Per- and Polyfluoroalkyl Substances (PFASs) Usage

NOTE: This document presents a compilation of information regarding known Per- and Polyfluoroalkyl Substances (PFASs) use and sources based upon a search of existing literature from a variety of sources (e.g., scientific journals, scientific publications, etc). EPA has compiled the information to help its regional offices and others identify possible contamination sources at sites with known or suspected PFAS releases. It may also help identify types of sites that may warrant further investigation for possible PFAS contamination. The compilation is entirely for informational purposes and is intended to serve as a general resource; readers should not construe it to be an exhaustive, definitive list. Decisions for investigation of PFAS releases at a site should be based on a site-specific determination in light of site-specific information. EPA anticipates updating the information as the Agency becomes aware of additional existing information or as new information becomes available.

PFASs are a class of man-made chemicals. They generally consist of a carbon backbone with fluorines saturating most of the carbons and at least one functional group, such as a carboxylic acid, sulfonate, amine, and others. If all the carbons except for the ones binding the functional group are saturated with fluorine, then the substance is called a perfluoroalkyl substance. If most but not all carbons are saturated with fluorine, then the substance is called a polyfluoroalkyl substance. Perfluorooctanoic acid (PFOA) and perfluorooctanesulfonate (PFOS) are the two most commonly known PFASs.

The list of uses below is not meant to indicate information about concentrations of PFAS within any applications. In some applications, the PFAS concentration within the product may have been de minimis, or an extremely tiny percentage. Unless stated, the information also does not indicate which specific PFAS was used or whether the usage was only in the past or is still currently being used. A table of PFAS acronyms, name, and CASRN that are cited in this usage list is provided at the end of the document.

The list is divided into numbered sections with information about the different industries. The following table lists the section number, industry, and the page number where the information starts. The numbering of the sections is not meant to imply importance of the various industries and usages. The numbering is simply used to allow for easy reference.

1. Fire-fighting foam
   - Numerous Superfund, federal facilities, and state-managed sites are known to have environmental media with PFAS contamination from this source.
   - Aqueous film-forming foams (AFFF) are used to extinguish hydrocarbon fires at airports, train yards, oil refineries, and other locations. (UNEP 2011)
   - Perfluorinated carboxylic acids manufactured by electrochemical fluorination were used as components in AFFF from about 1965-1975. POSF-based AFFF became the product of choice from the 1970s forward. (Prevedouros, Cousins et al. 2006) U.S. Naval Research Laboratory tested foam beginning in the early 1960's. (https://www.nrl.navy.mil/accomplishments/materials/aqueous-film-foam/).
   - PFASs are also used in dry fire-extinguishing agents to make powder nonwettable by hydrocarbons. (Kissa 2001)
   - Perfluorosulfonic acids (C2-C10), Perfluorocarboxylic acids (C4-14), fluorotelomer sulfonates, perfluoroalkyl sulfonamide amino carboxylates, perfluoroalkyl sulfonamido amines, fluorotelomer betaines, fluorotelomer sulfonamido amines, fluorotelomer sulfonamide betaines, fluorotelomer thiohydroxy ammonium, fluorotelomer thioamido sulfonates, and more are associated with AFFF. (Backe, Day et al. 2013, Barzen-Hanson and Field 2015, Barzen-Hanson, Roberts et al. 2017)
   - Protein-based fire fighting foam uses longer chain PFAS with numerous amide groups linked to the functional end of the molecule. (Knepper 2012)
2. Metal plating and finishing
   - Numerous sites are known to have environmental media with PFAS contamination from this source. In at least a few cases, the contamination appears to have come from air emissions.
   - PFASs are used as a surfactant, wetting agent, and mist suppressing agent for chrome plating. It was previously used for decorative chrome plating, but new technology is making that obsolete. It may still be used in hard chrome plating. (UNEP 2011)
   - PFAS use for second generation wetting agent fume suppresant (WA/FS) was first reported in the chromium plating industry in 1954. The original second generation WA/FS was a PFAS with an amino group. Later PFAS included potassium perfluoroalkyl sulfonate, amine perfluoroalkyl sulfonate, K-PFecHS, and AFtS 6:2. The third generation WA/FS which were introduced in the late 1980s/early 1990s also contain PFAS including organic fluorosulfonate and TEA-PFOS. (EPA 1998) On September 19, 2012, EPA finalized a rule to phase out PFOS containing WA/FS from hard and decorative chromium electroplating and chromium anodizing tanks as part of the NESHAP requirements. The compliance date for eliminating the use of PFOS-based fume suppressants was September 21, 2015. There is no information as to if the non-PFOS WA/FS contains other PFAS besides PFOS however. (EPA 2012)
   - PFASs improve the quality of electroless plating of copper and stabilize coating baths for depositing nickel-boron layers. (Kissa 2001)
   - PFASs are used in electroplating of copper, nickel, and tin. It improves the stability of the baths and improves overall performance. PFASs can be used as a leveling agent for zinc electrodeposition. (Kissa 2001)

