perfluoropentane sulfonate (PFPeS-)	-	-	-
Perfluorohexane sulfonate (PFHxS-)	-	-	-
Perfluoroheptane sulfonate (PFHpS-)	-	-	-
Perfluorooctane sulfonate (PFOS-)	-	-	-
Perfluorodecane sulfonate (PFDS-)	-	-	-
Perfluoro ethanoate (PFEtA-) (Trifluoroacetate)	-	-	-
Perfluoro propanoate (PFPrA-)	-	-	-
Perfluoro butanoate (PFBA-)	-	-	-
Perfluoro pentanoate (PFPeA-)	-	-	-
Perfluoro hexanoate (PFHxA-)	-	-	-
Perfluoro heptanoate (PFHpA-)	-	-	-
Perfluoro octanoate (PFOA-)	-	-	-
Perfluoro nonanoate (PFNA-)	-	-	-
Perfluoro decanoate (PFDA-)	-	-	-
Perfluoro undecanoate (PFUnDA-)	-	-	-
Perfluoro dodecanoate (PFDoDA-)	-	-	-
Perfluoro tridecanoate (PFTrDA-)	-	-	-
Perfluoro tetradecanoate (PFTeDA-)	-	-	-
Perflurooctane sulfonamide (PFOSA)	-	-	-
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate (HFPO DA-)	-	-	-
6:2 Fluorotelomer sulfonate (6:2 FTS-)	-	-	-
Ammonium 4,8-Dioxa-3H-perfluoro nonanoate (ADONA-)	-	-	-
6:2 Fluorotelomer alcohol (6:2 FTOH-)	-	-	-
8:2 Fluorotelomer alcohol (8:2 FTOH-)	-	-	-
6:2 Fluorotelomer thioether amido sulfonate (6:2 FTTAoS-)	-	-	-

Notes:

1. Pending due to limited information on chronic and acute toxicity of PFASs to aquatic organisms and bioaccumulation and uptake in the food chain. Refer to Tables D-4e (chronic and acute aquatic toxicity) and D-4f (bioaccumulation) for available action levels. Surface water action levels for PFASs pending development of action levels
2. Source of Freshwater EALs: Refer to Appendix 1, Table D-2a for basis. Includes consideration of drinking water action levels.
3. Source of Marine EALs: Refer to Appendix 1, Table D-2b for basis.
4. Source of Estuarine EALs: Refer to Appendix 1, Table D-2c for basis.

Surface water action levels lowest of drinking water goal (freshwater only), chronic aquatic habitat goal, goal to address bioaccumulation in aquatic organisms and subsequent consumption by humans, and general nuisance goal (odors, etc.). Refer to Chapter 2 of text and Appendix 1 for details.

Estuarine action levels lowest of freshwater and marine action levels.

TABLE E. [1]SOIL VAPOR SCREENING LEVELS FOR EVALUATION OF VADOSE-ZONE LEACHATE (Potential impacts to highly vulnerable drinking water aquifers)

CHEMICAL PARAMETER	Target Groundwater Screening Level (µg/L)	Soil Vapor Screening Level (µg/m^3)
Perfluorobutane sulfonate (PFBS-)	-	-
Perfluoropentane sulfonate (PFPeS-)	-	-
Perfluorohexane sulfonate (PFHxS-)	-	-
Perfluoroheptane sulfonate (PFHpS-)	-	-
Perfluorooctane sulfonate (PFOS-)	-	-
Perfluorodecane sulfonate (PFDS-)	-	-
Perfluoro ethanoate (PFEtA-) (Trifluoroacetate)	1.8E+01	5.0E+04
Perfluoro propanoate (PFPrA-)	5.1E-01	1.5E+00
Perfluoro butanoate (PFBA-)	-	-
Perfluoro pentanoate (PFPeA-)	-	-
Perfluoro hexanoate (PFHxA-)	-	-
Perfluoro heptanoate (PFHpA-)	-	-
Perfluoro octanoate (PFOA-)	-	-
Perfluoro nonanoate (PFNA-)	-	-
Perfluoro decanoate (PFDA-)	-	-
Perfluoro undecanoate (PFUnDA-)	-	-
Perfluoro dodecanoate (PFDoDA-)	-	-
Perfluoro tridecanoate (PFTrDA-)	-	-
Perfluoro tetradecanoate (PFTeDA-)	-	-
Perflurooctane sulfonamide (PFOSA)	-	-
2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate (HFPO DA-)	-	-
6:2 Fluorotelomer sulfonate (6:2 FTS-)	-	-
Ammonium 4,8-Dioxa-3H-perfluoro nonanoate (ADONA-)	-	-
6:2 Fluorotelomer alcohol (6:2 FTOH-)	-	-
8:2 Fluorotelomer alcohol (8:2 FTOH-)	-	-
6:2 Fluorotelomer thioether amido sulfonate (6:2 FTTAoS-)	-	-

