Per- and Poly-Fluorinated Alkyl Substances Chemical Action Plan (PFAS CAP) – 2019 Updates

Updated Sources and Uses Chapter

In 2017, the Washington State departments of Ecology and Health shared draft PFAS CAP chapters with external parties for review and comment. Comments received are available online. This document is either an update of a 2017 draft or a new 'chapter.' Ecology and Health are sharing chapters with interested parties prior to the April 2019 PFAS CAP webinar (*previously planned for March*). Updates will be discussed during the April webinar. We expect to publish the entire Draft PFAS CAP around June 2019 followed by a 60-day comment period.

In April 2019, Ecology and Health will host a PFAS CAP webinar (*date not yet set*) to:

- Briefly review activities underway: firefighting foam, food packaging, drinking water.
- Review updated/new chapters – comments will be accepted on the updated chapters. Responses will be provided after the 2019 public comment period (summer 2019).
- Discuss preliminary recommendations – requesting comments and suggestions from interested parties – due a week after the webinar.
- Submit comments online.

Quick summary of PFAS CAP efforts:

- PFAS CAP Advisory Committee and interested parties met in 2016, 2017 and 2018.
- September 2017 Draft PFAS CAP chapters posted:

Intro/Scope	Environment
Biosolids	Health
Chemistry	Regulations
Ecological Toxicology	Uses/Sources

- March of 2018, Ecology and Health published the Interim PFAS CAP.
- The 2019 updated PFAS CAP "chapters" to be posted (in the order we expect to post on the PFAS CAP website):

Biosolids	*Analytical methods (new)*
Ecological Toxicology	Chemistry
Environment	*Fate and Transport (new)*
Regulations	*Economic analysis (new)*
Uses/Sources	*Preliminary Recommendations (new)*
Health	

Questions - contact Kara Steward at kara.steward@ecy.wa.gov.

This document is posted on the PFAS CAP Website - https://www.ezview.wa.gov/?alias=1962&pageid=37105

Sources and Uses

Summary

Sources and uses of per- and polyfluoroalkyl substances (PFAS) in Washington are discussed in the following categories. Estimating or quantifying PFAS releases to the environment and exposure to residents was not possible.

Primary manufacturing of PFAS, releases occur from wastewater discharges, waste disposal and air emission. There are no known primary PFAS manufacturing operations in Washington State. The DuPont facility that operated in Washington from 1906 to 1975 manufactured explosives (DuPont Museum 2018).

Secondary manufacturing, where PFAS are used as part of the manufacturing or industrial process, manufacturing emissions or waste management could result in PFAS releases. These operations can include aerospace, automotive, aviation, building and construction, cable and wiring, electronics, energy, and food processing. An estimated 1,200 Washington businesses could use PFAS or a PFAS-containing product in their operations. Investigation, research and outreach to these businesses is recommended to identify PFAS use, evaluate release potential and availability of safer alternatives.

Firefighting foam can release PFAS to the environment during use, storage, training, and annual testing. An estimated 1.5 million liters of aqueous film forming foam (AFFF) is maintained in Washington State by fire departments, civilian airports, military installations, petroleum storage and transport, and road tunnels. A survey of firefighting foam users is needed to confirm the volume, use and releases of PFAS-containing AFFF. This outreach would encourage best management practices, containment and proper disposal of PFAS-containing AFFF, and availability of safer alternatives.

Waste management related PFAS releases have been documented in other states, including air emissions, wastewater discharges, land application of industrial sludges, and landfill disposal. Investigation into the presence of PFAS at Washington's 600 wastewater treatment plants and 53 waste disposal facilities is recommended. In addition to identifying sources and releases, research is needed to identify treatment technologies and monitoring requirements.

Household products that are sources of PFAS include cosmetics and personal care products; treatments on textiles, upholstery, carpets and leather; coatings and floor finishes; cleaning agents; automobile and ski waxes; and nonstick cookware. Further research and data related to exposure to PFAS in the home is needed, including the availability of safer alternatives.

Occupational exposure to PFAS has been documented at retail stores where products containing PFAS are sold, and service industries that use products containing PFAS. Further research and data related to occupational exposure to PFAS is needed, including the availability of safer alternatives.

Historic releases in Washington are estimated based on global estimates published in the literature.

1.0 Introduction

PFAS describes a class of over 4,730 chemicals (OECD 2018). PFAS are synthetic, not found naturally and resist degradation in the environment. Some PFAS are highly persistent and mobile in the environment and bioaccumulative in humans. PFAS provide resistance to corrosion and high temperatures, low friction solids or lubricants, and grease-, oil-, water- and stain-resistance. Past PFAS production, use, and trade have released these chemicals to the environment, leading to soil, surface water, and groundwater contamination. Refer to other chapters for detailed discussion of PFAS.

As of October 2018, known PFAS groundwater contamination in the U.S. includes 193 sites in 40 states (SSEHRI 2018; EWG 2018). Groundwater contamination sites across the U.S. are impacted by firefighting foam use and training at military installations, civilian airports or fire stations, and a few fire events. Other activities reported to impact groundwater include manufacturing of PFAS and secondary manufacturing use of PFAS products or chemicals. Impacts to groundwater are also reported from waste disposal, landfill leachate, land application of industrial sludge, and discharges of wastewater to treatment facilities or septic systems.

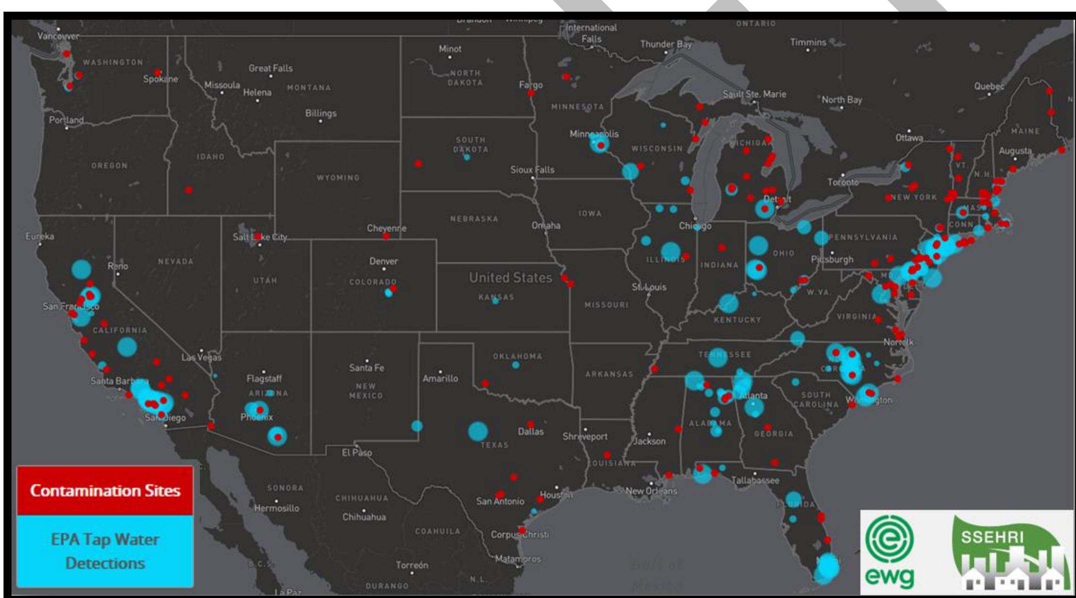

Figure 1 – Map of U.S. PFAS contamination sites (EWG 2018).

2.0 Secondary manufacturing

Release of PFAS can occur at manufacturing sites where PFAS are used as part of the manufacturing or industrial process. Use of PFAS in secondary manufacturing operations is not reported when PFAS is used, discharged, or disposed.

Fourteen contaminated sites across the U.S. indicate PFAS releases from automobile, carpet, cable or wire, metal plating, paper, plastics, and textiles manufacturing (SSEHRI 2018). PFAS releases and release mechanisms differ among the manufacturing processes. PFAS releases could result from air emissions, wastewater discharges, stormwater runoff or waste disposal. Examples of secondary manufacturing include (ITRC 2017, SSEHRI 2018):

- **Automotive**: mechanical components, surface treatments for textiles, upholstery, carpets, and leather.
- **Aviation and aerospace**: mechanical components, hydraulic fluids.
- **Electroplating and etching**: Corrosion prevention, mechanical wear reduction; aesthetic enhancement; surfactant; wetting agent/fume suppressant for chrome, copper, nickel and tin electroplating; and postplating cleaner.
- **Industrial surfactants, resins, molds, and plastics**: Manufacture of plastics and fluoropolymers, rubber, and compression mold release coatings; plumbing fluxing agents; fluoroplastic coatings, composite resins, and flame retardants for polycarbonate.
- **Medical products**: surgical products and medical fabrics.
- **Oil and mining**: surfactants, evaporation inhibitors, solvents, and fire suppression.
- **Paper products and packaging**: surface coatings to repel grease and moisture. Uses include non-food paper packaging (for example, cardboard, carbonless forms, masking papers) and food-contact materials (for example, pizza boxes, fast food wrappers, microwave popcorn bags, baking papers, pet food bags).
- **Semiconductor industry**: top anti-reflective coatings, bottom anti-reflective coatings, and etchants, with other uses including surfactants, wetting agents, and photo-acid generation.
- **Textiles and leather treatments**: factory or consumer applied coatings to repel water, oil, and stains: examples include protective clothing and outerwear, umbrellas, tents, sails, architectural materials, carpets, and upholstery.
- **Wire manufacturing**: coating and insulation.

The U.S. Census Bureau listed 577,445 businesses in Washington State in 2015 (US Census 2015). Table 1 lists the number Washington businesses in selected the NAICS codes that include potential PFAS use (Infogroup 2012). Figure 2 shows the general location of the businesses in Table 1 in each county of the state. There is no evidence that any of these operations use PFAS or have released PFAS during their operations. PFAS use is not an indication that a release could have occurred. In addition to the manufacturing businesses in Table 1 – use of PFAS-containing products like car waxes and polishes have been identified as source of groundwater contamination (NHDES 2018). There are over 700 car washes listed in Washington State, not shown on Figure 2. Additional investigation is recommended to identify PFAS use and determine if there are PFAS releases of concern. Additional research is recommended to identify safer alternatives to the use of PFAS.

