

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

September 2017 DRAFT Per- and Poly-Fluorinated Alkyl Substances Chemical Action Plan (PFAS CAP)

The Washington State departments of Ecology and Health prepared a draft of several PFAS CAP chapters for external review. This document is one chapter to a planned multi-chapter PFAS CAP. This material may be modified in response to comments and the content re-organized for the final Action Plan.

The September 2017 Draft PFAS CAP includes:

- Health, Environment, Chemistry, Regulations – posted online by 09/20/2017
- Uses, Intro – posted online by 10/06/2017

The draft chapters may include cross-references to other sections/chapters in the Draft PFAS CAP or notes where additional information will be provided in a later draft.

The PFAS CAP Advisory Committee will discuss comments on these draft chapters at the November 1, 2017 meeting.

Ecology and Health are asking interested parties to provide feedback. Comments on these draft documents are due to Ecology by **October 20, 2017**.

Comments on all chapters will be accepted after October 20th. Comments received by October 20 will be reviewed at the November 1 Advisory Committee meeting.

Submit comments, suggestions, and questions to Kara Steward at
kara.steward@ecy.wa.gov

The Draft PFAS CAP documents are posted at
<https://www.ezview.wa.gov/?alias=1962&pageid=37105> (at the bottom of the webpage).

PFAS USE and RELEASE

An overview of per- and poly-fluorinated alkyl substance (PFAS) production is provided in this chapter. Due to the great breadth of the PFAS category, the use and release information is focused on those materials of interest to the CAP. Specifically, we focused on the long-chain (high bioaccumulation) products in PFSA and PFCA categories. These include PFOS and PFOA and longer chain entities. This category also includes non-polymeric materials which have the ability to degrade into the long-chain entities.

We also focused on long-chain fluorotelomer polymers, which have the ability to degrade to PFSA or PFCA materials.

Several references are provided that contain more details about historic PFAS production than is included in this PFAS CAP. PFAS manufacturing is not known to occur in Washington State. The discussion of PFAS use focuses on data and estimates for Washington State. A summary of several studies of PFAS in consumer products is included in this chapter.

PFAS Production

The process for producing PFAS-PFSA was developed in the 1940s – a detailed discussion of PFAS-PFSA chemistry is provided in the Chemistry chapter. Since 1950, PFAS compounds, surfactants and polymers have been widely used in numerous industrial and commercial applications.

PFAS-PFAA are still being produced worldwide, but the production of long-chain PFAS has greatly declined over the past 15 years in the U.S., Europe, and Japan. Perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA) and related long-chains are no longer produced or used by major manufacturers in the U.S., Europe, and Japan. Some Manufacturers in China, India and Russia continue to use long-chains under no existing regulation (Fluoro-Council 2017). There are no known manufacturers of any PFAS in Washington State.

PFOS Production

The 3M Company began producing PFOS in the 1940s. Perfluorooctane sulfonyl fluoride (POSF) is used as an intermediate in the production of PFOS and PFOS derivatives, and the production of POSF can be used as an indicator of the total production of PFOS-related substances. POSF production reached a peak from 1970 through 2002 in 2002 with an estimated total cumulative production from 1970 through 2002 of 96,000 metric tons (1 metric ton is equal to 1.10231 ton). From 1970 to 2002, the main end uses of the POSF-derived substances were (DEPA 2013, Paul 2009):

- Carpet: 48,000 metric tons
- Paper and packaging: 24,000 metric tons

Commented [A1]: Recommended wording for narrowing the PFAS category to materials of interest.

Commented [A2]: Should be more specific if this CAP is referring to the invention of the ECF process and manufacture of PFOS and related derivatives. Refer to section below.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

- Apparel: 12,500 metric tons
- Performance chemicals (hydraulic fluids): 6,000 metric tons
- AFFF: 10,000 metric tons

Reduction of PFOS production occurred in 2002 when 3M voluntarily discontinued production of PFOS and other long-chain PFAS. 3M was the major global manufacturer of PFOS. Additionally, in 2009 PFOS was included in the Stockholm Convention list of Persistent Organic Pollutants with acceptable purpose and specific exemptions [see, e.g. <http://chm.pops.int/Implementation/NIPs/Guidance/GuidanceonBATBEPfortheuseofPFOS/tabid/3170/Default.aspx> that is referenced in one of the DRAFT CAP chapters]. with restrictions on its use internationally. (Buck 2011) After 2002, 3M switched to less bioaccumulative short-chain PFAS PFSA such as PFBS (MDH 2012).

After 2002, PFOS global production continued at an estimated 1,000 tons per year. PFOS and its derivatives are still manufactured in China, with a production of more than 200 tons of its precursor POSF in 2006 (Buck 2011).

PFOA and PFNA Production

The estimated global production of PFOA and ammonium perfluorooctanoate (APFO) from 1951-2004 is 3,600-5,700 metric tons, while the manufacturing of perfluorononanoic acid (PFNA) and ammonium perfluorononanoate (APFN) during the same period is estimated at 800-2,300 metric tons (Prevedouros *et al.*, 2006). PFOA and its related compounds are mainly used as surfactants.

In 1999, global annual APFO production was approximately 260 metric tons. A 2009 Organization for Economic Co-operation and Development (OECD) survey reported manufacture of 5.5 metric tons of PFOA and related compounds (note: OECD PFAS surveys were completed in 2004, 2006 and 2009).

Reduction of PFOA production resulted from a 2006 stewardship agreement between EPA and eight leading global companies to reduce production and releases of PFOA, its precursors and higher homologs such as C9, C10, and C11. That agreement included a commitment to 95% reduction of global emissions and product content by the end of 2010 and elimination by the end of 2015. All participating companies reported that they met the stewardship goals (EPA 2014). Production of PFOA in the U.S. ceased before 2015. Other national and international agreements also affected PFOA production (Buck 2011).

Fluorotelomer Production

Worldwide production of fluorotelomers for polymer production and surface coatings has been estimated at 11,000 to 13,000 tons per year (Lindstrom 2011, DEPA 2013). Five long-chain fluorotelomers that potentially may degrade to PFOA and PFNA were reported as present in

Commented [A3]: Please consider inserting text from this reference: Xie, S., Wang, T., Liu, S., Jones, K.C., Sweetman, A.J., Lu, Y., 2013. Industrial source identification and emission estimation of perfluorooctane sulfonate in China. Environ. Int. 52, 1–8.

Commented [A4]: Please consider defining related compounds. Do you mean non-polymeric chemicals derived from PFOA?

Commented [A5]: Please consider inserting text from this reference: Li Li et al., 2015. "Estimating industrial and domestic environmental releases of perfluorooctanoic acid and its salts in China from 2004 to 2012". Chemosphere 129, 100-109. DOI:10.1016/j.chemosphere.2014.11.049

Commented [A6]: Please consider adding some brief explanation of the production of fluorotelomers that are then converted to fluorotelomer polymers. And then describe how they are used.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

products at 20 metric tons per year (OECD 2011). An analysis of the fluorochemical market predicts continued growth in fluoropolymer use in the electronic, construction and automotive industries (Grand View Research 2016).