- PFASs can be used to treat metal surfaces to prevent corrosion, reduce mechanical wear, or enhance aesthetic appearance. They promote the flow of metal coatings and prevent cracks during drying. (Kissa 2001)
- Similar to chromium plating operations, chromium anodizing operations use PFAS as WA/FS. Chromium anodizing facilities use chromic acid to form an oxide layer on aluminum to provide resistance to corrosion. The chromium anodizing process is used to coat aircraft parts (such as wings and landing gears), as well as architectural structures that are subject to high stress and corrosive conditions. (EPA 2012)
- An US EPA Significant New Use Rule in 2007 for PFAS lists exceptions for the rule as a "fume/mist suppressant in metal finishing and plating baths. Examples of such metal finishing and plating baths include: Hard chrome plating; decorative chromium plating; chromic acid anodizing; nickel, cadmium, or lead plating; metal plating on plastics; and alkaline zinc plating." (EPA 2007)
- PFAS dispersion products, which are used to coat metals, have been manufactured since 1951. (Prevedouros, Cousins et al. 2006)
- Some PFASs are effective blocking agents for aluminum foil. Monfluor 91 is a noted brand name for this. (Kissa 2001)
- An EPA NESHAP Rule lists the NAICS code associated with these industries as 332813 with MACT codes 1607, 1610, and 1615. (EPA 2012)
- PFBS, PFHxS, PFOS, PFOA, PFNA, and PFDA are associated with metal plating. (Knepper 2012)
- Brand names associated with PFAS dust suppression include Fluorotenside-248, SurTec 960, and Fumetrol (ATOTECH).

3. Landfills
    - Numerous sites are known to have environmental media with PFAS contamination from this source.
    - Landfills can be a source of PFASs if waste containing PFASs was deposited in the landfill. Numerous industrial and consumer products contain PFAS.
    - Landfills can also be a source of PFASs if certain PFAS polymers were placed in the landfill because some polymers can degrade to the monomers in landfills. (Washington and Jenkins 2015, Washington, Jenkins et al. 2015)
4. Textiles
    - PFASs are used extensively by the textile industry for their ability to repel oil, water, and stains. Many types of outwear such as jackets, shoes, and umbrellas are treated with PFASs. Household products such as carpets, upholstery, and leather are also treated. Outdoor equipment such as tents and sails are treated. (UNEP 2011)
    - PFAS dispersion products, which are used to coat fabrics, have been manufactured since 1951. (Prevedouros, Cousins et al. 2006)
    - PFAS brand names associated with textiles include Scotchgard (3M) and Zonyl, Foraperle, and Capstone (DuPont)
5. Paper and cardboard packaging
    - PFASs have been used to produce waterproof and greaseproof paper. Packaging includes food contact paper such as plates, popcorn bags, pizza boxes, and food

containers and wraps. Packaging also includes non-food contact applications such as folding cartons, carbonless forms, and masking papers. (UNEP 2011) (Kissa 2001)

- Perfluorooctyl sulfonamido ethanol-based phosphates were the first substances used to provide grease repellence to food contact papers, and then fluorotelomer thiol-based phosphates and polymers were used. The fluorosurfactants were added to the paper through the wet end press where cellulosic fibers are mixed with additives. The phosphate-based fluorinated surfactants provide good oil repellency but have limited water repellency. Hence, acrylate polymers with fluorinated side chains derived from sulfonamido alcohols and fluorotelomer alcohols were very widely used polymers when oil, grease, and water repellence was needed. Recently, perfluoropolyether-based phosphates and polymers have become widely used treatments for food contact paper and paper packaging. (Knepper 2012)
- In 2016, FDA announced that it would no longer provide for the use of diethanolamine salts of mono- and bis(1H,1H,2H,2H perfluoroalkyl) phosphates where the alkyl group is even-numbered in the range C8–C18; pentanoic acid, 4,4-bis [(gamma-omegaperfluoro-C8-20-alkyl)thio] derivatives, compounds with diethanolamine; and perfluoroalkyl substituted phosphate ester acids, ammonium salts formed by the reaction of 2,2-bis[([gamma], [omega]-perfluoro C4-20 alkylthio) methyl]-1,3-propanediol, polyphosphoric acid and ammonium hydroxide in food contact paper and paperboard. (FDA 2016) Separately, FDA also announced that it would no longer provide for the use of certain ammonium bis (N-ethyl-2-perfluoroalkylsulfonamido ethyl) phosphates and perfluoroalkyl acrylate copolymers in food contact paper and paperboard. (FDA 2016)
- PFAS brand names associated with packaging include Scotchban (3M), Baysize S (Bayer), Lodyne (Ciba, BASF), Cartafluor (Clariant), and Zonyl (DuPont).