Notes:

1. Not applicable. Targeted PFASs not significantly volatile.

Attachment 3

Detailed PFAS EALs

(HIDOH January 2026)
Supplement to Volume 2, Appendix 1 of HIDOH EHE Guidance

Attachment 4

Total PFAS Risk Fact Sheet

(HIDOH January 2026)

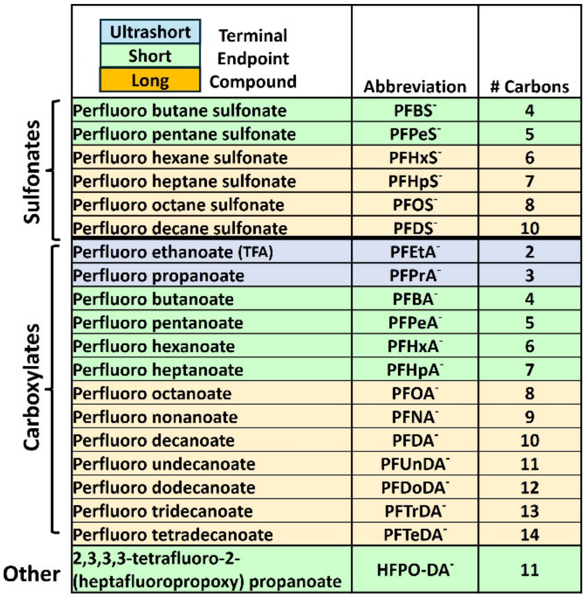
Assessment of Total PFAS Risk

This Fact Sheet is an accompaniment to the HIDOH Technical Memorandum *Interim Soil and Water Environmental Action Levels (EALs) for Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs)* and the HIDOH PFAS webpage (HIDOH 2024a,b). The Fact Sheet summarizes a method to calculate the cumulative health risk posed by exposure to different groupings of PFAS compounds. The approach is intended to be used by environmental professionals familiar with the collection of samples and basic methods used to quantify the health risk posed by exposure to contaminants in environmental media.

What are PFASs?

Per- and polyfluoroalkyl substances (PFASs) are manmade chemicals used in many industries since the 1940s to make things waterproof, non-stick, and stain resistant. Examples of materials that may contain PFASs include firefighting foam, carpet, furniture, waterproof clothing, and certain types of food packaging. Similar compounds are also found in influent, effluent and biosolids associated with municipal and industrial wastewater treatment plants as well as leachate from landfills. These chemicals are often described as “forever chemicals” because they do not breakdown over time and can build up in the environment and our bodies. Additional information can be found on the Hawai´i Department of Health PFAS webpage (HIDOH 2024).

PFASs are named in part based on the number of carbons in the compound. Long-chain compounds are generally more toxic than shorter chain compounds. Toxicological studies have demonstrated that exposure to even low levels of PFASs over many years in food, water and other media can pose health risks. Health risk is assessed in terms of a short list of “Terminal PFASs” (Figure 1). These compounds have been extensively studied and are believed to pose the greatest health risk. The compounds might be originally present in contaminated soil, water or food or they might be generated by the breakdown of more complex, “precursor” PFASs compounds after being ingested.



	Ultrashort Short Long Terminal Endpoint Compound	Abbreviation	# Carbons
Sulfonates	Perfluoro butane sulfonate	PFBS$^-$	4
	Perfluoro pentane sulfonate	PFPeS$^-$	5
	Perfluoro hexane sulfonate	PFHxS$^-$	6
	Perfluoro heptane sulfonate	PFHpS$^-$	7
	Perfluoro octane sulfonate	PFOS$^-$	8
	Perfluoro decane sulfonate	PFDS$^-$	10
Carboxylates	Perfluoro ethanoate (TFA)	PFEtA$^-$	2
	Perfluoro propanoate	PFPrA$^-$	3
	Perfluoro butanoate	PFBA$^-$	4
	Perfluoro pentanoate	PFPeA$^-$	5
	Perfluoro hexanoate	PFHxA$^-$	6
	Perfluoro heptanoate	PFHpA$^-$	7
	Perfluoro octanoate	PFOA$^-$	8
	Perfluoro nonanoate	PFNA$^-$	9
	Perfluoro decanoate	PFDA$^-$	10
	Perfluoro undecanoate	PFUnDA$^-$	11
	Perfluoro dodecanoate	PFDoDA$^-$	12
	Perfluoro tridecanoate	PFTrDA$^-$	13
	Perfluoro tetradecanoate	PFTeDA$^-$	14
Other	2,3,3,3-tetrafluoro-2-(heptafluoropropoxy) propanoate	HFPO-DA$^-$	11