Table 1 – Secondary manufacturing in Washington

NAICS code name	Count of Businesses
All other plastics product manufacturing	241
Automobile manufacturing (plating activity)	13
Aviation and Aerospace	165
Carpet rug mills	13
Corrugated solid fiber box manufacturing	28
Electroplating, plating, polishing, anodizing	60
Leather hide tanning finishing	12

NAICS code name	Count of Businesses
Medical products	249
Other fabricated wire product manufacturing	74
Oil (petroleum) and mining	128
Paper mills (except newsprint)	54
Paper bag coated treated paper manufacturing	69
Paperboard mills	10
Pulp mills	18
Semiconductors related devices manufacturing	33
Textile fabric finishing mills	46
Total of secondary manufacturing by NAICS code	**1,213**

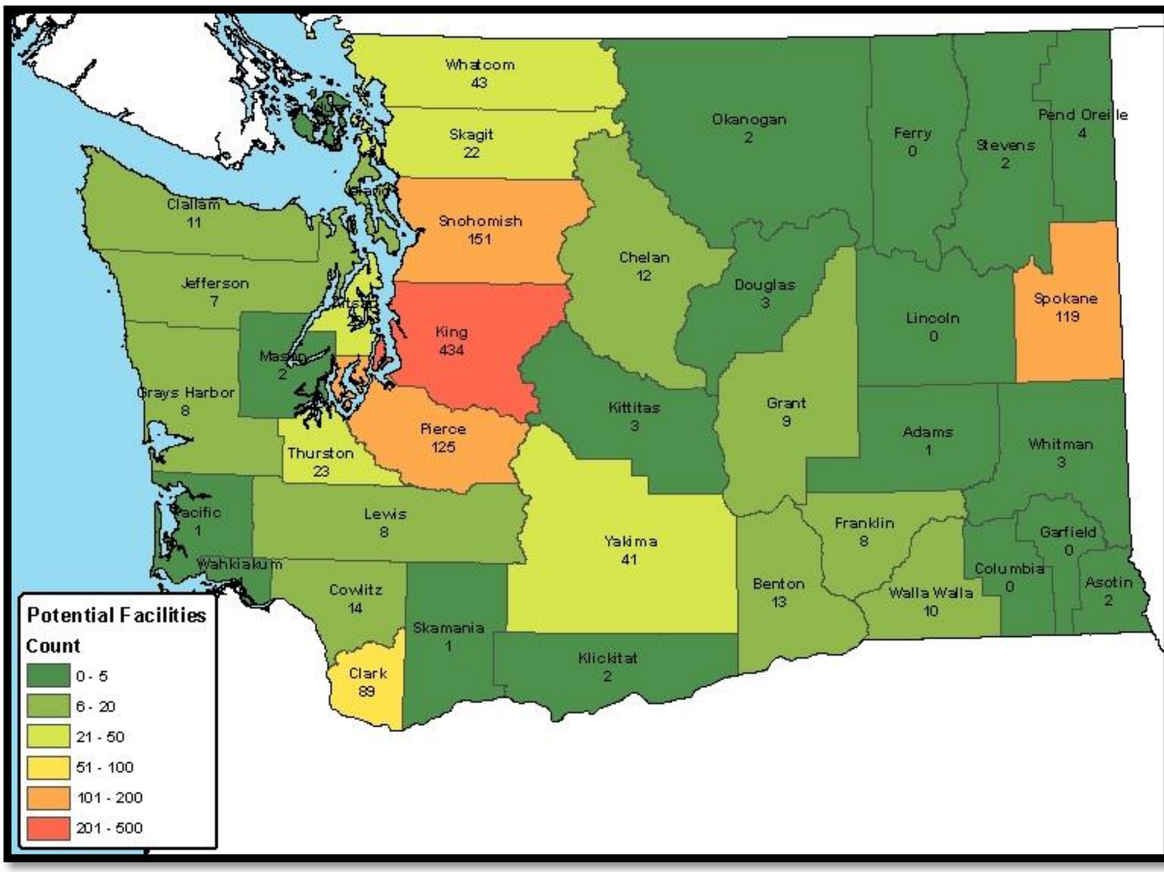

Figure 2 – Count of secondary manufacturing facilities by county based on NAICS code.

3.0 Firefighting Foam

In 2018, Washington State passed the Firefighting Agents and Equipment – Toxic Chemical Use law (Chapter 70.75A Revised Code of Washington (RCW)) that banned the use of PFAS-containing firefighting foam in training exercises by all foam users. In 2020, the sale of PFAS-containing firefighting foam is banned, except where use of fluorinated firefighting foam is required by federal law (for example at military installations), and for petroleum refineries and terminals, or chemical plants that produce or use flammable liquids.

Firefighting foam, while not a large use category, is often used in uncontrolled circumstances including training exercises with little or no barrier to direct environmental release. PFAS-containing firefighting foams have been implicated in many cases of groundwater contamination (Hu et al., 2016). Environmental releases of firefighting foam include emergency response, testing, and emergency activation of fire suppression systems in hangars, leaks from storage tanks or supply lines, and training exercises. These releases occur at airports, refineries, bulk storage terminals and other facilities handling large volumes of flammable liquid hydrocarbons (HEPA 2018).

> *For more information about the development of firefighting foam and how it works refer to ITRC 2018, Hughes 2004, and NYSPPI 2018.*

Facilities that could store aqueous film-forming foam (AFFF) for use at the facility are listed below. A survey of facilities in these categories would help determine the quantity of PFAS-containing AFFF in Washington State. There is no evidence that any of these operations use PFAS or have released PFAS during their operations.

- Electrical power generation from coal, diesel or gas.
- General chemical storage.
- Military installations, civilian airports, fire departments.
- Mineral, oil, gas extraction.
- Mining for coal or minerals.
- Petroleum production, exploration, storage, refining.
- Production of aluminum, batteries, bitumen, brewing and distilling, coal works, dangerous goods, explosives, paints, polishes, adhesives.

3.1 Fire departments and fire training

According to the Washington Fire Chiefs Association there are approximately 350 public fire agencies within the state (Senter 2019). Fire agencies are better known as fire departments, fire districts, regional fire authorities and port fire departments. In addition to these public agencies, there also exists U. S. Department of Defense (DOD) and private/industrial firefighting forces. Each fire agency has one or more fire stations to serve their community. Typically fire agencies have training facilities located at a one of their facilities for in-service training. Frequently fire agencies create regionalized training centers where resources are pooled for multi-agency out of service training. A current list of regionalized fire training centers does not exist but could be created through survey.

Use of AFFF for fire training has occurred both locally and at regional fire training sites across the state. The following lists some of the larger and frequently used regional training facilities:

- Big Bend Community College Air Rescue Firefighting Training, Moses Lake.
- City of Seattle Joint Training Facility, Seattle.
- Kitsap County Regional Training Center, Bremerton.
- Mark Noble Regional Fire Training Center, Olympia.

- North Bend Fire Training Academy, North Bend.
- Puget Sound Regional Fire Authority Fire Training Center.
- Spokane Regional Training Center, Spokane.
- Tacoma Fire Department Training Center, Tacoma.
- Yakima Fire Department Training Center, Yakima.

Other uses of AFFF include portable and wheeled fire extinguishers available for DOD, residential, commercial and industrial users. Estimates of fire extinguisher use is currently not available.

In early 2018, the Washington Fire Chief s Association polled its membership to begin to quantify impacts of the proposed legislation that would eliminate PFAS-containing AFFF from training exercises and curtail sales a year later. Feedback, while limited, indicated that most large fire agencies had moved away from using PFAS-containing AFFF. Other feedback related to the availability of reasonable alternatives and how to safely dispose of PFAS-containing AFFF. In response the Washington Fire Chief s Association held presentations on the subject at their annual conference and raised awareness through its newsletter and other various mediums. Safe disposal of PFAS-containing AFFF at no cost to the public fire agency should be considered to facilitate compliance during this transition. Use of non-fluorinated firefighting foam is recommended, more research is needed to identify safer alternatives to PFAS.

In the absence of state-wide survey information, fire agency storage of AFFF in Washington is estimated from the 2004 Hughes report. In 2004, Hughes estimated U.S. public fire departments (excluding airports) possessed 5.14 million liters of AFFF (all measurements are reported in metric units – Hughes reported 1,360,000 gallons of AFFF). This estimate included a 35 percent margin of error. Adjusting the national estimate in Hughes to Washington State (23 percent of the US by population), the fire service possesses 118,577 liters of fluorinated and non-fluorinated firefighting foam (the margin of error represents a range from 77,075 to 160,078 liters of foam). Detailed information about firefighting foam within the Washington State fire service could be collected through survey.

3.2 Civilian airports

U.S. airports have been required to procure and use AFFF that meets the standards set by the Federal Aviation Administration (FAA) which currently requires the use of AFFF that meets military specifications (required to be fluorinated). In October 2018, the US Congress passed legislation directing the FAA to allow airports to use non-fluorinated firefighting foam. The change is required to be implemented within three years using the latest version of the National Fire Protection Association 403 – Standard for aircraft rescue and firefighting services at airports. NFPA 403 includes a fluorine-free synthetic foam option.

The FAA issues operating certificates to airports that comply with certain operational and safety standards. Current regulatory requirements related to firefighting at airports are found in 14 CFR Aeronautics and Space, Part 139: Certification of Airports, specifically 139.317: Aircraft rescue and firefighting: Equipment and agents. FAA provides guidance in Advisory Circulars – the most recent on Aircraft Fire Extinguishing Agents (AC 150/5210-6D) states that foam concentrates must meet the performance test requirements of US Military Specification (MIL-SPEC) MIL-F-24385F, which includes the requirement that the foam be fluorinated (FAA 2004).