Through voluntary efforts, including the U.S. EPA PFOA Stewardship Program, major manufacturers in the U.S., Europe, and Japan no longer manufacture, use, or sell long-chain fluorotelomer-based products on a global basis. These companies have moved to short-chain fluorotelomer-based products that offer an improved environmental and toxicological profile over the long-chain substances. Production of long-chain based fluorotelomer substances ceased in the U.S. on or before the end of 2015. Production of these long-chain fluorotelomer substances continues in China.

Commented [A7]: The last sentence in this paragraph seems misplaced as this market research report addresses fluoropolymers, which are not the same as fluorotelomers. It is out of context. Please consider removing.

US Production Data

Under the Toxic Substances Control Act, EPA gathers production data for chemical substances in commerce, including PFOS and PFOA. Table 1 lists the annual volumes of PFOS and PFOA reported to the EPA in the Chemical Reporting Database (EPA 2017). The reports to EPA include national production volume (in ranges), other manufacturing information, and processing and use information. Some information submitted to the EPA is withheld as confidential. The totals include both domestic production and imports. After 2002, no reports are recorded in the Chemical Reporting Database for perfluorobutanoic acid (PFBA), PFOS or PFOS potassium salt. PFOA and APFO data are recorded in the database as withheld from 2012 to 2015.

Commented [A8]: See public EPA Stewardship Program data.

Table 1 – Reported PFAS, PFOS, PFBA and PFOA Production in the U.S. (thousands of pounds per year)

PFAS	1986	1990	1994	1998	2002	2006	2012-15
PFOA	10-500	NR	10-500	10-500	10-500	<500	Withheld
APFO	10-500	10-500	10-500	10-500	500-1000	<500	Withheld
PFBA	10-500	NR	NR	NR	NR	NR	NR
PFOS	NR	NR	10-500	NR	10-500	NR	NR
PFOS potassium salt	10-500	10-500	10-500	10-500	10-500	NR	NR

NR – no reports
(EPA 2017, ATSDR 2015)

Commented [A9]: Can the authors please confirm that the title is correct? Does the table include all PFAS substances reported in the CDR? Key points from the above paragraphs can be included here, e.g., dates when PFOS, POSF, PFOA and long-chain fluorotelomer production ceased in the USA (please include similar information in the following chapter “EU Production Data”).

EU Production Data

The OECD conducts surveys on production and releases of some PFAS and published several lists of PFAS. The 2006 survey identified 960 PFOS, PFAS, PFOA and perfluoroalkyl carboxylic acids (PFCA) substances, of which 623 substances are included in the list of pre-registered

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

substances under the European Union Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) (ECHA, 2012b). Many side-chain-fluorinated polymers on the OECD 2007 list are not registered under REACH.

In 2013, REACH registrations included 23 PFAS. The total registered tonnage of PFOS, PFOA, APFO production under REACH is in the range of 15-150 ton/yr. The total consumption of PFAS with end-uses, considering global production, is likely in the 2,000-4,000 ton per year range (DEPA 2013) – see Table 2.

Table 2 – Estimated PFAS Use in the EU in 2011 (tons per year)

Substance group	Estimated EU consumption-use in 2011	Use
PFOS and related substances	2-10 ton/yr	Metal plating industry (81%) Photographic industry Semiconductor industry Hydraulic fluids in aviation industry
PFOA and APFO	25-50 ton/yr	Fluoropolymer production (majority) Photographic industry Semiconductor industry
Longer chained PFCA and related substances	No data	
Short-chain PFAAs	30-130 ton/yr	Limited data: Surfactants, reactive processing aids
Fluorotelomers	No registrations	
Side-chain-fluorinated polymers	2,000-4,000 ton/yr	Probably same as world market: Textiles and apparel (50%) Carpet and carpet care products Coatings, including those for paper products

(DEPA 2013, DEPA 2016)

PFAS Uses

Due to their unique physical and chemical properties, PFAS are used in a variety of industrial applications and consumer products. PFAS (did you mean PFOS and derivatives) have been used to provide non-stick surfaces on cookware and waterproof coatings for textiles and paper products. They serve as high performance surfactants in numerous products that must flow freely, including paints, cleaning products, fire-fighting foams used to fight fuel-based fires, and engineering coatings used in semiconductor production (EPA 2015b). PFOS and PFOA were used in the United States in carpets, leathers, textiles, upholstery, paper packaging, coating additives, and as a waterproofing or stain resistant agent (EPA 2016b, 2016c).

Commented [A10]: Because polymers are not required to be registered under REACH.

Commented [A11]: This table does not list “Production” but “Use”. Should it be moved to the next chapter? Would “No Data” be more precise wording than “No registrations”?

Commented [A12]: Longer than what? PFOA?

Commented [A13]: What does this mean? What is a reactive processing aid?

Commented [A14]: This is confusing. Side-chain fluorinated polymers are fluorotelomers.

Commented [A15]: This section would be easier to understand if the uses were discussed by chemical. PFOS is used for.... PFOA is used for.... Etc. Suggest you add a short paragraph at the beginning that describes the generic use of PFOA and PFOS in commerce.

Commented [A16]: This is not accurate. Derivatives of PFOS and other ECF chemicals were used. PFOA was not used in these applications. Fluorotelomer-based products were used, but are not PFOA based. PFOA was not a component in products, but may have been present as an unintended manufacturing impurity.

PFOS has been used as a surfactant in many different applications, most notably in aqueous film-forming foam (AFFF)¹ to extinguish flammable liquid fires and in fume suppressants used in metal plating processes and in the semiconductor industry. PFOS was a major component of AFFF manufactured by 3M. Limited uses of PFOS-related chemicals are allowed for which alternatives are not yet available, including use in aviation fluid, photomicro lithography, film processing, as an etchant, and for metal plating and finishing (40 CFR §721.9582).

PFOA has been used in ~~as a polymerization processing aid~~ ~~a variety of consumer products~~ and in the production of fluoropolymers, and is generated ~~in small quantities~~ as a degradation product of ~~other long-chain fluorotelomer-based products~~ ~~perfluorinated compounds~~. PFOA was used in the United States primarily as an aqueous dispersant agent in the manufacture of fluoropolymers ~~and in a variety of water, oil, and stain repellent products~~. ~~PFOA is resistant to environmental degradation and biotransformation. It is not incorporated into the fluoropolymer, but can appear in the final fluoropolymer product as an unintended impurity.~~

It is used to make fluoropolymer substances that impart valuable properties such as fire resistance, ~~lubricity~~ and oil and water repellency. It is used in numerous applications such as in cooking surfaces, food containers and contact paper, toothpaste, shampoos, polishes and waxes, electronics, lubricants, stain repellants on carpets and upholstered furniture, flame repellants, firefighting foams, paints, emulsifiers, and plumbing tape. The United States production of PFOA has been phased out but it is produced in other countries (EPA 2016a).

The OECD 2009 survey results showed that PFAS continue to have a wide range of uses. The 2009 OECD survey sought information on the production and use of PFAS with chain lengths of 6 carbons or more. The survey includes information about PFAS release to the environment during manufacturing and formulation of products (there is no manufacturing of PFAS or PFAS products in Washington, so those ‘release’ estimates are not applicable). Responses to the OECD survey referred to general uses for the PFAS in products, such as ‘processing agents’ or ‘manufacturing intermediates.’ The survey included a report of PFAS concentrations in the products, generally ranged between 0.1 part per million (ppm) and 80,000 ppm (equal to 8 percent). The total amount of these chemicals present as residues in products was nearly 45 metric tons. Several perfluorinated chemicals were reported to be present only as impurities with no specific use in products being reported. PFAS have been employed in hundreds of other applications across almost all industrial sectors, some of which are highlighted in Table 3.