Figure 1. Terminal PFAS compounds. HFPO- DA considered “terminal” due to recalcitrance to breakdown in the environment.

What are Environmental Action Levels?

The Technical Memorandum accompanying this Fact Sheet presents “Environmental Action Levels (EALs)” for soil, water and, for volatile PFAS, indoor air and vapors that can accumulate underground at PFAS spill areas (HIDOH 2024a). Action levels are provided for each of the Terminal PFASs noted in Figure 1 plus a short list of more complex, “precursor” PFASs. The EALs reflect concentrations of PFASs in soil and drinking water and air that are not expected to pose a significant health risk to young children or adults even after many years of exposure. Exceeding an action level does not necessarily indicate an imminent health risk, but it does indicate that additional evaluation is warranted.

The action levels focus on the protection of mothers and young children from long-term exposure to PFASs and associated noncancer-related health risks, such as effects to the liver and kidney. Potential cancer risks are also considered for some PFASs, but noncancer-related risks and the protection of mothers and young children takes precedence. Protection against noncancer health risks to these groups is believed to also be protective against cancer risks. Refer to the accompanying Technical Memorandum for additional information.

How are samples collected and tested for PFASs?

Samples of soil and water to be tested for PFASs should be collected in accordance with methods described in the HIDOH *Technical Guidance Manual* (TGM, HIDOH 2024). Samples of soil, sediment, biosolids and other particulate matter must be obtained using Decision Unit and Multi Increment® Sample (DU-MIS) investigation methods outlined in Sections 3 and 4 of the TGM. (Multi Increment® is registered trademark of EnviroStat, Inc.) Methods for the collection of representative samples of surface water and groundwater are discussed in Section 6 of the TGM.

Assessment of Total PFAS Risk requires up to three separate laboratory analyses – analysis prior to sample oxidation, analysis following sample oxidation and analysis for Total Organic Fluorine. The method used to oxidize a sample is referred to as "Total Oxidizable Precursors" or "TOPs." Sample data based on TOPs processing are most useful for assessment of risk. Analysis of a sample prior to sample oxidation is primarily useful for forensics proposes and determination of the origin of the PFAS contamination.

The same method is used for both pre-TOPs and post-TOPs analysis. Some laboratories have developed equivalent or improved methods. Check with the laboratory prior to the collection of samples to determine which method is most appropriate for your needs.

What is "TOPs" analysis?

Complex, PFAS precursor compounds are broken down to Terminal PFAS compounds through a laboratory sample processing method referred to as "Total Oxidizable Precursors" or "TOPs" (Houtz and Sedlak 2012, Ateia 2023, Pelch 2023). The sample is heated with an oxidizing agent under alkaline conditions. Much like pruning branches from a tree to exposure the underlying trunk, this strips functional groups from complex, "precursor" PFAS compounds and generates a new set of Secondary Terminal PFASs compounds specific to the types of precursors originally present (Figure 2).

An example is the oxidation of 6:2 fluorotelomer thioether amido sulfonic acid (6:2 FtTAoS), the primary PFAS compound in aqueous firefighting foam (AFFF). TOPs effectively clips off the large, functional group attached to 6:2 FtTAoS, leaving behind the Terminal PFAS compound perfluoroheptanoate (PFHpA^{-}). This simulates metabolism and breakdown of 6:2 FtTAoS in the body. For reasons that are not yet well understood, additional shorter-chain PFAS like pefluorohexanoate (PFHxA^{-}) and perfluorobutanoate (PFBA^{-}) can also be generated. Note that the anion forms of the compounds are typically found in nature.