Eleven airports in Washington are certified by the FAA to handle aircraft rescue and firefighting are listed below (FAA 2018). In addition to airports listed below, there are 124 general aviation, reliever, and private airports and airstrips around the state (WSDOT 2017).

WSDOT Aviation has reached out to several larger general aviation airports that do not have a requirement for AFFF under the FAA Part 139 requirement and have found that they do not possess any firefighting foam or personal protective equipment (PPE) that contained PFAS (Wright 2019). A more detailed survey of all civilian airports would determine where PFAS-containing firefighting foam or PPE has been stored or used. Use of non-fluorinated firefighting foam is recommended, more research is needed to identify safer alternatives to PFAS.

The amount of AFFF at airports is based on the amount carried on aircraft rescue and firefighting vehicles as well as the reserve available at the airport. Aircraft rescue and firefighting indexes indicate ascending order of aircraft length: A for aircraft less than 18 meters in length and up to E for aircraft longer than in 60 meters in length. Estimated quantities of AFFF stored at civilian airports based on each aircraft rescue and firefighting index: Index A: 2,101 liters, Index B: 4,088 liters, Index C: 11,564 liters, and Index E: 25,434 liters (Hughes 2004).

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

AFFF is also used in airplane hangars – according to NFPA standard 409 "Standard on Aircraft Hangars." Aircraft hangars require overhead foam sprinkling for the entire hangar if the floor area exceeds 1,858 square meters: 11,356 liters of AFFF concentrate. Foam capacity increases for a hangar floor greater than 3716 square meters: 22,712 liters of AFFF concentrate. Hughes estimated hangar AFFF storage for airport index categories C at 43,721 liters per airport and E at 289,205 liters (Hughes 2004). These totals assumed AFFF storage in hangars were proportional to the FAA index estimates.

FAA regulations (14 CFR Part 139) establishes the minimum aircraft firefighting capability for each index. AFFF quantities stored at FAA certified airports are estimated from Hughes (2004) using the estimates for A, B, C, and E aircraft rescue and firefighting indexes and for associated storage for hangars. There are additional users that maintain supplies of AFFF, examples would include airplane manufacturers, overnight shipping aircraft hangars, and fuel storage. Hughes (2004) provided quantities of AFFF stored by Boeing at 217,472 liters and FedEx at 378,541 liters at all U.S. locations. PFAS-containing AFFF quantities stored at Washington certified airports are listed in Table 2.

Table 2 – Estimated AFFF storage at certified airports and hangars (combined totals)

Airports in each FAA Index code	AFFF storage (liters)	AFFF hangar storage (liters)
A = 6 airports	12,605	-
B = 3 airports	12,265	-
C = 1 airport	11,564	43,721
E = 1 airport	25,434	289,205
TOTAL	**61,868**	**332,926**

Many airports have instituted best management practices associated with the testing of aircraft rescue and firefighting equipment required for use of AFFF (ACRP 2017, FAA 2004, NFPA 2014). Certified airports must annually test the AFFF proportioning equipment to maintain their Part 139 Certification. These tests require spraying the foam for 30 seconds and collecting a sample of the foam to verify that the proper concentration of AFFF is dispensed. AFFF best management practices recommend collection and proper disposal of the foam and any impacted soil. Recent FAA guidance allows testing to be performed in a closed system, some airports may opt to use this system for future annual tests (FAA 2019). Fire response training can be conducted at the airport or at other fire training locations.

3.3 Military installations

As required by law, DOD installations in Washington State no longer use AFFF containing PFAS in training operations (Shirley 2018). AFFF storage and use at DOD sites includes ships, shore facilities and firefighting vehicles (Hughes 2004). There are 19 active military installations in Washington State, including 10 operated by the U.S. Coast Guard. PFAS-containing AFFF quantities stored at active Washington military installations estimated from Hughes (2004) are in Table 3.

Table 3 – Military AFFF storage (combined totals)

Military installations	Estimated AFFF concentrate stored (liters)
4 Navy	78,184
3 Army	3,585
2 Air Force	26,173
10 Coast Guard	13,438
Total	**121,380**

The Department of Defense and Department of the Navy inventoried fire and crash training sites at U.S. installations. The military is assessing the risk of groundwater contamination from firefighting foam at these locations (DOD 2014, DON 2016b). This inventory identified sites in Washington State where PFAS use or releases may have occurred:

- 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.
- Yakima Training Center, Yakima – 1 fire training area.
- Naval Base Kitsap – 5 sites.
- Naval Air Station Whidbey – 8 sites.

The Department of the Navy is implementing a comprehensive strategy to manage and address PFAS in drinking water on and off Navy installations, cleanup of perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) contaminated sites, and destruction of legacy AFFF (DON 2017). The strategy includes:

- AFFF control, removal, and disposal – (DON 2016a) the Department of the Navy intends to remove, dispose, and replace legacy AFFF that contains PFOS or PFOA – once environmentally suitable substitutes are certified to meet MIL-SPEC requirements.
- Identification of potential areas of concern from use of AFFF for fire and emergency response and test and training activities.
- Testing for PFOS and PFOA in Navy public water systems and to determine if PFAS are known or suspected to have been released within 1-mile of the water source (DON 2017).

3.4 Petroleum storage and transport

Petroleum is refined, stored, and transported from and around Washington State. Petroleum products stored at gas stations are not included in this discussion. Transport and storage of fuel from railcar, tanker, pipeline, or refinery has the potential for fire or explosion, requiring the availability and use of fire suppression. Fire suppression systems at these facilities may include PFAS-containing AFFF. Use of non-fluorinated firefighting foam is recommended, more research is needed to identify safer alternatives to PFAS.

Ecology regulates equipment and oil transfer, storage, and handling at 121 facilities to ensure protection of environmental and public health. There are three facility types, shown on Figure P. Each facility has different types of requirements, depending on their classification, but all are required to have some type of spill prevention plan. Regulated facilities are trained to prevent, prepare for, and respond to spills when they occur. Ecology does not track the firefighting foam stored at these facilities. Hughes (2004) estimated 59,052 liters of AFFF concentrate per refinery in the U.S. For the 5 refineries in Washington, that amounts to 295,262 liters of AFFF. The following brands of AFFF have been reported to be stored or used at these refineries:

- 3M Light Water 3X6 AR-AFFF
- Aer-O-Foam XL-3
- Chemgard 3 percent AR-AFFF
- FireAde 2000
- National Foam (Universal Plus 3/6 percent AR-AFFF)
- Thunderstorm 1 X 6, 3 X 6 and 1 X 3 AR-AFFF Ansul/Williams
- Thunderstorm FC601A

Oil tankers transporting petroleum product into Puget Sound are required by federal shipping regulations to maintain a supply of fire suppressant on the tanker (46 CFR). That volume of foam liquid must be sufficient to provide a minimum of 20 minutes of flow through nozzles across the cargo tank deck. Hughes (2004) estimated 3,785 liters of AFFF are maintained per oil tanker and 189 liters for other merchant ships. International shipping regulations require fire extinguishing systems adequate for the fire hazard that may exist, but fire extinguishing systems using perfluorocarbons are prohibited (International Maritime Organization 2007).

In addition to refineries, other petroleum facilities include blending facilities, tank farms, loading and fueling terminals, and other flammable liquid storage. Fire protection at these facilities include AFFF systems constructed according to NFPA standards. AFFF storage at these facility types, in Table 4, are estimates. Ecology regulates these facilities in four categories:

- **Class 1** facilities are large, fixed shore-side facilities such as refineries and refueling terminals. This definition includes facilities that transfer to or from tank vessels and pipelines.
- **Class 2** facilities are mobile facilities, such as tanker trucks and portable tanks.
- **Class 3** category of oil-handling facilities applies to small tank farms and terminals that transfer oil to non-recreational vessels that have a fuel capacity of 39,746 liters (10,500 gallons) or more. This definition does not include facilities that transfer to tank vessels and pipelines, as they are Class 1 facilities.
- **Class 4** facilities are marinas or other small fueling facilities that transfer oil to non-recreational vessels with a total oil capacity of less than 39,746 liters.

Table 4 – AFFF storage at petroleum related facilities

Description	**Count of facilities**	**AFFF/facility**	**Estimated AFFF**
Refineries	5	59,052 liters	295,262 liters
Large refueling terminal, pipeline	20	7570 liters	151,400 liters
Mobile facility	24	3785 liters	90,840 liters
Transfer >10,500 gal capacity	5	3785 liters	18,925 liters
Transfer <10,500 gal capacity	67	1892 liters	126,764 liters
TOTAL	**121**		**683,191** liters

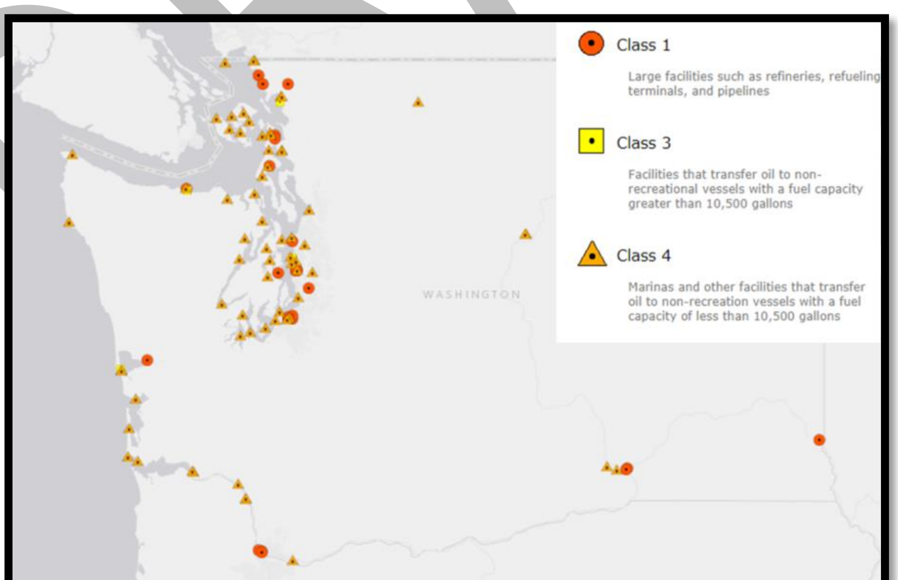

Figure 3 – Oil transfer, storage and handling facilities[1].