6. Industrial and household cleaning products
   - Because of their surfactant properties, PFASs have been used to lower surface tension and improve wetting and rinse-off in many industrial and household cleaning products such as carpet spot cleaners, alkaline cleaners, denture cleaners and shampoos, floor polish, and dishwashing liquids. They were also used in car wash products and automobile waxes. (UNEP 2011) PFAS in windshield wiper fluid prevents icing of the windshield. (Kissa 2001) They are useful for cleaning hard surfaces in general including wood, glass, countertops, and flooring. (Knepper 2012)
   - They can be used in cleaners containing strong acids and bases, including those for cleaning concrete, masonry, and metal surfaces (such as airplanes). PFAS in nonaqueous cleaning agents aid removal of adhesives and in dry cleaning of textiles or metal surfaces. Machine parts are cleaned after nickel plating with a solution containing PFOS. (Kissa 2001)
   - PFASs are used in cleaning formulations that remove calcium sulfate scale from reverse osmosis membranes. (Kissa 2001)
   - PFAS brand names associated with cleaning include Novec (3M) and PolyFox (OMNOVA Solutions)
7. Surface coating, paint, varnish, and inks

- PFASs have been used in coating, paint, and varnish to reduce surface tension for substrate wetting, levelling, dispersing agents, and improving gloss and antistatic properties. In dyes and inks, they can be used as pigment grinding aids and combat pigment flotation problems. (UNEP 2011) Perfluorinated urethanes enhance the protective properties of anticorrosive paints. (Kissa 2001)
- Fluorinated surfactants in ink jet printer inks improves processing and image quality on porous or non-porous media. (Knepper 2012)
- Certain ski waxes use PFAS. (Charonnat 2001) (Plassmann and Berger 2013)
- 6:2 monoPAP, 6:2 diPAP, 8:2 monoPAP, 8:2 diPAP, 10:2 monoPAP, and 10:2 diPAP are associated with inks. (Knepper 2012)

8. Plastics, resins, and rubber
    - PFOA is used to manufacture certain plastics or applied plastics such as polytetrafluoroethylene (PTFE) and polyvinylidine fluoride (PVDF). PTFE has hundreds of uses in consumer and industrial products such as applications noted elsewhere in this paper of textiles, medical industries, cookware, etc. PVDF has unique and useful properties, and so it is used in critical industrial applications like handling chemicals, automotive fuel hoses, electrical cable insulation and jacketing, architectural coatings, high purity piping, and semiconductor piping. (van der Putte 2010)
    - APFN is primarily used as a processing aid in fluoropolymer manufacture, most notably polyvinylidene fluoride (PVDF). (Prevedouros, Cousins et al. 2006)
    - PFASs are used as mold-release agents for thermoplastics, polypropylene, epoxy resins, polyurethane elastomer foam molding. (Kissa 2001)
    - PFASs have been used in formulations for antiblocking agents for vulcanized and unvulcanized rubbers. (Kissa 2001)
    - PFASs in silicone rubber sealants make the seal soil resistant. (Kissa 2001)
    - PFASs improve wetting of fibers or fillers in composite resins and speed escape of bubbles. (Kissa 2001)
    - PFAS are used to make perfluorinated membranes that are used in fuel cells, chlor-alkali cells, and water, caustic soda, and caustic potash electrolyzers. They were first invented in 1962 (Heitner-Wirguin 1996)
    - PFBS has been used as a flame retardant for polycarbonate by Miteni under the brand name RM 65. (Miteni product information) Other polycarbonates are described as having PTFE in them. (RTP Co. http://web.rtpcompany.com/info/data/0300/flame.htm)
    - PTFE is best known by brand name Teflon (DuPont, now Chemours). Nafion (Chemours) and Flemion (AGC Chemicals Company) are name brand perfluorinated membranes.
9. Adhesives
    - PFASs are used in solvent-based and water-based adhesives to assure a complete contact between the joining surfaces and retard foaming. PFAS surfactants added to rubber allows adhesiveless bonding to steel. (Kissa 2001)