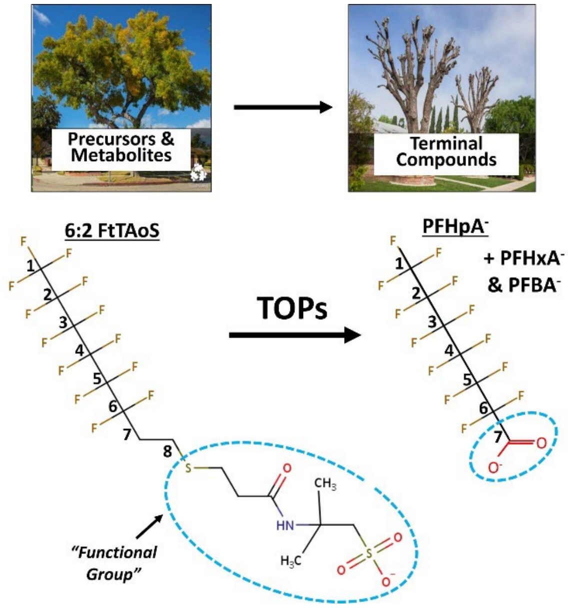


Figure 2. Oxidation of 6:2 FtTAoS to generate the Terminal Endpoint compound PFHpA^{-}.

How is the total health pisk posed by exposure to PFASs determined?

The cumulative health effects posed by PFASs is assessed with respect to three groups of Terminal PFASs that could be present in a sample (Figures 3 & 4), defined for use in this guidance as: 1) “Primary Terminal PFASs,” 2) “Secondary Terminal PFAS,” and 3) “Excess Fluorine PFASs.” Primary Terminal PFASs are compounds represent Terminal PFAS compounds originally present in the sample and reported prior to TOPs processing (“pre-TOPs”). Secondary Terminal PFASs are compounds generated by the breakdown of precursor compounds following TOPs processing. Any additional PFASs in a sample are identified by comparing the concentration of Total Organic Fluorine reported for the sample to the concentration of organic fluorine predicted by concentrations of Primary and Secondary Terminal PFASs. The difference is referred to as “Excess Fluorine.” Detailed analysis of samples with excess fluorine typically identifies the associated compounds as “ultrashort” PFASs such as the two-carbon compound perfluoroethanoate (PFEtA^-, aka trifluoroacetate) and the three-carbon compound perfluoropropanoate (PFPrA^-).

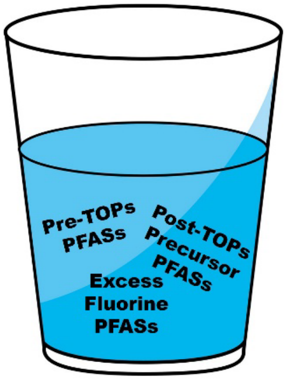


Figure 3. Three groups of PFASs potentially present in contaminated media.

Post-TOPs data are especially important for soil, biosolids and other particulate media, where significant concentrations of precursor compounds might be present. Total Organic Fluorine data tend to be more important for PFAS-contaminated water, where significant concentrations of ultrashort compounds have been identified in field studies.

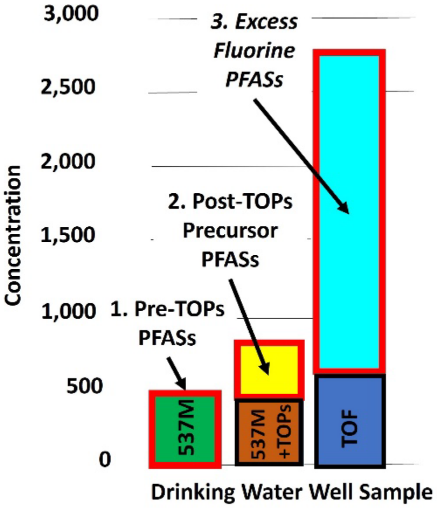


Figure 4. Three groups of PFAS-related compounds in contaminated media (Method 537M shown as an example).

Total PFAS Risk is calculated by dividing the concentration of each Primary Terminal PFAS and Secondary Terminal PFAS by the corresponding action level. The concentration of additional, Excess Fluorine PFASs is divided by the action level for the ultrashort compound PFPrA^-. The ratio of the reported concentration of a compound to the corresponding action level is referred to as the “Hazard Quotient (HQ).” The sum of the Hazard Quotients calculated for Primary and Secondary Terminal PFASs is referred to as a “Hazard Index (HI).” Adding the Hazard Indices for Primary Terminal PFASs and Secondary Terminal PFASs to the Hazard Quotient calculated for Excess Fluorine PFASs generates a cumulative Hazard Index for Total PFASs Risk as a whole:

Total PFAS Risk = Pre-TOPs HI + Post-TOPs Precursor HI + Excess Fluorine HQ.