Oil spill response resources are tracked on the Worldwide Response Resource List (Ecology 2018). These records indicate dispersant is stored by Marine Spills Response Corporation in Everett (14,190 gallons or 53,715 liters) and at Burlington Northern Santa Fe yards in Vancouver (275 gallons or 1041 liters), Seattle (275 gallons or 1,041 liters) and Pasco (550 gallons or 2,082 liters). There is no information in the Worldwide Response Resource List to indicate the type of dispersant, containing PFAS or PFAS-free.

Ecology funds oil spill response equipment located around the state (including AFFF) and provides training to local responders on how to safely and effectively deploy the equipment. Cached equipment has been used a number of times since deployment, and has effectively limited the spreading of and environmental damage from oil spills and reduced the time and costs associated with oil spill cleanup. AFFF covered under this grant funding is limited to non-fluorinated products.

3.5 Tunnels

National Fire Protection Association standard 502 provides fire protection and fire life safety requirements for road tunnels, bridges, and other limited access highways (NFPA 2011). In Seattle, tunnels using a deluge foam fire suppression system are the I-90 Mercer Island, I-90 Mt. Baker, and the I-5 Convention Center (Cox 2019). Use of non-fluorinated firefighting foam is recommended, more research is needed to identify safer alternatives to PFAS. Other Seattle tunnels use a fixed water firefighting system: Battery Street, downtown Seattle transit for bus and train, and SR99 Replacement Tunnel.

Table 5 – Road tunnels with fixed foam firefighting systems in Seattle

Tunnel	**Route**	**Length**	**Lanes**	**Estimate of AFFF storage (liters)**
Mercer Island	I-90	914 meters	8	48,510
Mt Baker	I-90	1067 meters	8	28,334
Convention Center	I-5	167 meters	12	11,735
TOTAL				**88,579**

3.6 Summary of AFFF quantities

Table 6 summarizes the estimates firefighting foam quantities in Washington State. The 2011 updated inventory of AFFF included annual consumption estimates for several of the sectors in Table 6. In 2011, Darwin provided updated quantities of PFOS-containing AFFF and estimates of AFFF use. Use of AFFF occurs during training, fire suppression, system testing, inadvertent discharge or leakage, or disposal (Darwin 2011). Use of non-fluorinated firefighting foam is recommended, more research is needed to identify safer alternatives to PFAS. The quantity and use estimates in Table 6 should be verified by conducting a user survey.

[1] https://fortress.wa.gov/ecy/coastalatlas/storymaps/spills/spills_sm.html?&Tab=nt3

Table 6 – Estimated AFFF quantities in Washington State

AFFF use sector	Estimated AFFF quantity	Estimated annual use
Fire departments	118,577 liters	7% or 2,218 liters
Fire extinguishers*	Not able to estimate*	Unknown
Civilian airports	61,867 liters	12% or 7,424 liters
Airport hangars	332,476 liters	9% or 29,923 liters
U.S. Military installations	121,131 liters	10% or 12,113 liters
Petroleum refineries	295,262 liters	12% or 35,431 liters
Other petroleum facilities	388,003 liters	12% or 46,560 liters
Merchant ships/Oil cargo tankers*	189 to 3,785 liters per vessel*	Unknown
Oil response storage	57,879 liters	12% or 6,945 liters
Seattle tunnels	88,579 liters	None
TOTAL storage	**1,463,774 liters**	**140,614 liters** (11%)

*not included in total

3.7 Spill reports

When oil or other hazardous substances are spilled a report is required to be submitted to Ecology. Since 2007, Ecology has maintained the Emergency Reporting Tracking System for these reports. Reports entered into that system that refer to releases of firefighting foam are summarized in Table 7. Most of these reports were related to activities that occurred on or near water or where firefighting foam entered a waterway. These voluntary reports refer to fuel, water and foam but do not specify if the material released contains PFAS. These reports are shared with local agencies and other response personnel. Information in these reports is not independently verified.

Table 7 – Firefighting release incidents voluntarily reported to Ecology

Year	Number of reported incidents	Released fuel, water, AFFF (liters)
2007	1	76
2009	3	30
2010	3	15
2011	4	1,908
2012	2	34,163
2013	3	2,468
2014	2	15
2015	1	38
2016	9	1,177,535*
TOTAL	**28**	**1,216,248**

* Note: one incident in August 2016 reported the use of 1,173,477 liters (310,000 gallons) of water with firefighting foam at an industrial facility.

4.0 Waste Management

Release of PFAS has been shown to occur at manufacturing sites where PFAS are used as part of the industrial process. Fourteen contaminated sites across the U.S. are linked to PFAS releases from automobile, carpet, cable or wire, metal plating, paper, plastics, and textiles manufacturing (SSEHRI 2018). PFAS releases and release mechanisms differ among the manufacturing processes. PFAS releases could result from air emissions, wastewater discharges, stormwater runoff or waste disposal.

4.1 Wastewater treatment plants

Wastewater is the water "waste" that results from domestic uses such as restroom use, bathing, food preparation, and laundry, or industrial uses such as manufacturing, mining, and commercial businesses. Some wastewaters are treated on site (for example single family septic systems or industries that treat their own wastewater prior to disposal to the environment), but large volumes of waste are treated by publicly owned wastewater treatment plants (WWTPs). Publicly owned WWTPs in many cases accept wastewater from local industries and businesses that contain higher levels of toxic compounds than found in domestic waste. There are approximately 15,500 operational public WWTPs in the U.S., and approximately 72 percent of these are considered small systems (serving a population of 10,000 or fewer people and an average daily wastewater flow of less than one million gallons per day) (EPA 2019). Many industries treat their wastewater under state and federal regulatory programs. The waste streams produced by wastewater treatment include both liquids (effluent) and solids (sludge). There are more than 600 WWTPs in Washington.

Different contaminants enter wastewater depending on how and where water is used. Wastewater that contains pollutants (for example chemicals or organic matter) must be treated before it can be released back into the water environment. In Washington, WWTP effluent can be discharged to surface waters or to ground, and all WWTPs must meet a high level of pollutant removal technology2. In cases where effluent is discharged to ground, it is further regulated to meet the Washington Groundwater Quality Standards (Chapter 173-200 Washington Administrative Code (WAC)). Effluent discharged to surface waters must meet the state's Surface Water Quality Standards (Chapter 173-201A WAC). Industrial users who discharge to publicly owned WWTPs must comply with national and state pretreatment requirements.

At this time the EPA has not developed numeric nationally recommended surface water quality criteria for PFAS. States generally adopt EPA's nationally recommended water quality criteria into state surface water quality standards instead of developing state-specific criteria, largely because of the high cost of criteria development and because of the lack of available and adequate toxicological data to support the equations used to calculate criteria. In the case of PFAS, some states have adopted, or are developing, surface water quality criteria for some PFAS. For instance, Michigan adopted a surface water criterion of 12 ng/L for PFOS (MIDEQ 2019). Effluent limits for publicly owned WWTPs are largely based on meeting the technology and water quality-based requirements. Effluent limits for industries are also based on technology requirements and water quality-based standards. Because PFAS water quality criteria are not contained in either federal or Washington water quality-based standards and regulations, effluent limits for PFAS have not been developed. In addition, EPA-approved methods for monitoring compliance with effluent limits for PFAS have not yet been developed and adopted by EPA.

[2] All Known Available and Reasonable Technology: WAC 173-218-030

Industries that discharge to publicly-owned WWTPs must comply with federal and state pretreatment requirements. At present, PFAS requirements have not been applied to industries in Washington.

Routine wastewater influent and effluent monitoring is required by federal and state regulations and laws, and small and large systems have different monitoring requirements. The specific pollutants that are generally sampled for under the Clean Water Act (for large discharges that reach surface waters) include priority toxic pollutants (126 specific substances), conventional pollutants (5-day biochemical oxygen demand, total suspended solids, pH, fecal coliform, and oil and grease), and non-conventional pollutants (such as ammonia, chlorine, color, iron, and total phenols). State regulations frequently include additional pollutants that must be addressed (e.g. temperature). PFAS are not included in the lists of pollutants that require monitoring under the Clean Water Act. PFAS are also not included in the Washington Groundwater Standards, which sets groundwater-quality-based requirements for discharges to land.

PFAS are found in numerous products that contribute to domestic and non-domestic waste streams, as well as in contaminated drinking water supplies. Because PFAS sources are so pervasive, the wastewaters that arrive at WWTPs contain these compounds. Publicly owned treatment systems that receive domestic wastewater have traditionally been designed and constructed to meet technological requirements to remove solids from the influent (primary treatment) and to further remove some conventional pollutants (secondary treatment) to meet a "technology-based" standard of effluent quality. These systems did not incorporate specific design considerations for PFAS or other toxics removal. Beyond the technology-based treatment requirements, water-quality-based toxics regulation is an ongoing process as WWTPs and others work to reduce levels of toxics entering WWTPs, and as WWTPs work to optimize operations of current process infrastructure and to evaluate additional technologies and approaches to reduce toxics. Significant challenges exist in this effort because of the extremely low concentrations that are being targeted for many pollutants, as well as the lack of known technology to attain these concentrations. Because PFAS is a relatively newly identified pollutant, and is gaining attention at the state and national level, some states have begun to sample WWTP effluent for PFAS.

Some WWTP effluents in Washington have been sampled for PFAS compounds as parts of special studies. The Environment Chapter discusses PFAS tests in WWTP effluent. Where PFAS compounds have been sampled for, they have been found at levels similar to WWTPs in other areas of the U.S., and at lower concentrations than plants treating wastewater containing AFFF.