Table 3 – Product Categories and PFAS Use

Product category	PFAS use in products
Automotive	low friction bearings and seals, lubricants, tubing, seals, wire insulation, metal plating, wire plating and other equipment, fuel additives, surfactants, emulsifiers, hydraulic fluid

¹ AFFF are chemical mixtures developed to extinguish and prevent re-ignition of hydrocarbon fuel-based fires. PFOS was a commonly used fluorosurfactant in AFFFs (before phase-out in 2002)

Commented [A17]: A good overview of currently permitted uses of PFOS and PFOS-related substances can be found in a report references in one of the other CAP chapters: <http://chm.pops.int/Implementation/NIPs/Guidance/GuidanceonBATBEfortheuseofPFOS/tabid/3170/Default.aspx>

Please include that the use of stockpiled PFOS containing firefighting foam is permitted in the USA. Please see the FFFC survey previously provided. Please include text of the SNURs regulating PFOS and POSF-based substances and please comment if imported goods are included in this regulation.

Commented [A18]: PFOA is not used in consumer products. It is used as a polymerization aid in the manufacture of fluoropolymers.

Commented [A19]: This is not accurate. See above comment.

Commented [A20]: No, fluoropolymers do not provide these properties. That is fluorotelomers. We would be happy to provide a more appropriate list for the use of fluoropolymers

Commented [A21]: None of this is accurate. PFOA is not used in any of these applications.

Commented [A22]: Recommend a clearer separation of PFAA, telomer polymers and the fluoropolymers that are used. The data reported is a mixture of all these products

Commented [A23]: The content is unclear as it does not describe which PFAS is used for each application listed. Please consider reformatting and to include PFAS, PFCA, and potential precursor substances.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Product category	PFAS use in products
Aviation, Aerospace & Defense	hydraulic fluid additives, insulators, solder
Biocides	plant growth, insecticides, pesticides, insect repellent
Cable & wiring	coating for weathering, flame and soil resistance, surface treatments
Construction	additives in paints and coatings, varnishes, adhesives, and sealants, plumbing tape and paste
Electronics	flame retardants, insulators, solder
Energy	solar collector film
Firefighting	foams for petroleum fires for aerospace, oil transport, and oil refineries; firefighting equipment
Food Packaging and Processing	paper coatings for fast food and candy wrappers, microwave popcorn and pizza box liners; fabrication materials
Homes and Businesses	carpet and carpet care products, cleaning products, outdoor and upholstered furniture, cookware coated with PTFE; stain/water repellants on clothing, bedding materials, upholstered furniture, carpets; waxes, floor polishes, printing inks,
Industrial	electronics, semiconductor, aerospace, automotive, pesticides, photography, oil & mining (surfactants)
Medical	equipment, surgical patches, cardiovascular grafts, implants, surgical drapes/gowns (stain/water repellent), fluoropolymer or Teflon tubing
Personal products	toothpaste, shampoo, cosmetics, sunblock, moisturizers, hand creams, textiles and apparel, outdoor clothing and equipment
Planes	upholstery, carpet, tubing, seals, wire insulation, metal plating, wire plating and other equipment, fuel additives, lubricants, surfactants, emulsifiers, hydraulic fluid, stain/water repellants on upholstery and carpets
Textiles, leather & apparel	porous fabrics, oil and water repellent, stain release

In 2015, there were 237,538 businesses registered in Washington State. Table 4 lists the number of establishments identified in a potentially related North American Industry Classification System code (ESD 2017). The food manufacturing industry includes subcategories of businesses that may use PFAS treated food packaging paper. Not all of the businesses in each code category are assumed to use PFAS chemicals in their operations.

Table 4 List of businesses in Washington (2016)

NAICS Code	Industry	Total WA Businesses
311	Food manufacturing	993

Commented [A24]: Does this table outline industries in Washington State that potential use or have used the PFAS is scope?

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

313	Textile mills	21
314	Textile product mills	148
315	Apparel manufacturing	90
316	Leather and allied product manufacturing	26
322	Paper manufacturing	99
323	Printing and related support activities	497
324	Petroleum and coal products manufacturing	56
325	Chemical manufacturing	284
326	Plastics and rubber products manufacturing	201
332	Fabricated metal product manufacturing	1,115
333	Machinery manufacturing	433
334	Computer and electronic product manufacturing	394
335	Electrical equipment and appliance mfg.	129
336	Transportation equipment manufacturing	482
337	Furniture and related product manufacturing	406
339	Miscellaneous manufacturing	788
	Total number of businesses	6,162

PFAS Product Use

The amount of PFAS in consumer products in Washington State is difficult to estimate. One way to create a Washington estimate is to scale the global estimate of the use of PFAS in products (see the beginning of this chapter) to Washington State.

The US comprises 24 percent of the global economy, Washington State is 2.55 percent of the US economy. Applying that ratio to the PFAOS production/use estimates of 96,000 metric tons of PFOS/POSF and 8,000 metric tons of PFOA and related compounds results in a very rough estimate of PFAOS in Washington State products (Table 5). The use of PFOS included inks, varnishes, waxes, fire-fighting foams, metal plating and cleaning, coating formulations, lubricants, water and oil repellents for leather, paper and textiles (Paul et al., 2009).

For example: Global use of POSF in carpet from 1970-2002 was 48,000 metric tons, the Washington state proportion of that total is 294 metric tons (324 tons). The annual use of POSF in carpet in Washington could be 10 ton/year (over the 32 year period from 1970-2002). The 10.1 tons of POSF per year in carpet used in Washington could emit 4.5 tons of POSF and PFOS each year (using the consumer use/disposal emission rates in Table 1 of Paul 2009).

Table 5 – Estimated Historic Washington State PFAOS Uses and Releases (1970-2002)

Product	PFAOS in WA Products	PFAOS Emissions
Carpet	10.1 ton/yr	4.5 ton/yr
Paper and packaging	5.1 ton/yr	0.1 ton/yr
Apparel	2.6 ton/yr	2.7 ton/yr

Commented [A25]: What is the difference between this section and the previous section, “PFAS Use”? Consider a new heading. Additionally, this is generally information on PFOS, not all PFAS.

Commented [A26]: Do you have some justification for this methodology?

Commented [A27]: This table is somewhat misleading. It assumes that PFAS used in products is available for emissions and not, for example, bound to the substrate. In carpets for example, the fact that carpets are treated with PFAS chemicals and then disposed of in a landfill does not mean those PFAS chemicals will be emitted. True they are a potential latent source but it is not a given they will be released into the environment.

Commented [A28]: A) There might be an error in row “Apparel” as emissions are higher than use. B) The term “Performance Chemical” and “Surfactants” are not defined. C) is it possible to estimate imports of treated goods/or substances into WA and how much of these imports might be based on long-chain PFAS? D) “Emissions” should be better defined and list the compartment emitted to (landfill, incinerator, water, air, soil)

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Performance chemicals	1.3 ton/yr	0.0 ton/yr
AFFF	2.1 ton/yr	2.0 ton/yr
Surfactants	1.0 ton/yr	0.5 ton/yr
TOTAL	22.2 ton/yr	9.8 ton/yr

Note: estimated values were converted from metric tons to U.S. tons.