A Hazard Index greater than “1” indicates a potential health concern that requires additional evaluation.

An Excel-based spreadsheet that accompanies this Fact Sheet and Technical Memorandum makes calculation of a Hazard Index easy. Use of the spreadsheet is strongly recommended.

Where can I get more information?

Detailed information on the methods used to assess PFAS health risk can be found in the HIDOH Technical Memorandum that accompanies this Fact Sheet (HIDOH 2024a). Additional information can be found in the references noted below and by searching for specific topics on the internet.

References:

Ateia, M., Chiang, D., Cashman, M and C. Acheson, 2023, Total Oxidizable Precursor (TOP) Assay - Best Practices, Capabilities and Limitations for PFAS Site Investigation and Remediation: Environmental Science and Technology Letters, Vol. 10, pp 292−301.

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Houtz, E.F. and D.L. Sedlak, 2012, Oxidative Conversion as a Means of Detecting Precursors to Perfluoroalkyl Acids in Urban Runoff: Environ. Sci. Technol. 2012, 46, 9342−9349, dx.doi.org/10.1021/es302274g

Pelch, K.E., McKnight, T. and A. Anna Read, 2023, 70 analyte PFAS test method highlights need for expanded testing of PFAS in drinking water: Science of the Total Environment, Vol. 876, 10 June 2023, 162978.

Attachment 5

Total Risk Calculator (January 2026; separate Excel file)

Attachment 6

Summary of Previous Updates

January 2026 Update:

- Text noting the inclusion of the vapor emission pathway to the drinking water action level model for PFEtA$^-$ and PFPrA$^-$ added to Section 6.1.1. Environmental Action Levels for PFEtA$^-$ and PFPrA$^-$ were affected.
- Exposure Time for vapor emission component of tapwater action level model corrected from 24 hrs/day to 4.2 hrs/day to reflect default in HIDOH (2024) EAL guidance (reflects default time spent using showers, washing machines, dishwashers, etc.). Tapwater action levels for PFEtA$^-$ and PFPrA$^-$ were affected.
- Discussion of inhalation Reference Concentrations in Section 4.1 (Human Toxicity) edited for clarity.

February 2025 Update:

HFPO-DA added to "Primary Terminal PFASs" category due to recalcitrance to breakdown in the environment and TOPs processing. Option to input sample data for HFPO-DA added to accompanying "Total PFAS Risk" calculator. Environmental Action Levels for HFPO-DA were not affected.

November 2024 Update:

- Perfluoroethanoate added (PFEtA$^-$, aka trifluoroacetate);
- Reference for sorption coefficients for multiple compounds and solubility in one case updated to USEPA CompTox database (refer to Table 2; figures updated accordingly; corresponding soil leaching action levels affected);
- Method used to calculate excess organic fluorine in samples modified (negligible change in calculation of Total PFAS Risk);
- Allowance made in accompanying Total PFAS Risk calculator for consideration of alternative, cumulative toxicity of "Excess Fluorine PFASs" group of compounds and corresponding comparison of sample data to alternative, risk-based action levels (requires provision of supporting technical information);
- Soil direct-exposure action levels for HFPO DA$^-$ corrected.

July 5, 2024, Update: Soil action level for PfHxS$^-$ in Table B-1 and Table B-2 (Direct Exposure) and Summary Table B (final soil action level) corrected to 0.025 mg/kg.

April 2024 Updates:

- Target Hazard Quotient of "1" used to generate soil action levels for direct exposure;
- Calculation of cumulative noncancer hazard ("Hazard Index") required for both soil and drinking water data (includes groundwater classified as a current or potential source of drinking water);
- Automatic calculation of a Hazard Index based on input sample data included in Total PFAS Risk spreadsheet accompanying this Technical Memorandum;
- Figure depicting relative toxicity of PFASs in comparison to other common contaminants added (Figure 6).
- Reference Concentration for 6:2 fluorotelomer sulfonate (6:2 FTS) corrected to 0.001 mg/m^3 (MIDEGLE 2020);
- Toxicity factors, physiochemical constants and action levels for following compounds added:
    - Perfluoropentane sulfonate and Perfluoropropanoate (identified in groundwater samples);
    - 6:2 fluorotelomer alcohol and 8:2 fluorotelomer alcohol (used to coat food wrappers and compostable food containers); and
    - 6:2 fluorotelomer thioether amido sulfonate (primary PFAS in modern AFFF);

- USEPA drinking water Maximum Contaminant Levels (MCLs) and MCLGs for PFOA, PFOS, PFBS, PFHxS, PFNA and HFPO-DA added (USEPA 2024a);
- Reference dose for PFHxS updated to reflect RfD used to develop USEPA MCGL; and
- Guidance and accompanying Excel spreadsheet added for calculation of sample-specific "Total PFAS Risk."