When PFAS enter wastewater treatment plants there is a mix of long and short chain compounds, as well as a large number of precursor compounds that can form PFAA. This mixture is subject to bacterial degradation during the treatment process (see Fate and Transport Chapter, in particular the sections on biotic and abiotic transformation). Degradation and transformation result in the formation of PFAS that are able to be identified in laboratory analyses. Prior to development of improved analytical methods used to identify this phenomenon (see Analytical Methods Appendix), it appeared as though WWTPs were increasing the mass balance of PFAS during the treatment process, instead of increasing the concentrations of the suite of measurable PFAS.

Solids that are part of the influent wastewater and also generated during secondary treatment of wastewater are largely removed prior to discharge of the treated effluent. These solids, called sludge, are either treated as waste for disposal or treated as a resource. Sludge from many domestic WWTPs is transformed into the product termed "biosolids." Biosolids are used in agriculture to improve the quality of agricultural lands for crop production. Application of biosolids is regulated under state and federal regulatory programs. The Biosolids Chapter provides more discussion.

Ecology should determine the range of PFAS concentrations in WWTP influent, effluent, and sludge. Given that the current required treatment technologies at WWTPs are not designed to address PFAS, and because we do not know the PFAS removal performances of different treatment technologies (e.g. secondary, secondary with nutrient removal, tertiary membrane filtration), Ecology should investigate the removal that different treatment technologies provide for PFAS, and evaluate whether monitoring requirements are needed. Ecology should evaluate the multiple-benefits of different technologies, including nutrient removal and removal of a broad spectrum of contaminants if concern. Ecology should consider monitoring requirements in light of the lack of Clean Water Act water quality criteria and approved analytical methods for PFAS.

4.2 Onsite wastewater treatment systems

Onsite wastewater treatment systems (commonly called septic systems) can be sources that release pollutants, including chemical contaminants, to groundwater. Leachate from septic systems can contaminate domestic drinking water wells in areas with high septic system density. Incomplete degradation or sorption during treatment in septic tanks and leach fields allow some contaminants to percolate to the groundwater. PFAS were reported in domestic wells in a Massachusetts study where septic systems were prevalent (Schaider et al 2016).

4.3 Landfilled products

Waste disposal in Washington includes all waste that goes to landfills or incinerators in the state, including waste brought from out-of-state, but does not include waste sent out-of-state for disposal. A total of 9,540,438 metric tons of waste were disposed in all types of landfills and incinerators in Washington in 2016 (Ecology 2016a).

Table 8 – Summary of waste disposed in 2016.

Landfill Type	Facilities in Washington	Metric tons disposed
Municipal Solid Waste Landfills	17	7,251,109
Inert Waste Landfills	23	1,553,080
Limited Purpose Landfills	12	505,098
Waste to Energy Facility	1	231,152
Total	**53**	**9,540,438**

Landfills contain a variety of materials ranging from inert materials (like wood or ash) to hazardous materials (like solvents and other chemicals). Some materials have a high water content. Municipal solid waste landfills have as much as 34 to 48 percent water by weight. When surface water percolates through the landfill and decomposes waste, it causes changes in the chemical environment and lowers the pH, which releases more water, metallic ions, hydrogen sulfide, and possibly additional contaminants. Leachate is the liquid that contains dissolved and suspended materials that drains from a landfill. Current regulations require municipal solid waste landfills and limited purpose landfills[3] to have liner systems and sample leachate. It is not usually possible to collect leachate samples in older, unlined landfills.

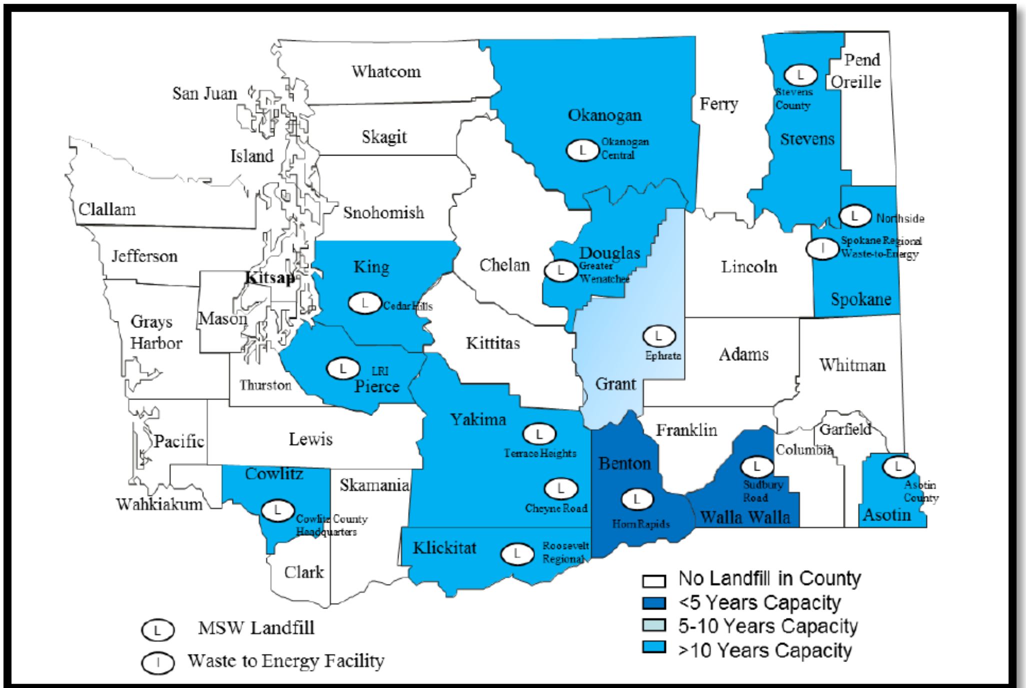

Figure 4 – Location of landfills and remaining capacity (2015).

Landfills either pump leachate to an evaporation pond or send it to a WWTP. Table 9 shows measured and approximate data for landfills that send leachate to treatment plants in Washington State.

Table 9 – Landfill leachate production in Washington State.

Landfill	County	Type	Million liters per year
Cedar Hills	King	MSW	825.90
Headquarters Road	Cowlitz	MSW	212.48
LRI/304th Street	Pierce	MSW	30.81
Tenant Way	Cowlitz	MSW	17.45
Hawks Prairie	Thurston	MSW	11.85
Port Angeles	Clallam	MSW	4.73
Olympic View	Kitsap	MSW	4.16
Inman	Skagit	Ash	2.42
Recomp	Whatcom	Ash	0.92
Hidden Valley	Pierce	MSW	0.42
Fort Lewis LF5	Pierce	MSW	0.008

[3] Limited purpose landfills include segregated industrial solid waste, construction, demolition and land clearing debris, wood waste, ash (other than special incinerator ash), contaminated soil and contaminated dredged material – WAC 173-350-100.

Landfill	County	Type	Million liters per year
Aberdeen	Aberdeen	MSW	unknown
Circle C	Clark	MSW	unknown
Hoquiam	Hoquiam	MSW	unknown
Lady Island	Clark	LP	unknown
Northside	Spokane	MSW	unknown
Rainbow Valley	Pacific	MSW	unknown
Rayonier Mt. Pleasant	Clallam	MSW	unknown
Tacoma City Municipal	Pierce	MSW	unknown
Vashon	King	MSW	unknown
Total leachate per year			**1,111.148**

Landfill type: MSW – municipal solid waste, LP – limited purpose

In all landfills there is the possibility that leachate can contaminate groundwater. Even in lined landfills leaks in the liner system result in groundwater contamination. Contaminants such as volatile organic compounds and PFAS can be transported in landfill gas formed during waste decomposition.

Sampling leachate for PFAS can help determine if those chemicals are going to the WWTP or if they could result in groundwater contamination. PFAS in landfills can come from a variety of sources such as industrial wastes, carpeting/upholstery, waterproofed clothing, food waste, biosolids, and foam used to fight landfill fires. The state of Washington does not require landfills to analyze leachate for PFAS, consequently no estimates on the amount of PFAS is possible.

Data from other states indicate that a variety of PFAS are found in landfill leachate. A study in Germany identified 44 PFAS in landfill leachate. One study showed a range of PFOA in leachate in U. S. landfills ranging from 0.15 to 9.2 µg/L. Measurements in Chinese landfills are as high as 214 µg/L.

Waste characterization studies

A waste characterization study involves sampling, sorting and surveying waste material delivered to landfills over a one year period. Ecology conducted waste characterization studies in 2009 and 2015 (Ecology 2010; Ecology 2016b). Wastes were separated into 130 material types in 2009 and 156 material types in 2015. A few of those material types include products that may contain PFAS: carpet, furniture, textiles, and paper and packaging. The landfilled quantity for those products are summarized in Table 10.

The amount of PFAS-containing materials landfilled in Washington State is unknown. The disposed volumes listed in Table 10 are used to estimate PFAS disposal in Washington State.

Table 10 Waste characterization data: average for 2009 and 2015

Material Type	Annual Metric Ton Landfilled	Percent of total disposed
Carpet	64,873	1.4
Furniture	59,842	1.3
Textiles	167,357	3.7
Paper packaging	332,543	7.2
TOTAL four types	**624,615**	**12.17**

Material Type	Annual Metric Ton Landfilled	Percent of total disposed
TOTAL waste landfilled	**4,589,537**	

Carpet: PFAS used in flooring products include carpet and carpet cleaning and treatment products. From 1970 to 2002 carpet applications included perfluorooctanesulfonyl fluoride (POSF)-derived substances, including PFOS (DEPA 2013). Since 2002, fluoropolymers (like perfluoroalkane sulfonyl fluorides (PASF)) or fluortelomer-based acrylate polymers have also been used for carpet stain resistance and carpet care treatments (KEMI 2015).

Over 90 percent of carpets used in homes, and 100 percent of commercial carpeting, are made from plastic. Carpets remain in place for 10 to 12 years or longer before disposal. Between 50 and 90 percent of carpet is treated for stain resistance with fluorinated substances. Stain resistant treatments are lost each year through vacuuming, steam cleaning, and eventual disposal. Carpet in landfills can take hundreds of years to degrade. Chemicals used to treat carpet are widely dispersed in areas where carpeting is popular, like North America.