Global PFAS emission estimates during consumer use and disposal are applied to the estimates of PFAS in Washington products in Table 5. It has been reported that 85% of PFAS emissions are a result of consumer use of a PFAS treated product. Emissions during use of consumer products include losses from stain repellent treated carpet, waterproof apparel, and AFFF. This would occur differently over the lifetime of the product use and differ between product types (like carpet versus treated paper). (Paul 2009)

Table 5 focuses on historic consumption of PFAS-containing products in Washington State. Due to the reduction in PFOS and PFOA production, more recent estimates are needed to reflect current PFAS consumption. A recent estimate from Denmark indicates a total quantity of PFAS products to be in the range from 14 to 34 metric tons per year. The major products in this estimate were textiles/apparel (taking up 50% of global production), carpets, packaging and other articles.

Washington State is larger than Denmark in area, population and gross domestic production. Using the ratio of gross domestic production between Washington and Denmark, a current estimate of PFAS product consumption would be 16 to 38 tons per year (converted from metric tons).

Fire-fighting foams - Class-B (flammable liquid) fire-fighting foams include AFFF, Fluoroprotein (FP), and film forming fluoroprotein foam (FFFP). PFAS-based class B fire-fighting foams have been used since the 1970s for vapor suppression, firefighting and fire-fighting training at airports, refineries, bulk storage terminals and other facilities handling large volumes of flammable liquid hydrocarbon. PFAS are used in fire foam products because of their ability to produce a foam that will wet the surface of liquid hydrocarbon, resulting in a much faster foam spreading rate than is possible using only hydrocarbon-based surfactants. AFFF is released directly into the environment when used – for training or fire suppression. Fire-fighting foam containing >0.001 PFOS (by weight) have been banned for use in the EU since 2011, disposal is required by high-temperature incineration. Several studies have identified fire training as a high potential source for PFAS contamination in groundwater. (DEPA 2014, Concawe 2016)

Potential sources of PFAS contamination related to AFFF use are distributed across Washington State based on the location of airports, military sites, fire training centers and locations where foam has been used to extinguish petroleum fires. AFFF storage and use may also occur at petroleum refineries, petroleum transportation areas, and specific manufacturing installations where fire suppression is installed in a facility.

Commented [A29]: Was it an estimate of PFAS or PFOS?

Commented [A30]: In Denmark? During what time period?

Commented [A31]: Citation?

Commented [A32]: Please include wording that the use of stockpiled PFOS-based firefighting foam is still permitted in the USA (see above comment Page 5). The listed fire training centers might no longer be using fluorine containing training foam (as suggest by the best practice guidance published by the Fire Fighting Foam Coalition; https://docs.wixstatic.com/ugd/331cad_188bf72c523c46adac082278ac019a7b.pdf)

Commented [A33]: And AR-AFFF Alcohol Resistant AFFF

Commented [A34]: AFFF was actually invented in the 1960s for military applications especially the Navy.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Fire departments and fire training - According to the Washington State Fire Marshalls office there is no comprehensive list of all of the fire-training facilities in the state. Several fire training sites are listed below.

- Big Bend Community College Air Rescue Fire Fighting Training, Moses Lake
- North Bend Fire Training Academy, North Bend
- City of Seattle Joint Training Facility, Seattle
- Spokane Fire Department – Training, Spokane
- Tacoma Fire Department Training Division, Tacoma
- Yakima Training Center Fire Department, Yakima
- Kent Fire Department – Fire Training Center

Airports - Other areas where fire activities (training or fire suppression) may occur include airports. The 11 airports certified by the FAA to handle aircraft rescue and firefighting are listed below (FAA 2017). In addition to those listed below, there are 150 general aviation, reliever, and private airports and airstrips around the state (WSDOT 2017).

- Bellingham International, Bellingham
- Snohomish County (Paine Field), Everett
- Grant County International, Moses Lake
- Tri-Cities, Pasco
- Pullman/Moscow Regional, Pullman
- Boeing Field/King County International, Seattle
- Seattle-Tacoma International, Seattle
- Spokane International, Spokane
- Walla Walla Regional, Walla Walla
- Pangborn Memorial, Wenatchee
- Yakima Air Terminal (McAllister Field), Yakima

The Department of Defense inventoried fire and crash training sites where the military is assessing the risk of groundwater contamination from firefighting foam (DOD 2014). This inventory identified 5 sites in Washington State where PFAS use or releases may have occurred. Those sites are listed below. There are other active and inactive military installations located around Washington State.

- Four Lakes Communications Air Guard Station (closed), Cheney – 1 research site
- Fairchild Air Force Base, Spokane – 2 training areas
- Joint Base Lewis-McChord, Tacoma - 6 training areas and 2 spill locations
- Naval Air Station Whidbey Island, Whidbey Island – 4 sites
- Yakima Training Center, Yakima – 1 fire training area

Petroleum transport, storage, and refining occurs around Washington State. Several petroleum and biodiesel facilities are located in Washington. Petroleum refineries are located

Commented [A35]: Which PFAS?

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

along Puget Sound: British Petroleum Phillips, Tesoro, Shell, and US Oil. These petroleum refineries process, on average, about 24.3 million gallons daily. The crude oil and refined product is transported by tanker, barge, railcar and pipeline. In 2013, 8.5 billion gallons of oil were imported into Washington State by vessel, pipeline and rail, nearly 70 percent by vessel. The volume of petroleum product stored, processed and transported is projected to increase. (Ecology 2015). A conceptual model of the movement of oil into and out of Washington State is shown in Figure 2. The conceptual model includes current and potential future transport should the full build-out and expansion of proposed facilities in Puget Sound, Grays Harbor, and the Lower Columbia River occur.



Figure 1 - Oil Movement Conceptual Model (Ecology 2015)

Public safety risks exist due to the potential for fires and explosions related to spills from railcar, tanker, pipeline, or refinery. Sixteen crude-by-rail accidents occurred in the US and Canada between 2013 and 2015, nine involved fire (Ecology 2015). On June 3, 2016, sixteen oil containing railcars derailed from a 96-car train, several caught on fire near Mosier Oregon. Approximately 47,000 gallons of oil were spilled or consumed in the fire. Fire-fighting foam AR-AFFF was used to extinguish the fire and water was used to cool tank cars (OOEM 2016).

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.



Figure 2 - Oil train derailment, June 3, 2016, near Mosier, Oregon (OOEM 2016).

Ecology uses grant funding to stage oil spill response equipment caches around the state and provide spill training local responders how to safely and effectively deploy the equipment. The equipment has been used a number of times since the equipment was deployed, and has effectively limited the spreading and environmental damage of spills and has reduced the time and costs associated with oils spill cleanup.



Figure 1 Oil spill response caches

Biosolids - Washington regulations (Chapter 173-308 WAC-Biosolids Management) differentiate between wastewater solids that meet the regulatory standards, classified as “biosolids”, and those solids not meeting the standards which are defined as “sewage sludge.” Washington law requires that biosolids be land applied to the greatest extent possible and sewage sludge be disposed in a landfill. Biosolids are land applied for their nutrient and soil amending properties. Land application of biosolids is conducted almost exclusively in conjunction with commercial farming operations across the state.