April 2023 Update:

- Toxicity factors and EALs for ADONA added;
- Updated reference for PFHxA toxicity;
- Tapwater action levels updated to reflect a target noncancer Hazard Quotient of 1 versus 0.5 (used in previous editions) to match the anticipated approach for calculation of USEPA Maximum Contaminant Levels Goals for PFASs (refer to Section 8.0);
- Section added to discuss calculation of cumulative, noncancer hazard for drinking water resources impacted by multiple PFASs (refer to Section 9.0);
- Discussion of volatile PFASs added, although toxicity factors for the subject compounds are not currently available;
- Summary of Method 8327 for testing of PFASs in groundwater, surface water, and wastewater samples added;
- Table 4b revised to note correct final RfDs used to generate EALs (EALs not affected);
- Direct exposure soil action levels for unrestricted (e.g., residential) land use revised to correct calculation error (Appendix 1, Table I-1).

December 2022 Update: Soil and groundwater action levels added for 6:2 Fluorotelomer sulfonate (6:2 FTS^-). Action levels for HFPO DA^- and $PFHxA^-$ revised to reflect toxicity factors published by USEPA (USEPA 2021, 2022a). Action levels for $PFOS^-$, $PFOA^-$, $PFHxS^-$ and $PFNA^-$ were updated to reflect toxicity factors published by ATSDR (ATSDR 2021). The ATSDR toxicity factors have also been incorporated into the USEPA Regional Screenings Levels (RSL) guidance (USEPA 2022b).

Additional updates to EALs are anticipated in 2023 as new guidance on key compounds of interest, laboratory methods, toxicity studies and related information is compiled and reviewed by HIDOH staff. This includes review of interim drinking water advisory levels for PFOS and PFOA published by the USEPA in June 2022 (USEPA 2023). Draft Maximum Contaminant Levels (MCLs) for the same compounds anticipated to be published by the USEPA in 2023. The understanding of health impacts from exposure to individual PFASs continues to evolve as new studies are conducted and published. Further updates will incorporate additional health effects data as available.

August 2021 Update: Equation 1 was reorganized and revised to correct the parameter units. No changes were made to the EALs.

April 2021 Updates: Action levels for $PFBS^-$ were updated to reflect a revised oral Reference Dose toxicity factor for $PFBS^-$ published by the USEPA (USEPA 2021a). This resulted in a reduction of tapwater and soil direct exposure and leaching action levels for $PFBS^-$. Default, acute aquatic toxicity action levels for $PFHxS^-$, $PFBA^-$, $PFHxA^-$, $PFUnDA^-$ and $PFDoDA^-$ and associated soil leaching action levels revised to correct error in Fall 2020 tables. The updates affect soil and groundwater action levels for these chemicals at sites where groundwater is not a source of drinking water and is situated >150m from a body of surface water (Table B). Action levels for other site scenarios and other PFASs were not affected. The updated action levels replace and take precedence over action levels presented in the previous, December 2020 technical memorandum. (Revised to add Table 4b.)

This memorandum presents interim, soil and groundwater Environmental Action Levels (EALs) for screening of sites contaminated with perfluoroalkyl and polyfluoroalkyl substances (PFASs). Brief overviews of key topics are presented with references provided for additional details. The action levels represent a supplement to the Hawai´i Department of Health (HIDOH), Hazard Evaluation and Emergency Response (HEER) Office guidance document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* ("EHE guidance;" HIDOH 2017). A separate, Excel-based "EAL Surfer" of electronic lookup tables specific to PFASs is available for download from the EHE guidance webpage (refer to weblink included with reference). Guidance in this memorandum updates and replaces guidance presented in a July 2020 draft, technical memorandum posted for public review.

Updates to the PFASs guidance are anticipated in the future as new information and additional experience is obtained. Comments and suggestions for edits are welcome and should be submitted to Roger Brewer with the HEER Office (roger.brewer@doh.hawaii.gov). A recorded presentation on the PFASs guidance is posted to the HEER Office webinar webpage (made prior to December 2020 update; https://health.hawaii.gov/heer/guidance/heer-webinars/)