Based on two reports, a wide range of estimates can be applied to the 65,000 metric tons of carpet annually disposed in Washington landfills:

- One study reported an average concentration of 75 mg/kg (part per million) of PFOS in a mix of treated and untreated carpet (DEPA 2013). Applying that concentration to the carpet annually disposed results in an estimate of 7 metric tons of PFOS annually disposed in Washington. That would result in a total of 214 metric tons of PFOS over a 30 year period.
- A Swedish estimate reported that treated synthetic carpet contains up to 15 percent PFAS (KEMI 2015). That concentration would reflect a total of 14,300 metric tons of PFAS annually disposed in Washington. That would result in a total of 430,000 metric tons of PFAS landfilled over a 30 year period.

Furniture: PFAS are used to treat leather and upholstered furniture for stain resistance, from 1970 to 2002 using PFOS and after 2002 perfluorobutane sulfonyl fluoride (PFBS). The U.S. imports 70 percent of its upholstered furniture from China, other imports come from Vietnam, Mexico, Canada and Italy (World Furniture Online 2017). Furniture usually remains in use for more than 15 years before landfilling.

Based on data from a Danish study, the following are estimates for landfill disposal of PFOS in the 71,424 metric tons of upholstered furniture disposed annually (DEPA 2013):

- Using an average concentration of 80 mg/kg of PFOS in treated leather, disposal of 5.7 metric tons of PFOS. That would result in a total of 171 metric tons landfilled over a 30 year period.
- Based on a concentration of 2.4 mg/kg in a mix of treated and non-treated furniture, disposal of 0.17 metric tons of PFOS. That would result in a total of 5 metric tons of PFOS over a 30 year period.

Textiles: Current treatments of textiles include fluoropolymers (like polytetrafluoroethylene or PTFE) used in highly porous fabrics like outdoor clothing and camping equipment; side-chain fluorinated polymers (like PASF or fluortelomer-based acrylate polymers) used as surface treatments on textiles and leather. Current polymer chemistry used for textiles includes polyfluorinated/perfluorinated (meth)acryl polymers (C2-20). Other polymers include fluorinated urethanes (C4-18). Other raw materials include various polyfluorinated/perfluorinated substances. These are alkyl sulfonamide derivatives (C4-9), alkyl ammonium compounds (C4-7), alkyl alcohols (C3-14), and a smaller number of alkyl sulfonic acids/sulfinic acids (C8), alkyl thiols (C8-20), alkyl sulfonamides (C8), alkyl esters (C8-14), alkanes/alkenes (C6) and alkanoyl/sulfonyl chlorides or fluorides (C8). Protective clothing uses surface treatments of side-chain fluoropolymers or woven fluoropolymer textiles, examples include fire retardant clothing used for medics, pilots and firemen. (KEMI 2015)

Table 3 lists 137,755 metric tons of textiles annually disposed, not all of these textiles are PFAS-treated. For the purpose of this estimate, fifty percent of that total is assumed to be PFAS-treated, that represents 68,877 metric tons of textiles disposed annually:

- 43 metric tons of PFAS annually landfilled based on 627.3 mg/kg perfluoro-carboxylic acid (PFCA) in textiles (Khotoff et al. 2013). Over a 30 year period: 1,300 metric tons of PFCA.
- 2,066 metric tons of PFAS annually landfilled based on 3 percent by weight of PFAS in treated textiles (KEMI 2015). Over a 30 year period: 62,000 metric tons of PFAS.

<u>Food packaging</u>: Surface treatment and impregnation products provide water, oil, and grease resistance, and non-stick performance for paper and packaging. These include both food-contact materials such as popcorn bags, pizza boxes, and fast-food wrappers, but also non-food applications, such as masking papers and folding cartons. Paper, cardboard and packaging has a very short lifespan from use to disposal. Treated food contact material is generally limited to a one-time use.

Current fluorinated applications include mainly side-chain fluorinated polymers and polyfluoroalkyl phosphonic acids (PAPs and diPAPs). Other major substance groups are poly/perfluorinated alkyl thiols (C4-20), poly/perfluorinated alkyl sulfonamide derivatives (C4-9), and poly/perfluorinated alkyl phosphorus compounds (C8). There are a smaller number in the substance groups alkyl esters (C6-14), alkyl silicones/siloxanes (C6) and alkyl sulfonic/sulfinic acids (C8). (KEMI 2015)

An estimated 17 percent of disposed paper products and packaging is treated (Trier et al. 2011). For this estimate, twenty percent of 223,771 metric tons of paper and packaging was used to estimate impacts from landfilled textiles. An estimated 44,751 metric tons of PFAS treated textiles are used for the estimates below:

- 1.13 metric tons of PFAS annually landfilled based on 25.2 mg/kg fluortelomer alcohol (FTOH) in treated paper and packaging (Liu et al. 2015). Over a 30 year period: 33.83 metric tons of FTOH.
- 671 metric tons of PFCA annually landfilled based on 1.5 percent by weight of PFCA in treated paper products (KEMI 2015). Over a 30 year period: 20,139 metric tons of PFCA.

<u>Summary</u> of the low and high PFAS disposal estimates based on the limited information from the waste sort data and available product testing data. The greatest sources of PFAS disposal appears to come from carpet and textiles. More research is needed to determine the presence of PFAS in landfilled materials.

Table 11 – Annual PFAS disposal estimates by material type

Material Type	Low estimate of PFAS disposal	High estimate of PFAS disposal
Carpet	7.15 metric ton/year	14,300 metric ton/year
Textiles	43.21 metric ton/year	2,066 metric ton/year
Furniture	0.17 metric ton/year	5.71 metric ton/year
Compostable paper, packaging	1.13 metric ton/year	671 metric ton/year
TOTALS	**51.66 metric ton/year**	**17,043 metric ton/year**

4.4 Waste disposal reports

Washington's Dangerous Waste Regulation requires businesses to properly manage, store and dispose of hazardous waste (Chapter 173-303 WAC). This regulation identifies halogenated organic compounds as a state-only "dangerous waste" due to persistence. Fluorine is a halogen, therefore PFAS are halogenated organic compounds. PFAS present in a waste above 100 ppm must be properly managed and disposed as dangerous waste (WAC 173-303-040).

Dangerous waste disposal must be reported to Ecology and, since 2010, those reports have been entered into the TurboWaste database. PFAS is not specifically reported to the database. Data entered into TurboWaste that may contain PFAS include wastes described as AFFF, fire debris and suppressant. Those reports are summarized in Table DW, the submitted reports do not all indicate the presence of PFAS. TurboWaste data is reported in pounds, for consistency throughout this chapter, the data was converted to kilograms.

Table 12 – Dangerous waste disposal reports from 2010 to 2016 (kilograms)

Waste	2010	2011	2012	2013	2014	2015	2016
AFFF	1,252	6,762	877	931	1,528	5,640	40,632
Fire debris	1,316	722	784	8,634	6,378	504	1,555
Suppressant	1,946	6,112	2,445	25,908	96,272	2,867	0
Total	**4,514**	**13,596**	**4,105**	**35,473**	**104,179**	**9,010**	**42,187**

5.0 Consumer products

5.1 PFAS in children's products

The Children's Safe Products Act (CSPA – Chapter 70.240 RCW) authorized Ecology and Health to develop a list of chemicals of high concern to children and a process for manufacturers to report on the presence of those chemicals in children's products. The Children's Safe Products Reporting Rule (WAC 173-334-130) includes PFOS and PFOA in the list of 85 chemicals of high concern to children. PFOS was included in the first list of reporting chemicals adopted in rule in 2011. PFOA was added to the reporting list in 2017 rule adoption. Manufacturers are required to annually report the presence of PFOS or PFOA in children's products sold in Washington State. Annual reports include the manufacturer name, product category and component, chemical function and concentration. Manufacturer reports are available online at https://fortress.wa.gov/ecy/cspareporting/Default.aspx.

A summary of the manufacturer data is provided in Table 13. For all products, PFOS was reported to be present at concentrations less than 100 parts per million, except for the artists accessories report from 2014 which reported PFOS at 100 to 500 parts per million.

Table 13 - Reports of PFOS in children's products, at concentrations below 100 parts per million.

Product category	2014	2016	2017	Chemical function
Artists Accessories*	1			UV stabilizer
Baby Feeding – Bibs	1			Contaminant
Blankets/Throws (Non Powered)	1			Contaminant
Board Games/Cards/Puzzles Variety Packs	1			Contaminant
Dresses	1	1		Contaminant
Full Body Wear Variety Packs		1		Manufacturing additive
Indoor Footwear – Fully Enclosed Uppers	1			Contaminant
Jackets/Blazers/Cardigans/Waistcoats	1	1	1	Colorant; Contaminant
Overalls/Bodysuits	1	1	14	Colorant; Flame retardant; Contaminant
Pants/Briefs/Undershorts	1		14	Flame retardant; Contaminant
Pantyhose/Stockings	1			Contaminant
Shirts/Blouses/Polo Shirts/T–shirts	1		22	Colorant; Flame retardant; Contaminant
Shoes – General Purpose	1			Contaminant
Skirts	1		1	Flame retardant; Contaminant
Sleepwear Variety Packs	1			Contaminant
Socks	1			Contaminant
Sportswear – Full Body Wear	1	4		Colorant; Contaminant
Sportswear – Lower Body Wear	1	1	2	Colorant; Flame retardant; Contaminant
Sportswear – Upper Body Wear	1	5	4	Colorant; Flame retardant; Water proofing
Sweaters/Pullovers	1			Contaminant
Trousers/Shorts	1			Contaminant
Upper Body Wear/Tops Variety Packs		1		Colorant
Total reports	**20**	**15**	**58**	

* - PFOS reported at 100 to 500 parts per million.