Currently, about 85-90 percent of biosolids generated in Washington are land applied. Biosolids are applied to less than 1 percent of the state’s farmland on an annual basis. Most fields in Washington do not have biosolids applied annually. On wheat/fallow rotations applications are made every other year at most and commonly every 4th year.

The chemistry of biosolids is often reflective of the chemistry of our daily lives (Hundal 2011). PFAS substances are not specifically regulated by the federal or state rules that apply to wastewater treatment residuals. The concentration of PFOS/PFOA in biosolids has been reported from a variety of sources outside of Washington State with PFOS often being the most abundant (Loganathan 2007, Sepulvado 2011, Venkatesan 2013, Zareitalabad 2013, Ulrich 2016, Arvaniti 2015).

Industrial sources of PFAS can influence concentrations of these compounds in biosolids when a wastewater treatment plant receives influent directly from industries that work with

Commented [A36]: This is not a use. Move to a more appropriate chapter.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

fluorotelomer compounds. Washington State does not have commercial PFAS production facilities. Industrial discharges are separated from domestic wastewater treated at the 300 + wastewater treatment plants in the state that produce biosolids for land application.

Archived samples of biosolids from the EPA National Sewage Sludge Survey in 2001 were combined into 5 composite samples and analysis showed concentrations of PFOS at 403 +/- 127 µg/kg, and PFOA at 34 +/- 22 µg/kg (Venkatesan 2013). These data represented 94 waste water treatment plants in 32 states, but did not include Washington State. No known concentration data for PFOS/PFOA in Washington biosolids is currently available. PFOS/PFOA analysis of water effluent from four waste water treatment plants in Washington did not include an analysis of biosolids for these compounds (Ecology 2010) (refer to the **Environment** chapter for more information).

Metal plating industry uses PFOS (an allowed use under REACH – see **Regulations** Chapter) as a mist suppressant, specifically in hard chrome plating. Emissions of PFOS in this industry occurs mainly in the wastewater and chromium sludge. Emissions to air are considered to be low. PFOS in wastewater depends on the installation and process. Levels range from 0.3 to 1 part per million. PFOS in chromium sludge analyses found 3.1 to 3.8 parts per million. Wastewater treatment technologies at the metal plating plants removed 88 to 99 percent of the PFOS from the waste stream. (DEPA 2013)

Commented [A37]: The use of PFOS in the USA was phased-out as of September 21, 2015 (<https://www.arb.ca.gov/toxics/chrome/fumesuppressantfactsheet.pdf>)

PFAS Reporting

Several Washington regulations require businesses to track, manage and report on the import, use and disposal of chemicals, products, and waste. Reporting occurs under the Children’s Safe Products Reporting Rule (Chapter 173-334 Washington Administrative Code (WAC)) and the Dangerous Waste Rule (Chapter 173-303 WAC).

Children’s Safe Products Reporting Rule requires manufacturers to report the use of 66 chemicals in children’s products offered for sale in Washington State. PFOS is one of the chemicals required to be reported when present in children’s products. Since 2012, manufacturers have submitted a total of 45,918 reports into the Children’s Safe Products Reporting database for all of the 66 chemicals. There are five manufacturer reports of PFOS present in 35 categories of children’s products. These reports indicated the presence of PFOS in shoes, socks, clothing, art accessories, and games at concentrations ranging from less than 100 ppm (34 reports) and 100 to 500 ppm (1 report) (Ecology 2017).

Commented [A38]: Worth noting that PFOA has been added

Dangerous Waste Regulation requires businesses to properly manage, store and dispose of hazardous waste. Under Washington’s regulations halogenated organic compounds that are persistent and present in a waste above 100 ppm are considered “dangerous waste” (WAC 173-303-040). Wastes that meet these definitions must be properly managed. Fire-related wastes have been reported to Ecology under the Dangerous Waste regulation. The wastes reported are summarized in Table 6.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Table 6 – Fire related dangerous wastes reported to Ecology (pounds)

Row Labels	2010	2011	2012	2013	2014	2015	2016
AFFF	2,760	14,912	1,975	2,052	3,369	12,437	89,597
Fire debris	2,902	1,592	1,688	19,039	16,864	1,112	3,430
Suppressant	4291	13,477	5,391	57,131	209,493	6,321	
TOTAL	9,953	29,981	9,054	78,222	229,726	19,870	93,027

Commented [A39]: Is there information available about how much of that waste contained PFAS and at what exact concentration and which specific PFAS?

Table 7 details the companies that reported disposal of firefighting foam or suppressant in the TurboWaste database.

Table 7 – Firefighting foam or suppressant disposal reports from 2010 -2016

Reporting Entity	Foam or suppressant (pounds)
BNSF Railway Company Spokane	42
Boeing North Boeing Field	89,769
Burlington Environmental LLC Kent	233,802
General Dynamics Ordnance and Tactical Systems	18
Joint Base Lewis McChord	2,173
Jorgensen Forge Corp	1,835
King County Fire Dist 28	4,587
Naval Base Kitsap at Bangor	7,244
Redmond Fire Department	650
Shell Oil Products US Seattle Terminal	59,052
Stabbert Yacht and Ship LLC	1,000
US ARMY HQ I Corps & Fort Lewis	17,910
US Army Yakima Training Center	58
US Navy Puget Sound Naval Shipyard	595
WA DOT Eagle Harbor Repair Facility	300
Western States Fire Protection	4,170

Commented [A40]: Is there information available about how this firefighting foam was disposed – maybe via incineration? Does the TurboWaste database specify the PFAS? Do we know what type of foam was used/disposed of?

Spills of oil or other hazardous substances are required to be reported to Ecology. Releases of other materials are reported on a voluntary basis and tracked in the Environmental Response Tracking System – this information is accessible by local jurisdictions. Since 2007, 29 reports of firefighting foam releases have been entered into the system (Table 8). Most of these reports were related to fires that occurred on or near water or the firefighting foam entered a waterway. The reported quantities are not verified.

Table 8 – Firefighting incidents reported to Ecology

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Year	Number of reported incidents	Released gallons of fuel, water, AFFF
2007	1	20
2009	3	8
2010	3	4
2011	4	504
2012	2	9,025
2013	3	652
2014	2	4
2015	1	10
2016	9	311,072
TOTAL	28	321,299

PFAS Waste Estimates

Releases of PFAS can be estimated based on use and disposal of products treated with PFAS. Two Washington waste characterization studies provide estimates of annual disposal of carpet and coatings (Ecology 2010; 2016). Calculations of PFAS content in Washington’s waste carpet and coatings is based on PFOS analysis conducted in 2010 by the European Commission and a Danish waste stream analysis (EC 2011, DEPA 2013).

Carpets are a major application area for PFAS; between 50 and 90 percent of carpet were impregnated with PFOS (DEPA 2013). Carpets used in the home and office last 10 to 12 years before disposal. PFAS treatments are lost each year through vacuuming, steam cleaning, and eventual disposal. PFAS from carpet is widely dispersed in areas where carpeting is popular, like North America. Treated carpets have been reported to have a PFOS content of 88 mg/kg (DEPA 2013). A mix of treated and non-treated carpets are reported to have a PFOS content of 75 mg/kg. Continued release of PFOS occurs in the landfill after disposal.