- PFAS is used with urea-formaldehyde adhesive resins for wood particleboard bonding to improve the cold-water swelling and internal bond strength by reducing the resin's interfacial tension and improving substrate wetting. (Knepper 2012)
- PFAS brand names associated with adhesives include Zonyl FSN-100, FSO-100, FSA, FSP, and FSN. (Kissa 2001)

10. Antifogging
    - PFASs can be used on glass, metal, or plastic surfaces as an antimist film to prevent fogging of surfaces in humid environments such as bathrooms, automobile windshields, and eyeglass lenses. PFASs can also be used for the same with glass and plastic cover sheets used in agriculture. PFASs can be blended into transparent polyvinyl chloride, polyethylene, or ethylene-vinyl acetate film to reduce clouding. (Kissa 2001)
    - K-PFOS and nonionic surfactants are known to have similar uses. (Kissa 2001)
11. Cement additives
    - PFASs reduce shrinkage of cement. (Kissa 2001)
    - Cement tiles containing PFAS are more weather resistant than tiles made with other dispersants. (Kissa 2001)
    - PFASs improve primers used for coating cement mortar. (Kissa 2001)
12. Oil industry
    - PFASs may be used as surfactants to enhance recovery in oil or gas recovery wells. (UNEP 2011) (Kissa 2001) They improve subterranean wetting, increase foam stability, and modify the surface properties of the reservoir formation by lowering surface tension and foaming properties to well-stimulation additives. (Knepper 2012)
    - PFASs may be used as evaporation inhibitors for gasoline, and as jet fuel and hydrocarbon solvents. (UNEP 2011)
    - PFASs have been used in civil and military hydraulic oils to prevent evaporation, fires, and corrosion. (UNEP 2011) The use as an anti-erosion additive in fire-resistant phosphate ester aviation hydraulic fluids is listed in an US EPA Significant New Use Rule in 2002 as not being a new use and not applicable to the ban. (EPA 2002)
    - Petroleum-product storage tanks may use a floating layer of cereal grains treated with PFAS on top of the liquid surface to reduce evaporation loss. Similarly, evaporation of hydrocarbon fuel can be prevented by an aqueous layer containing PFAS. (Kissa 2001)
13. Mining industry
    - PFASs may have been used as surfactants to enhance recovery of metals from ores in copper and gold mines. (UNEP 2011)
    - PFASs are used in the ore flotation process to separate metal salts from soil and in electrowinning of metals. Aluminum and vanadium ore separation may use PFAS. (Kissa 2001, Knepper 2012)
    - PFASs are also used in nitrogen flotation to recover uranium. (Kissa 2001)
14. Photographic industry
    - PFASs have been used in manufacturing film, paper, and plates as dirt rejecters and friction control agents and to reduce surface tension and static electricity. (UNEP

2011) (Kissa 2001) An EPA Significant New Use Rule in 2002 lists their use "in coatings for surface tension, static discharge, and adhesion control for analog and digital imaging films, papers, and printing plates, or as a surfactant in mixtures used to process imaging films and states these are not considered new uses." (EPA 2002)
- PFOA and PFOS have both been used in this industry. (van der Putte 2010, UNEP 2011). PFBS, PFHxS, PFOS, and PFDS are associated with photoresists. (Knepper 2012)
- Photography industry users of PFAS include producers of consumer film, X-ray film for medical and industrial use, and the movie industry. (UNEP 2011)

15. Electronics industry
    - PFASs are used in the manufacturing of digital cameras, cell phones, printers, scanners, satellite communication systems, radar systems, and more. (UNEP 2011)
    - Cured epoxy resins are removed from integrated circuit modules by solutions containing small amounts of PFAS. (Kissa 2001)
    - PFOA is used to make fluoropolymers that are used in cable and wire insulation for computer networks. (van der Putte 2010) Insulated wire may be prepared by coating the wire electrophoretically and treating the wire with PFAS before baking. (Kissa 2001)
    - Electric circuits may be sealed with a material that contains PFAS. (Kissa 2001)
    - The products themselves are mostly PFAS-free. (UNEP 2011)
    - Zinc battery electrolyte may contain PFAS. Alkaline manganese batteries may have MnO_2 cathodes treated with PFAS. (Kissa 2001)
    - PFAS are used to make polymer electrolyte membrane for fuel cells since 1966. They have been commercially produced since 1972. (Ivanchev, Likhomanov et al. 2012, Chemours 2016)
    - PFASs are used in low-foaming noncorrosive wetting agents in solders for electrical parts and cleaning of electronic components. (Kissa 2001) PFAS stabilize foam in polar solvents used for surface preparation before welding. (Knepper 2012)
    - PFASs are used as lubricants coated on the surface of magnetic recording devices such magnetic tape, floppy disks, and disk drives. (Kissa 2001)
    - Chemours perfluorinated membranes used in fuel cells are known by brand name Nafion.
16. Semiconductor industry
    - PFASs are used to reduce surface tension and reflectivity of etching solutions for precise photolithography in the semiconductor industry. (UNEP 2011) An EPA Significant New Use Rule in 2002 lists their use "in as a component of a photoresist substance, including a photo acid generator or surfactant, or as a component of an anti-reflective coating, used in a photomicrolithography process to produce semiconductors or similar components of electronic or other miniaturized devices." (EPA 2002)
    - They are used in liquid etchant in photo mask rendering process. (UNEP 2011)
    - PFOA and PFOS have both been used in this industry. (van der Putte 2010, UNEP 2011)