5.2 PFAS in a typical home

PFAS exposure in the home occurs during product use and exposure to house dust containing PFAS. The greatest portion of the chronic exposure to PFAS for the general public, specifically to PFOS and PFOA, results from the intake of contaminated foods and contaminated drinking water, more discussion is provided in the Health Chapter (Trudel et al., 2008). Other sources of exposure could occur from PFAS-containing products in the home and in some occupations (EPA 2009, ITRC 2017). Studies of indoor air and house dust indicate exposure to PFAS from consumer products in the home like carpet care liquids, nonstick cookware, packaged fast food, and waterproof clothing (Health Chapter).

In a study published in 2009, EPA evaluated 116 products available in the typical home and tested each product for PFCA (EPA 2009). The main goal of that study was to identify and rank potentially important indoor sources based on PFCA content in articles of commerce. In the following tables, the EPA 2009 study data is provided and supplemented with data from more recent consumer products PFAS studies.

The EPA study estimated quantities of product categories present in a typical American home (EPA 2009). For example, in the EPA study a typical home was assumed to contain 150 square meters of PFAS-treated carpet and 50 square meters of PFAS-treated textiles and upholstery.

- Treated carpet: 60 percent of the U.S. home floor area of 250 square meters is carpeted.
- Textile and upholstery of 50 square meters: 10-20 square meters of fabric for an upholstered chair or sofa and 2 to 3 square meters of fabric for a jacket, shirt or pants.

Carpeting and upholstery involve large treated areas and stain-resistance treatment is a frequent specification among institutional purchasers (DTSC 2017). Textile-related products that use fluorinated applications include: outer garments, umbrellas, bags, sails, tents, parasols, car seat, covers, leather articles, and shoes.

Investigations indicate a variety of PFAS are present in a wide range of cosmetics, including sunscreen, foundations, concealers, hair spray, eye liners, creams, lotions and powders. The results varied widely across product types and brands, with highest measured PFAS concentrations in sunscreen and foundation (DEPA 2018). Examples of fluorinated ingredients in cosmetic products include: per/polyfluorinated acrylate polymers, naphthalenes, alkanes/alkenes, alcohols, siloxanes, silanes, sulfonamides, ethers, esters, phosphate esters, acrylates and acids. According to the European Commission's database on cosmetic ingredients, these substances are used in cosmetic products as emulsifiers, antistatics, stabilizers, surfactants, film formers, viscosity regulators and solvents (Schultes 2018).

Using the process developed by EPA, recent product testing study data are added to the 2009 data (EPA 2009, Herzke et al. 2015, Kotthoff 2015, Fujii 2013, Liu et al. 2015). Tables 14a and 14b list the top ten products for the sum of PFCA and FTOH/fluorotelomer sulfonate (FTS). Supplement 1 to this document provides estimates for more product testing data.

Table 14a – Estimated PFCA in consumer products in a typical home

Category name	Total PFCA	Reference	Typical Quantity	PFAS in the home
Pre-treated carpeting	484 µg/ m^2	EPA 2009	150 m^2	72,600 µg
Treated home textile and upholstery	346 µg/ m^2	Herzke et al. 2015	50 m^2	17,300 µg
Water proofing agents	29,889 µg/L	Herzke et al. 2015	0.5 L	14,945 µg
Pre-treated carpeting	57.2 µg/kg	Kotthoff 2015	50 kg	2,860 µg

Category name	Total PFCA	Reference	Typical Quantity	PFAS in the home
Food contact material (paper)	2,859.9 µg/kg	Kotthoff 2015	1 kg	2,860 µg
Treated floor waxes and stone/wood sealants	2,430 µg/kg	EPA 2009	1 kg	2,430 µg
Sunscreen	19,000 µg/kg	Fujii 2013	0.1 kg	1,900 µg
Treated home textile and upholstery	336 µg/kg	EPA 2009	5 kg	1,680 µg
Non-stick cookware	1,234.74 µg/kg	Herzke et al. 2015	1 kg	1,235 µg
Household carpet/fabric-care liquids and foams	953 µg/kg	EPA 2009	1 kg	953 µg
Dental floss and plaque removers	31.3 µg/kg	EPA 2009	0.005 kg	0.2 µg

Table 14a – Estimated FTOH or FTS in consumer products in a typical home

Category	FTOH/FTS	Reference	Quantity	FTOH/FTS in the home
Cleaning agents	667,700 µg/kg	Kotthoff 2015	1 kg	667,700 µg
Treated floor waxes and stone/wood sealants	423,000 µg/kg	Liu et al. 2015	1 kg	423,000 µg
Water proofing agents	464,774 µg/L	Herzke et al. 2015	0.5 L	232,387 µg
Treated home textile and upholstery	42,900 µg/kg	Liu et al. 2015	5 kg	214,500 µg
Carpet	4,010 µg/kg	Liu et al. 2015	50 kg	200,500 µg
Impregnating sprays (waterproofing)	1,857,300 µg/kg	Kotthoff 2015	0.1 kg	185,730 µg
Treated home textile and upholstery	757 µg/ m^2	Herzke et al. 2015	50 m^2	37,850 µg
Carpet samples	73.5 µg/kg	Kotthoff 2015	50 kg	3,675 µg
Membranes for apparel	1,590 µg/kg	Liu et al. 2015	1 kg	1,590 µg
Treated apparel	464 µg/kg	Liu et al. 2015	2 kg	928 µg

Based on the method used by EPA (2009), sources in a typical home:

- PFCA from carpet, carpet care products, textiles/upholstery, and floor waxes and polishes.
- FTOH and FTS from cleaners, carpet-care products, waterproofing spray, textiles, floor waxes and polishes, and carpet.

Further research is needed to better understand exposure from PFAS-containing products in the home:

- PFAS transfer from products to indoor air, dust and surfaces.
- The relationship between household products containing PFAS and inhalation exposure.
- Levels of dermal exposure from household products containing PFAS.
- Measures that reduce PFAS levels in homes, house dust and indoor air.
- Further research into the availability of safer alternatives.

6.0 Occupational Exposure

High levels of PFAS have been reported in some occupational settings, including retail stores where products containing PFAS are sold, and service industries that use products containing PFAS. These populations may see higher exposure than average, although still below the levels seen near AFFF-contaminated sites.

Langer et. al. 2010 measured indoor air concentrations of 14 PFAS[4] in various settings, and found the highest concentrations in stores selling outdoor equipment, a furniture shop, and a carpet shop. Table 15 lists the number of retail workers in Washington and average exposure numbers from Langer (ESD 2017a, Langer et al. 2010).

Table 15 Occupational exposure estimates.

Occupation	**Number of employees in WA**	**Average total PFAS air concentrations (ng/m^3)**	**Average exposure ng/day/kg bodyweight**
Retail trade workers in furniture and home furnishing stores	10,400	187	11.84
Retail trade workers in sporting goods stores	6,500	351	22.23

Schlummer et. al. 2013 found higher air concentrations of FTOH in carpet shops and stores selling outdoor textiles than Langer et. al. 2010. Ski waxers also have higher levels of exposure and recreational skiers could as well (Freberg et. al. 2010, Nilsson et. al. 2013). Ski competitions have been shown to release PFAS to snow and soil (Plassmann and Berger 2013).

Workers in other occupations could have PFAS exposure due to the use of products known to contain PFAS on the job. An estimated 251,322 Washington workers could be exposed at work when using PFAS-containing products (ESD 2017b). The estimated number of workers in specific occupations are listed below.

Automotive workers that could use PFAS-containing car wax or products used on the textiles in the car:

- Automotive & Watercraft Service Attendants: 2,217

[4] Fluorotelomer alcohols: 4:2 FTOH, 6:2 FTOH, 8:2 FTOH, 10:2 FTOH, 12:2 FTOH; Fluorotelemer acrylates: 6:2 FTA, 8:2 FTA, 10:2 FTA; Perfluorinated sulfonamido ethanols and perfluorinated sulfonamides: EtFOSA, MeFBSA, MeFOSA, MeFOSE, MeFBSE, EtFOSE (Langer et. al. 2010).

- Automotive Body & Related Repairers: 2,333
- Automotive Glass Installers & Repairers: 672
- Automotive Service Technicians & Mechanics: 12,864
- Cleaners of Vehicles & Equipment: 7,721

Carpet and furniture workers that could use PFAS-containing oil, stain and water repellents:

- Cabinetmakers & Bench Carpenters: 2,431
- Carpet Installers: 1,012
- Floor Layers, Except Carpet, Wood, & Hard Tiles: 401
- Floor Sanders & Finishers: 246
- Upholsterers: 316
- Furniture Finishers: 527

Textile workers that could use PFAS-containing oil, stain and water repellents:

- Fashion Designers: 358
- Shoe & Leather Workers & Repairers: 68
- Textile Cutting Machine Setters, Operators, & Tenders: 146
- Textile Wind/Twist/Draw-Out Machine Setters,Oprs & Tenders: 227
- Fabric & Apparel Patternmakers: 65
- Textile, Apparel, & Furnishings Workers, All Other: 87

Food service workers that could use PFAS-containing food packaging or paper:

- Food Service Managers: 2,297
- Food Preparation & Serving Worker Supervisors: 21,030
- Food Preparation Workers: 20,088
- Combined Food Preparation & Serving Workers, Inc Fast Food: 80,771
- Counter Attendants, Cafeteria/Concession & Coffee Shop: 14,553
- Food Servers, Nonrestaurant: 4,828
- Dining Room & Cafeteria Attendants & Bartender Helpers: 8,838
- Food Preparation & Serving Related Workers, All Other: 1,877
- Paper Goods Machine Setters, Operators, & Tenders: 1,773

Other workers that could use PFAS-containing cleaning products or cosmetics:

- Janitors/Cleaners, Except Maids & Housekeeping: 44,682
- Maids & Housekeeping Cleaners: 17,795
- Skincare Specialists (cosmetics): 1,099

7.0 Global estimate: Washington proportion

Global releases of PFAS are estimated in Prevedouros (et al. 2006), Paul (et al. 2009) and Boucher (et al. 2019). A proportion of the global use and disposal estimates are used to reflect historic releases of PFAS in Washington. Global estimates related to manufacture of PFAS are not reflective of Washington and not included. A brief summary of each estimate and the Washington proportion are provided.