Carpet disposal documented in two waste characterization studies indicates that about 105,000 tons of carpet are landfilled each year (Ecology 2010 and 2016). Using the 75 parts per million concentration, an estimated 788 tons of PFOS could have been annually disposed in the landfills in Washington. Based on the 12-year lifespan for carpet and the reduction in PFOS use in 2002, PFOS-treated carpet from homes or businesses should have all been disposed by 2014.

Coatings is the third largest category of PFAS treated consumer products, which includes upholstery, apparel and paper packaging.

Until 2002, leather and upholstered furniture would have been treated with PFOS. Furniture has an average lifespan of 10 years before disposal. PFOS-treated leather furniture was reported to contain 80 parts per million of PFOS (DEPA 2013). For all upholstered furniture a PFOS concentration was estimated at 2.4 parts per million. The two waste sort studies indicate an average annual disposal of 78,731 tons of furniture. Using the 2.4 part per million

Commented [A41]: PFOS and PFAS seemed to be used interchangeably here. Please use the specific chemical(s).

Commented [A42]: When? This industry has transitioned out of PFOS/long-chains in the U.S. years ago.

Commented [A43]: In Washington?

Commented [A44]: One should be careful about this assumption given some homes keep carpets longer than 10-12 years.

Commented [A45]: This should really be categorized as Textiles and Paper rather than as Coatings. Coatings is most often used for Paints and other related formulation applications.

Commented [A46]: As before 10 years may not be a suitable assumption for lifetime for treated Upholstery.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

concentration, an estimated 189 tons of PFOS could have been annually disposed in Washington landfills. Based on the 10-year lifespan for furniture, PFOS treated furnishings from homes or businesses should have all been disposed by 2012.

Textile disposal from the two waste sort studies indicate an average annual disposal of 303,697 tons of textiles. PFAS concentrations in textiles have been reported at levels of 10,683 µg/m² fluorotelomer alcohol (FTOH) to 400 µg/m² PFCA to 100 µg/m² PFOS related compounds (DEPA 2013). An estimate of PFOS disposal from textiles is not possible with this information. Textiles average a 3 to 5 year lifespan, PFOS treated textiles from homes or businesses should have all been disposed by 2007.

Paper, cardboard and packaging has a very short lifespan from use to disposal. Treated food packaging is generally limited to a one-time use. Recent studies of food contact materials identified over 115 PFAS substances from EU, USA and China in the industrial blends. Food contact material testing indicated PFAS present in the food at concentrations ranging from parts per billion to parts per million (for popcorn at 0.2 – 0.7 parts per million or mg/kg). (DEPA 2013) The data from the waste sort reports are not sufficiently detailed to identify the annual volume of treated paper and packaging disposed in Washington landfills.

PFAS in Consumer Products

Summary results from five consumer product testing studies are provided in Table 9. These studies were published between 2009-2017. The studies investigated products known to be manufactured or treated with PFAS. In general, the studies found PFAS compounds in the products tested. Each study investigated a different suite of PFAS compounds. Table 9 identifies some of the high levels of PFAS reported in each category of tested products.

Table 9 – Consumer Products Study Summary

Product Category	Highest Concentration	PFAS	Study
Firefighting foam			
AFFF	776,600 µg/L	FTS	Herzke 2012
Older AFFF	568,000 µg/L	PFOS	Herzke 2012
Older AFFF	901,300 µg/L	PFHpS	Herzke 2012
Older AFFF	370,000 µg/L	PFHxS	Herzke 2012
Older AFFF	253,700 µg/L	PFBS	Herzke 2012
Textiles			
Apparel	772 µg/kg	PFCA	EPA 2009
Apparel membrane	343 µg/kg	PFCA	EPA 2009
Apparel membrane	1,509 µg/kg	FTOH	Liu 2015
Awning cloth	10.9 µg/m ²	PFOA	Kotthoff 2015
Outdoor textiles	41 µg/m ²	PFOA	Kotthoff 2015
Outdoor textiles	35.4 µg/m ²	PFOS	Kotthoff 2015
Gloves	76.1 µg/kg	PFPA	Kotthoff 2015

Commented [A47]: A) Firefighting foam may not be a consumer product since the foam concentrates are not available at retail and consumer would have no application equipment to generate the foam. B) Does this table include the results from Washington State's own consumer article study? C) The column "PFAS" is not always specific and not all terms have been defined. For example, the term "PFCA" and "FTOH".

Commented [A48]: Please add Washburn, S.T., *et al.* "Exposure Assessment and Risk Characterization for Perfluorooctanoate in Selected Consumer Articles." *Environmental Science & Technology*, 39(11), 3904-3910, 2005.

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Product Category	Highest Concentration	PFAS	Study
Textile	42,900 µg/kg	FTOH	Liu 2015
Shoe leather	21.1 µg/m ²	PFOS	Herzke 2012
Leather	241.8 µg/m ²	PFBA	Kotthoff 2015
Mattress pad	2,270 µg/kg	PFCA	EPA 2009
Medical garment	3,070 µg/kg	PFCA	EPA 2009
Medical garment	1,460 µg/kg	FTOH	Liu 2015
Office furniture leather	38 µg/m ²	PFOS	Herzke 2012
Cleaners			
Car wheel cleaner	573 µg/kg	PFCA	EPA 2009
Cleaners	547,100 µg/kg	8:2 FTOH	Kotthoff 2015
Cleaners	81,900 µg/kg	6:2 FTOH	Kotthoff 2015
Cleaners	38,700 µg/kg	10:2 FTOH	Kotthoff 2015
Carpet Products			
Carpet	1.04 µg/m ²	PFOS	Herzke 2012
Carpet	4,010 µg/kg	FTOH	Liu 2015
Carpet	26.8 µg/m ²	PFBS	Kotthoff 2015
Carpet-care liquid	105,000 µg/kg	6:2 FTOH	Liu 2015
Commercial carpet care product	47,200 µg/kg	PFCA	EPA 2009
Pretreated carpet	1,830 µg/kg	PFCA	EPA 2009
Household carpet care	8,430 µg/kg	PFCA	EPA 2009
Personal Care Products			
Compounding agent	35,000 µg/kg	PFCA	Fujii 2013
Dental floss	96.7 µg/kg	PFCA	EPA 2009
Sunscreen	19,000 µg/kg	PFCA	Fujii 2013
Talc	2,500 µg/kg	PFCA	Fujii 2013
Foundation cosmetic	5,900 µg/kg	PFCA	Fujii 2013
Food contact paper			
Food contact paper	12,200 µg/kg	PFCA	EPA 2009
Food contact paper	4,640 µg/kg	PFOA	EPA 2009
Food contact paper	25,200 µg/kg	FTOH	Liu 2015
Food contact paper (2010)	658.1 µg/kg	PFOA	Kotthoff 2015
Food contact paper (2010)	489.4 µg/kg	PFDA	Kotthoff 2015
Food contact paper (2010)	182.8 µg/kg	PFHxA	Kotthoff 2015
Sealants			
Nanospray/impregnation	28.9 µg/kg	PFOA	Kotthoff 2015
Nanospray/impregnation	719,300 µg/kg	8:2 FTOH	Kotthoff 2015
Nanospray/impregnation	440,000 µg/kg	6:2 FTOH	Kotthoff 2015
Nanospray/impregnation	369,000 µg/kg	10:2 FTOH	Kotthoff 2015
Nanospray/impregnation	329,000 µg/kg	4:2 FTOH	Kotthoff 2015
Waterproofing agent	330,800 µg/L	FTOH	Herzke 2012
Waterproofing agent	208 µg/L	PFOA	Herzke 2012
Floor wax/stone sealant	423,000 µg/kg	FTOH	Liu 2015

