PFAS FAMILY HIERARCHY

EA Engineering, Science, and Technology, Inc., PBC

PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)

NONPOLYMERS

Perfluoroalkyl Substances
(all H atoms on all C atoms in alkyl chain attached to a functional group have been replaced with F)

- Perfluoroalkyl acids (PFAAs) A
  - Perfluoroalkyl carboxylic acids/ Perfluoroalkyl carboxylates (PFCAs)* 1 5 A
  - Perfluoroalkane sulfonic acids/ Perfluoroalkane sulfonates (PFSAs)** 1 B
  - Perfluoroalkane sulfinic acids (PFSiAs) 2 B
  - Perfluoroalkyl phosphonic acids (PFPAs) 1 C
  - Perfluoroalkyl phosphinic acids (PFPiAs) 1 C
- Perfluoroalkyl ether acids (PFESAs) D
  - Perfluoroalkyl ether carboxylic acids (PFECAs)**** 5 D
  - Perfluoroalkyl ether sulfonic acids (PFESAs) 5 D
- Perfluoroalkane sulfonamides (FASAs) 2 B
- Perfluoroalkane sulfonyl fluorides (PASFs) 3 B
- Perfluoroalkanoyl fluorides (PFAs) 3 B
- Perfluoroalkyl iodides (PFAIs) (Telomer A) 7 C
- Perfluoroalkyl aldehydes (PFALs) 2 C

Polyfluoroalkyl Substances
(all H atoms on at least one [but not all] C atoms have been replaced with F)

- Polyfluoroalkyl ether acids D
  - Polyfluoroalkyl ether carboxylic acids (PFECAs) 5 D
  - Polyfluoroalkyl ether sulfonic acids (PFESAs) 5 D
- Chloropolyfluoroalkyl ether acids 2 D
- Chloropolyfluoroalkyl acids 1 D
- Fluorotelomer substances C
  - n:2 Fluorotelomer sulfonic acids (FTSAs) 1 2 C
  - n:2 or n:3 Fluorotelomer carboxylic acids and unsaturated carboxylic acids (FTCAs and FTUCAs)*** 2 C
  - n:2 Fluorotelomer alcohols (FTOHs)*** 2 7 C
  - n:2 Unsaturated Fluorotelomer alcohols (FTUOHs) 2 C
  - n:2 Fluorotelomer iodides (FTIs) (Telomer B) 7 C
  - n:2 Fluorotelomer olefins (FTOs) 4 C
  - Semifluorinated N-alkanes (SFAs) / alkenes (SFenes) 6 C
  - n:2 Fluorotelomer acrylates/methacrylates (FTACs/FTMACs) 7 C
  - n:2 Fluorotelomer aldehydes (FTALs) and unsaturated aldehydes (FTUALs) 2 C
  - n:2 Polyfluoroalkyl phosphoric acid esters, polyfluoroalkyl phosphates, fluorotelomer phosphates (PAPs) 1 10 C
  - n:3 saturated / n:3 unsaturated acids 2 C
- Perfluoroalkane sulfonamido substances 2 3 B
  - N-Alkyl perfluoroalkane sulfonamides (MeFASAs, EtFASAs, BuFASAs) 3 B
  - (N-alkyl -) / Perfluoroalkane sulfonamidoethanols (MeFASEs, EtFASEs, BuFASEs),(FASEs) 3 B
  - N-Alkyl perfluoroalkane sulfonamidoethyl acrylates/Methacrylates (MeFAS(M)ACs, EtFAS(M)ACs, BuFAS(M)ACs) 3 B
  - (N-alkyl -) / Perfluoroalkane sulfonamidoacetic acids (MeFASAAs, EtFASAAs, BuFASAAs)/(FASAAs) 2 B

POLYMERS

- Fluoropolymers 8
- Perfluoropolyethers (PFPEs) 9
- Side-chain fluorinated polymers 10
  - Fluorinated urethane polymers
  - Fluorinated acrylate/methacrylate polymers
  - Fluorinated oxetane polymers

LEGEND

USES
1. Surfactants
2. Intermediate environmental transformation product
3. Principal raw material for perfluoroalkane sulfonyl-based products including surfactants and surface protection products
4. Raw material for surfactants and surface protection products
5. Some fluoropolymer polymerization aids such as PFOA
6. Ski wax, medical applications
7. Raw material for fluorotelomer-based surfactants and surface protection products
8. High molecular weight polymeric plastics such as PTFE
9. A broad class of polymers used largely as lubricants
10. Used for surface protection

MANUFACTURING PROCESS
- A Manufactured by either ECF or Fluorotelomer Process
- B Manufactured by ECF Process
- C Manufactured by Fluorotelomerization
- D Other Processes

NOTES
- * PFOA included in subgroup
- ** PFOS included in subgroup
- *** Unsaturated derivatives are intermediate transformation products
- **** Includes "GenX" chemicals