For the purpose of this estimate, the Washington proportion of global estimates is 0.65 percent. That rate is based on the U.S. representing 25 percent of worldwide consumption and Washington State is 2.6 percent of the US by population. Washington's historic PFAS emissions and releases are estimated to total 944 metric tons or an annual estimate of 29.5 metric tons from 1960 to 2002.

These estimates do not reflect all PFAS that may have been present in the global market or released to the environment. "Identifying and understanding production, use, releases and environmental presence of the various PFAS on the global market has been limited due to the complexity of the issue, data scarcity and fragmentation, and data confidentiality" (OECD 2018).

Prevedouros et al. (2006) described the sources, fate, and transport of PFCA in the environment. This report estimated PFCA and FTOH releases to the environment from direct (manufacture, use, consumer products) and indirect (impurities and precursors) sources. Manufacture estimates from this study do not apply to Washington State. The global estimates of use, disposal and emissions from firefighting foam, consumer and industrial products in Table 16 are adjusted to reflect an estimated proportion attributable to Washington State. These estimates apply to sources across a variety of timelines from 1960 to 2002. These releases and emissions represent 0.10 metric tons per year for Washington State (from 1960-2002).

Table 16 PFCA and FTOH Emissions in Metric Tons (Prevedouros et al, 2006)

Use, disposal and emissions	Estimated global emissions	Estimated Washington emissions
Consumer and industrial	520	3.38
AFFF	131	0.85
TOTAL	**651**	**4.23**

Paul et al. (2009) estimated global historic manufacture, consumer use and disposal of POSF, and environmental releases of POSF and PFOS from 1970 to 2002. Manufacture estimates in this study do not apply to Washington State. Total global consumer use and disposal of POSF from direct (use and consumer products) and indirect PFOS (precursors and/or impurities) sources in Table 17a and Table 17b reflect the Washington proportion. Estimates indicate that direct emissions from POSF-derived products are the major source to the environment resulting in releases into wastewater streams, primarily through losses from stain repellent treated carpets, waterproof apparel, and aqueous firefighting foams. These total releases and emissions represent 29.4 metric tons per year for Washington State (from 1970-2002).

Table 17a POSF Emissions in Metric Tons (Paul et al, 2009)

Use and disposal	Global use/disposal metric tons	Washington consumer use and disposal
Carpet	48,000	312
Paper and packaging	24,000	156
Apparel	12,500	81
AFFF	10,000	65
Performance chemicals (hydraulic fluids)	6,000	39

TOTAL	**100,500**	**653**

Table 17b POSF and PFOS Emissions to Water and Air in Metric Tons (Paul et al, 2009)

Consumer emissions 1970-2002	Global POSF/PFOS emissions	Washington POSF/PFOS emissions
Carpet	21,500	140
Apparel	12,600	82
Performance chemicals (hydraulic fluids)	9,610	62
Paper and packaging	367	2.4
AFFF	47	0.3
TOTAL	**44,124**	**286.7**

Estimates indicate that direct emissions from POSF-derived products are the major source to the environment resulting in releases into wastewater streams, primarily through losses from stain repellent treated carpets, waterproof apparel, and aqueous firefighting foams. These total releases and emissions represent 29.4 metric tons per year for Washington State (from 1970-2002).

Boucher et al. (2019) estimated global historic manufacture, consumer use and disposal of perfluorohexane sulfonate (PFHxS), perfluorodecane sulfonate (PFDS), perfluorohexane sulfonyl fluoride (PHxSF) and perfluorodecane sulfonate (PDSF) from 1958 to 2015. Manufacture estimates in this study do not apply to Washington State. Total global use and disposal of PFHxS and PFDS and degradate emissions are summarized in Table 18 and reflect the Washington proportion.

Table 18 PHxSF and PFDS Emissions in Metric Tons (Boucher et al, 2019)

Emissions from use, disposal and degradates*	Estimated global emissions	Estimated Washington emissions
PFHxS	32-126	0.2-0.8
PDFS	34-372	0.2-2.4
TOTAL	**66-498**	**0.4-3.2**

* minus production emissions

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Supplement 1: Estimated PFAS in consumer products in a typical home

Estimated PFCA in consumer products in a typical home

Category name	Total PFCA	Reference	Typical Quantity	PFAS in the home
Pre-treated carpeting	484 µg/ m^2	EPA 2009	150 m^2	72,600 µg
Commercial carpet-care liquids	12,000 µg/kg	EPA 2009	6 kg	72,000 µg
Treated home textile and FDAupholstery	346 µg/ m^2	Herzke et al. 2015	50 m^2	17,300 µg
Water proofing agents	29,889 µg/L	Herzke et al. 2015	0.5 L	14,945 µg
Pre-treated carpeting	57.2 µg/kg	Kotthoff 2015	50 kg	2,860 µg
Food contact material (paper)	2,859.9 µg/kg	Kotthoff 2015	1 kg	2,860 µg
Treated floor waxes and stone/wood sealants	2,430 µg/kg	EPA 2009	1 kg	2,430 µg
Sunscreen	19,000 µg/kg	Fujii 2013	0.1 kg	1,900 µg
Treated home textile and upholstery	336 µg/kg	EPA 2009	5 kg	1,680 µg
Non-stick cookware	1,234.74 µg/kg	Herzke et al. 2015	1 kg	1,235 µg
Household carpet/fabric-care liquids and foams	953 µg/kg	EPA 2009	1 kg	953 µg
Leather samples	627.3 µg/kg	Kotthoff 2015	1 kg	627 µg
Foundation cosmetic	5,900 µg/kg	Fujii 2013	0.1 kg	590 µg
Treated apparel	198 µg/kg	EPA 2009	2 kg	396 µg
Compounding agent	35,000 µg/kg	Fujii 2013	0.01 kg	350 µg
Talc	2,500 µg/kg	Fujii 2013	0.1 kg	250 µg
Outdoor textiles	187.8 µg/kg	Kotthoff 2015	1 kg	188 µg
Membranes for apparel	124 µg/kg	EPA 2009	1 kg	124 µg
Ski waxes	11,365.5 µg/kg	Kotthoff 2015	0.01 kg	113 µg
Gloves	169.4 µg/kg	Kotthoff 2015	0.2 kg	34 µg
Awning cloth (outdoor)	31.6 µg/kg	Kotthoff 2015	1 kg	32 µg
Treated food contact paper	3,100 µg/kg	EPA 2009	0.01 kg	31 µg
Electronics and electronic parts	25.51 µg/kg	Herzke et al. 2015	1 kg	26 µg
Thread sealant tapes and pastes	603 µg/kg	EPA 2009	0.02 kg	12 µg
Paints and inks	9.36 µg/kg	Herzke et al. 2015	1 kg	9 µg

Category name	Total PFCA	Reference	Typical Quantity	PFAS in the home
Water proofing agents	80.6 µg/kg	Kotthoff 2015	0.1 kg	8 µg
Treated non-woven medical garments	795 µg/kg	EPA 2009	0.01 kg	8 µg
Household carpet/fabric-care liquids and foams	3.5 µg/kg	Kotthoff 2015	1 kg	4 µg
Non-stick cookware	0.28 µg/ m^2	EPA 2009	1 m^2	0.3 µg
Dental floss and plaque removers	31.3 µg/kg	EPA 2009	0.005 kg	0.2 µg

Estimated FTOH or FTS in consumer products in a typical home

Category	FTOH/FTS	Reference	Quantity	FTOH/FTS in the home
Cleaning agents	667,700 µg/kg	Kotthoff 2015	1 kg	667,700 µg
Commercial carpet care liquids	105,000 µg/kg	Liu et al. 2015	6 kg	630,000 µg
Treated floor waxes and stone/wood sealants	423,000 µg/kg	Liu et al. 2015	1 kg	423,000 µg
Water proofing agents	464,774 µg/L	Herzke et al. 2015	0.5 L	232,387 µg
Treated home textile and upholstery	42,900 µg/kg	Liu et al. 2015	5 kg	214,500 µg
Carpet	4,010 µg/kg	Liu et al. 2015	50 kg	200,500 µg
Impregnating sprays (waterproofing)	1,857,300 µg/kg	Kotthoff 2015	0.1 kg	185,730 µg
Treated home textile and upholstery	757 µg/ m^2	Herzke et al. 2015	50 m^2	37,850 µg
Carpet samples	73.5 µg/kg	Kotthoff 2015	50 kg	3,675 µg
Membranes for apparel	1,590 µg/kg	Liu et al. 2015	1 kg	1,590 µg
Treated apparel	464 µg/kg	Liu et al. 2015	2 kg	928 µg
Outdoor textiles	799.3 µg/kg	Kotthoff 2015	1 kg	799 µg
Household carpet/fabric-care liquids and foams	372 µg/kg	Liu et al. 2015	1 kg	372 µg
Treated food contact paper	25,200 µg/kg	Liu et al. 2015	0.01 kg	252 µg
Treated home textile and upholstery	1.35 µg/m^2	Herzke et al. 2015	50 m^2	68 µg
Electronics and electronic parts	25.51 µg/kg	Herzke et al. 2015	1 kg	26 µg
Thread sealant tapes and pastes	1,220 µg/kg	Liu et al. 2015	0.02 kg	24 µg
Food contact material (paper)	23.4 µg/kg	Kotthoff 2015	1 kg	23 µg

Category	FTOH/FTS	Reference	Quantity	FTOH/FTS in the home
Gloves	98.3 µg/kg	Kotthoff 2015	0.2 kg	20 µg
Treated nonwoven mediCal garments	1,460 µg/kg	Liu et al. 2015	0.01 kg	15 µg
Non-stick cookware	10.55 µg/kg	Herzke et al. 2015	1 kg	11 µg
Electronics and electronic parts	0.57 µg/kg	Herzke et al. 2015	1 kg	0.6 µg