17. Etching
    - PFASs are used as wetting agents in etch baths. This includes glass etching, plastics etching, fused silica, and aluminum. They are also used in the semiconductor industry etching as noted above. (Kissa 2001)
18. Cosmetics and personal care
    - PFASs are used in cosmetics as emulsifiers, lubricants, or oleophobic agents. PFASs are also used in hair-conditioning formulations and hair creams. (Kissa 2001)
    - PFASs can be used in toothpaste to increase fluoride-enamel interactions. (Kissa 2001)
19. Pesticides
    - EtFOSA (sulfluramid) is an insecticide whose registration was cancelled in May 2008. (EPA 2007)
    - PFASs may be used as inert surfactants in pesticide products. K-NEtFOSAA and 3-[(heptadecafluorooctyl)sulfonyl]amino]-N,N,N-trimethyl 1-propanaminium iodide (CASRN 1652-63-7) have been used in pesticide formulations. Perfluoroalkyl phosphonic acids and perfluoroalkyl phosphinic acids have also been used as inert additives for pesticide formulations. (UNEP 2011, Knepper 2012)
    - PFASs can be used as dispersants and wetting agents for herbicides and to aid wetting and penetration in insecticides. (Kissa 2001)
20. Medical uses
    - Most video endoscopes contain a small amount of PFAS. (UNEP 2011)
    - PFASs are used as a dispersant in radio-opaque ETFE production for accuracy and precision in medical devices such as radio-opaque catheters for angiography and in-dwelling needle catheters. (UNEP 2011)
    - PFDA grafted onto polyurethane improved its compatibility with blood. (Kissa 2001)
    - PFASs facilitate dispersion of cell aggregates from tissues in a saline solution, used to diagnose cell abnormalities. (Kissa 2001)
21. Oil spills
    - Oil spills on water can be contained and prevented from spreading by injecting a chemical barrier containing PFAS into the water. (Kissa 2001)
    - Perlite or vermiculite treated with a cationic PFAS is claimed to be helpful in containing oil spills. (Kissa 2001)

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Abbreviations

Acronym	Name	CASRN
10:2 diPAP	10:2 Fluorotelomer phosphate diester	1895-26-7
10:2 monoPAP	10:2 fluorotelomer phosphate monoester	57678-05-4
6:2 diPAP	6:2 Fluorotelomer phosphate diester	57677-95-9
6:2 monoPAP	6:2 fluorotelomer phosphate monoester	57678-01-0
8:2 diPAP	8:2 Fluorotelomer phosphate diester	678-41-1
8:2 monoPAP	8:2 fluorotelomer phosphate monoester	57678-03-2
AFtS 6:2	Ammonium Fluorotelomer sulphonic acid 6:2	59587-39-2
APFN	Ammonium perfluorononanoate	4149-60-4
K-PFecHS	potassium perfluoroethyl cyclohexyl sulfonate	67584-42-3
K-NEtFOSAA	Potassium [ethyl(1,1,2,2,3,3,4,4,5,5,6,6,7,7,8,8,8-heptadecafluorooctane-1-sulfonyl)amino]acetate	2991-51-7
K-PFOS	Potassium perfluorooctane sulfonate	2795-39-3
NEtFOSA	N-Ethylperfluorooctanesulfonamide	4151-50-2
PFBS	Perfluorobutanesulfonic acid	375-73-5
PFDA	Perfluorodecanoic acid	335-76-2
PFDS	Perfluorodecanesulfonic acid	335-77-3
PFHxS	Perfluorohexanesulfonic acid	355-46-4
PFNA	Perfluorononanoic acid	375-95-1
PFOA	Perfluorooctanoic acid	335-67-1
PFOS	Perfluorooctanesulfonic acid	1763-23-1
POSF	Perfluorooctylsulfonyl fluoride	307-35-7
TEA-PFOS	tetraethylammonium perfluoroctyl sulfonate	56773-42-3

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