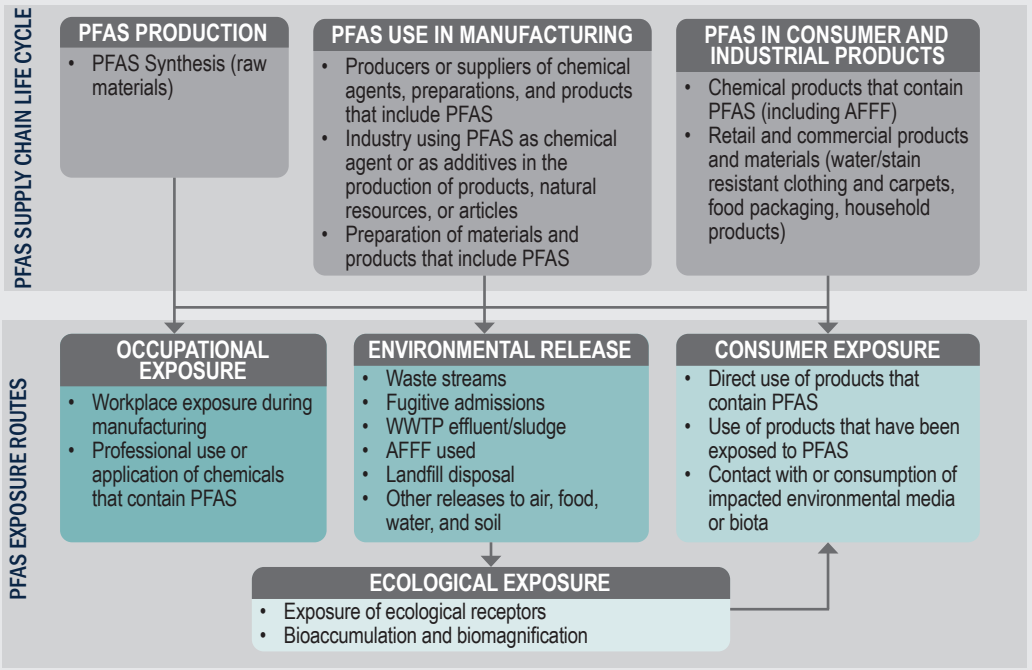
HIERARCHY
FAMILY
CLASS
SUB CLASS
GROUP
SUB GROUP

PRECURSOR KEY
POTENTIAL PFCA PRECURSORS
POTENTIAL PFSA AND PFCA PRECURSORS
POTENTIAL PFSA PRECURSORS

WHAT ARE PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)?

PFAS are a broad class of over 5,000 synthetic fluorinated chemicals used in a wide variety of manufacturing processes, consumer products, and specialty applications by commercial, military, state, and municipal sectors. PFAS have gained national attention due to their environmental persistence worldwide and potential risk posed to humans and the environment. PFAS do not breakdown easily and accumulate in the environment over time. Illustrated below is the PFAS life cycle and associated exposure routes.

PFAS SUPPLY CHAIN LIFE CYCLE AND EXPOSURE ROUTES



METHODS OF ANALYSIS

Methods for analyzing PFAS are not yet fully established. The table below summarizes analytical methods currently being used and in development.

EXISTING EPA METHODS	EPA Method 537.1	18 PFAS in drinking water - *Many analytical laboratories have developed non-standard modifications to this method to accommodate a wider range of matrices and analyses*
	EPA Method 533	25 PFAS in drinking water - *Targets and "short chain" PFAS.*
	Method 8327	24 PFAS in non-potable aqueous samples - *Considered to be a screening method due to elevated reporting limits*
	Draft Method 1633	40 PFAS in non-potable water, soil, sediment biosolids, landfill leachate, and fish tissue
	Other Test Method (OTM)-45	50 PFAS in air emissions samples from stationary sources - *Published but accepting community feedback*
	SW-846 Method 0010 Modified Method 5	Sampling train method for semi/non-volatiles in air emissions samples from stationary sources
	Modified Method TO-15	Volatile in air emission samples from stationary sources
EXISTING NON-EPA METHODS	ASTM D7979	Aqueous environmental samples
	ASTM D7968	Soil samples
	DOD QSM Table B-15	Quality control requirements for preparation/analysis of PFAS samples for non-drinking water media
METHODS IN DEVELOPMENT BY EPA	Ambient Air Methods	Several methods are under development, including real-time method, and methods for semivolatile and volatile PFAS
	Total Organic Fluorine	A rapid screening tool is under development to identify total PFAS presence/absence
	Total Oxidizable Precursors	EPA is evaluating the need to validate currently existing methods that identify PFAS precursors

PERFLUOROOCTANOIC ACID (PFOA) PERFLUOROOCTANESULFONIC ACID (PFOS) HEALTH EFFECTS WEIGHT OF EVIDENCE - *KNOWN TOXICOLOGICAL EFFECTS*

Target Organ or System	Animal Toxicity Studies	Human Epidemiological Studies	C8 Panel Conclusions (Human Studies)	Modes of Action
Serum cholesterol	●	●	Probable Link	• Persistence in tissues • Electrostatic binding to proteins • Actual or potential displacement of endogenous/exogenous substance normally bound to serum albumin such as fatty acid, minerals • Renal resorption • Initiating activation or suppression of gene transcription • Interference with intercellular communication
Diabetes	●	●		
Thyroid disease	●	●	Probable Link	
Liver disease	●	●		
Immune function	●	●		
Developmental effects	●	●		
Kidney disease	●	●		
Cancer	Kidney Testicular Pancreatic	Kidney Testicular	Probable Link	

Most completed studies on the toxicological effects of PFAS are limited to PFOA, PFOS, and/or PFHxS, only three of the 5,000+ PFAS. Additional studies are underway looking at the cumulative impacts of PFAS mixtures; however, there is still a lot of work to be done.

● Multiple studies and/or multiple lines of evidence
● Limited studies or uncertain lines of evidence
● Lines of evidence do not show positive correlation

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