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Product Category	Highest Concentration	PFAS	Study
Stone sealant	12,300 µg/kg	PFCA	EPA 2009
Stone sealant	3,720 µg/kg	PFOA	EPA 2009
Seal tape	3,540 µg/kg	PFCA	EPA 2009
Seal tape	3,490 µg/kg	PFOA	EPA 2009
Thread sealant tape/paste	1,220 µg/kg	FTOH	Liu 2015
Other/Miscellaneous			
Paint	5.8 µg/kg	PFOS	Herzke 2012
Printed circuit boards	0.40 µg/kg	PFOS	Herzke 2012
Nonstick cookware	1.09 µg/m ²	PFCA	EPA 2009
Nonstick cookware	415 µg/kg	PFOS	Herzke 2012
Ski wax	2,033 µg/kg	PFOA	Kotthoff 2015
Ski wax	1,840 µg/kg	PFHxA	Kotthoff 2015
Ski wax	1,737 µg/kg	PFDODA	Kotthoff 2015

EPA 2009 - In 2009, the EPA tested 116 articles of commerce for perfluoropentanoic acid (PFPeA), perfluorohexanoic acid (PFHxA), perfluoroheptanoic acid (PFHpA), PFOA, PFNA, perfluorodecanoic acid (PFDA), perfluoroundecanoic acid (PFUnDA), and perfluorododecanoic acid (PFDODA). The study investigated products that may contribute to indoor source of PFCA in house dust. The products were purchased from retail outlets, in stores and online, in the US from 2007 to 2008. (EPA 2009)

Herzke 2012 - A study of 30 consumer products from Norway and Sweden were analyzed for 24 PFAS compounds including: PFCA, perfluorooctane sulfonic acid (PFSA), 6:2 fluorotelomer sulfonate (6:2 FTS), Perfluorooctanesulfonamide (PFOSA) and FTOH (Herzke et al., 2012).

Fujii 2013 – Twenty-eight personal care products and compounding agents collected between 2007 and 2012 primarily from Japan and a few from France, Korea, and the United States were analyzed for PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnDA, PFDODA, perfluorotridecanoic acid (PFTrDA), and perfluorotetradecanoic acid (PFTeDA) (Fujii et al, 2013).

Liu 2015 – Between 2011 and 2013, the EPA analyzed 54 consumer products for 6:2 FTOH, 8:2 FTOH, and 10:2 FTOH, which are the precursors to PFCA (Liu et al., 2015).

Kotthoff 2015 - A total of 82 samples were analyzed for PFAA compounds and 59 samples were analyzed for FTOH (Kotthoff et al, 2015). The PFAA compounds consisted of 11 PFCA and 5 PFSA.

Schaider 2017 – A sixth study of 407 food packaging items from fast food restaurants across the United States were screened for fluorinated chemicals using particle-induced gamma ray emission spectroscopy (Schaider et al. 2017). Particle-induced gamma ray emission screens for total fluorine in the sample and does not differentiate between organic and inorganic fluorine. Samples were collected from 2014 to 2015 and from 6 product categories: food contact paper

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

like wrappers and bags (248), food contact paperboards (80), paper cups (30), other beverage containers (25), non-contact paper like the outer bags (15), and miscellaneous samples like lids and food containers (9). These screening results are not included in Table 9.

DRAFT

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

REFERENCES

- Venkatesan, A and R Halden. 2013. National inventory of perfluoroalkyl substances in archived U.S. biosolids from the 2001 EPA National Sewage Sludge Survey, *Journal of Hazardous Materials*. May 2013, 413-418;
- Agency for Toxic Substances and Disease Registry (ATSDR) 2015. Toxicological Profile for Perfluoroalkyls. Production, Import, Use, and Disposal. August 2015. Available from <https://www.atsdr.cdc.gov/toxprofiles/TP.asp?id=1117&tid=237#bookmark09>
- Buck, R.C., Franklin J, Berger U, Conder JM, Cousins IT, de Voogt P, Jensen AA, Kannan K, Mabury SA, van Leeuwen SP. *Perfluoroalkyl and polyfluoroalkyl substances in the environment: terminology, classification, and origins*. *Integrated Environmental Assessment and Management*, 2011. 7(4): p. 513-41.
- Concawe. Environmental fate and effects of poly and perfluoroalkyl substances (PFAS). Report 8/16. Prepared by ARCADIS for the Concawe Soil and Groundwater Taskforce. June 2016. Available at <https://www.concawe.eu/publication/environmental-fate-and-effects-of-poly-and-perfluoroalkyl-substances-pfas-report-no-816/>
- Danish Environmental Protection Agency (DEPA). 2013. Survey of PFOS, PFOA and other perfluoroalkyl and polyfluoroalkyl substances. Part of the LOUS-review. Environmental Project No. 1475, 2013. The Danish Environmental Protection Agency
- Department of Defense (DOD). 2014. DoD inventory of Fire/Crash Training Area Sites as of the end of FY 2014. Available at <https://www.documentcloud.org/documents/2755131-List-of-military-fire-and-crash-training-sites.html>
- Employment Security Department (ESD) Washington State. 2017. Establishment size data for 2016 Quarter 1. Accessed at: <https://esd.wa.gov/labormarketinfo/establishment-size>
- Ecology 2015. Washington State 2014 Marine and Rail Oil Transportation Study. Pub 15-08-010. March 1, 2015. Available from <https://fortress.wa.gov/ecy/publications/documents/1508010.pdf>
- Ecology 2017. Children's Safe Products Reporting Database. Accessed 8/1/2017: searched for PFOS reports. <https://fortress.wa.gov/ecy/cspareporting/Default.aspx>
- Ecology, 2010. Perfluorinated Compounds in Washington Rivers and Lakes, Ecology Publication 10-03-034, August 2010;
- Ecology. 2010. 2009 Washington Statewide Waste Characterization Study. June 25, 2010. Pub 10-07-023

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Ecology. 2016. 2015-2016 Washington Statewide Waste Characterization Study. October 31, 2016. Pub 16-07-032

US Environmental Protection Agency (EPA) 2002a. Federal Register, 40 CFR Part 721 - Perfluoroalkyl Sulfonates; Significant New Use Rule; Final Rule and Supplemental Proposed Rule. March 11, 2002. <https://www.gpo.gov/fdsys/pkg/FR-2002-03-11/pdf/02-5746.pdf>

EPA 2002b, Federal Register, 40 CFR Part 721 - Perfluoroalkyl Sulfonates; Significant New Use Rule, Final Rule. December 9, 2002 <https://www.gpo.gov/fdsys/pkg/FR-2002-12-09/pdf/02-31011.pdf>

EPA 2007, Federal Register, 40 CFR Part 721 - Perfluoroalkyl Sulfonates; Significant New Use Rule, Final Rule. October 9, 2007. <https://www.gpo.gov/fdsys/pkg/FR-2007-10-09/pdf/E7-19828.pdf>

EPA. 2009. *Perfluorocarboxylic acid content in 116 articles of commerce*. Washington, DC, EPA/600/R09/033, 2009.

EPA. 2014. Assessing and managing chemicals under TSCA. Fact Sheet: 2010/2015 PFOA Stewardship Program. 2014 Annual Progress. Available at: <https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/20102015-pfoa-stewardship-program-2014-annual-progress>

EPA 2015a. Federal Register, 40 CFR Part 721 - Long-Chain Perfluoroalkyl Carboxylate and Perfluoroalkyl Sulfonate Chemical Substances; Significant New Use Rule, January 21, 2015. <https://www.federalregister.gov/documents/2015/01/21/2015-00636/long-chain-perfluoroalkyl-carboxylate-and-perfluoroalkyl-sulfonate-chemical-substances-significant>

EPA 2015b. Perfluorooctanoic acid (PFOA) and fluorinated telomers: Frequent questions. 2015 [cited 2015 March 9]; Available from: <http://www.epa.gov/oppt/pfoa/pubs/faq.html>.

EPA 2016a. Assessing and managing chemicals under TSCA. Fact Sheet: 2010/2015 PFOA Stewardship Program. Accessed July 28. <https://www.epa.gov/assessing-and-managingchemicals-under-tsca/fact-sheet-20102015-pfoa-stewardship-program>

EPA 2016b. Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA). 2016, Environmental Protection Agency: Washington, D.C. p. 103. EPA 822-R-16-005. May.

EPA 2016c. Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS). Office of Water. EPA 822-R-16-004. May.

EPA 2017. 2016 Chemical Data Reporting Results. Accessed July 28, 2017. <https://www.epa.gov/chemical-data-reporting>

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

European Commission (EC). 2010. Regulation (EU) No 757/2010 of 24 August 2010, amending Regulation (EC) No 850/2004 of the European Parliament and of the Council on persistent organic pollutants as regards Annexes I and III. Official Journal of the European Union:25.08.2010

European Commission (EC) 2011. Expert Team to Support Waste Implementation. Final Report Study on waste related issues of newly listed POPs and candidate POPs. No ENV.G.4/FRA/2007/0066. Located at http://ec.europa.eu/environment/waste/studies/pdf/POP_Waste_2010.pdf

Federal Aviation Administration (FAA). 2017. Aircraft Rescue and Fire Fighting Airports. Available at https://www.faa.gov/airports/airport_safety/aircraft_rescue_fire_fighting/

FluoroCouncil, 2017a. *PFAS in Carpet and Furniture Applications DTSC Workshop*. 2017: Sacramento, California.

Fujii, Y; Harada, K; and Koizumi, A, 2013. *Occurrence of perfluorinated carboxylic acids (PFCA) in personal care products and compounding agents*. Chemosphere 93: 538-544.

Grand View Research. 2016. Fluorochemicals Market Analysis by Product (Fluorocarbons, Fluoropolymers, Inorganics & Specialties) By Application (Refrigeration, Aluminum Production, Blowing Agents, Components) And Segment Forecasts To 2024. January 2016. Report summary accessed at <http://www.grandviewresearch.com/industry-analysis/fluorochemical-market>

Herzke, D; Olsson, E; and Posner, S, 2012. Perfluoroalkyl and polyfluoroalkyl substances (PFAS) in consumer products in Norway – A pilot study. Chemosphere 88: 980-987.

Hundal, LS, K. Kuman, N. Basta and AE Cox. 2011 Evaluating Exposure Risk to Trace Organic Chemicals in Biosolids, BioCycle, August, 2011;

Kotthoff, M; Müller, J; Jüriling, H; Schlummer, M; and Fiedler, D. 2015. Perfluoroalkyl and polyfluoroalkyl substances in consumer products. Environmental Science and Pollution Reserach. 22: 14,546-14,559.

Lindstrom, A.B., M.J. Strynar, and E.L. Libelo, *Polyfluorinated compounds: Past, present, and future*. Environmental Science Technology, 2011. **45**(19): p. 7954-7961.

Liu, X; Guo, Z; Folk IV, E; and Roache, N, 2015. Determination of fluorotelomer alcohols in selected consumer products and preliminary investigation of their fate in the indoor environment. Chemosphere 129: 81-86.

Loganathan B, K. S. Sajwan, E. Sinclair, K. S. Kumar, K. Kannan. 2007. Perfluoroalkyl sulfonates and perfluorocarboxylates in two wastewater treatment facilities in Kentucky and Georgia, Water Research, Vol. 41, Issue 20, December 2007;

September 2017 DRAFT PFAS CAP – Uses Chapter for external review (10/06/17).
Do not cite or quote.

Minnesota Department of Health (MDH), 2012. *Public health assessment final release perfluorochemical contamination in Southern Washington County, Northern Dakota County, and Southeastern Ramsey County, Minnesota*. 2012.

Arvaniti, O and A. Stasinakis. 2015. Review of the occurrence, fate and removal of perfluorinated compounds during wastewater treatment, *Science of the Total Environment*, 2015, 81-92;

Organisation for Economic Co-operation and Development (OECD). 2011. PFCs: Outcome of the 2009 survey. Survey on the production, use and release of PFOS, PFAS, PFOA PFCA, their related substances and products/mixtures containing these sub-stances. OECD Environment, Health and Safety Publications, Series on Risk Management, No. 24.

Oregon Office of Emergency Management (OOEM). 2016. 2016 Mosier Rail Incident State Agency Response After-Action Report. November 10, 2016
http://www.oregon.gov/oem/Documents/MosierRail_StateAgency_AAR.pdf

Paul, A.G., Jones, K.C. and Sweetman A.J. 2009. A first global production, emission, and environmental inventory for perfluorooctane sulfonate. *Environmental Science and Technology*. Jan 15;43(2):386-92.

Schaider, L; Balan, S; Blum, A; Andrews, D; Strynar, M; Dickinson, M; Lunderberg, D; Lang, J; and Peaslee, G, 2017. [Fluorinated Compounds in U.S. Fast Food Packaging](#). *Environ. Sci. Technol. Lett.* 4: 105111.

Sepulvado, JG, AC Blaine, LS Hundal, and CP Higgins. 2011. Occurrence and Fate of Perfluorochemicals in Soil Following the Land Application of Municipal biosolids, *Environmental Science & Technology* 2011, Vol. 45, 8106-8112;

Ulrich, H, KP Freier, and M Gierig. 2016. Getting on with persistent pollutants: Decreasing trends of perfluoroalkyl acids (PFAAs) in sewage sludge, *Chemosphere* 161, 2016, 527-535;

Washington State Department of Transportation (WSDOT). 2017. All Washington State Airports – online map. Available <http://www.wsdot.wa.gov/aviation/AllStateAirports/>

Zareitalabad, P, J Siemens, M Hamer, and W Amelung. 2013. Perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) in surface waters, sediments, soils, and wastewater—A review on concentrations and coefficients, *Chemosphere* 91, 2013, 725-732;