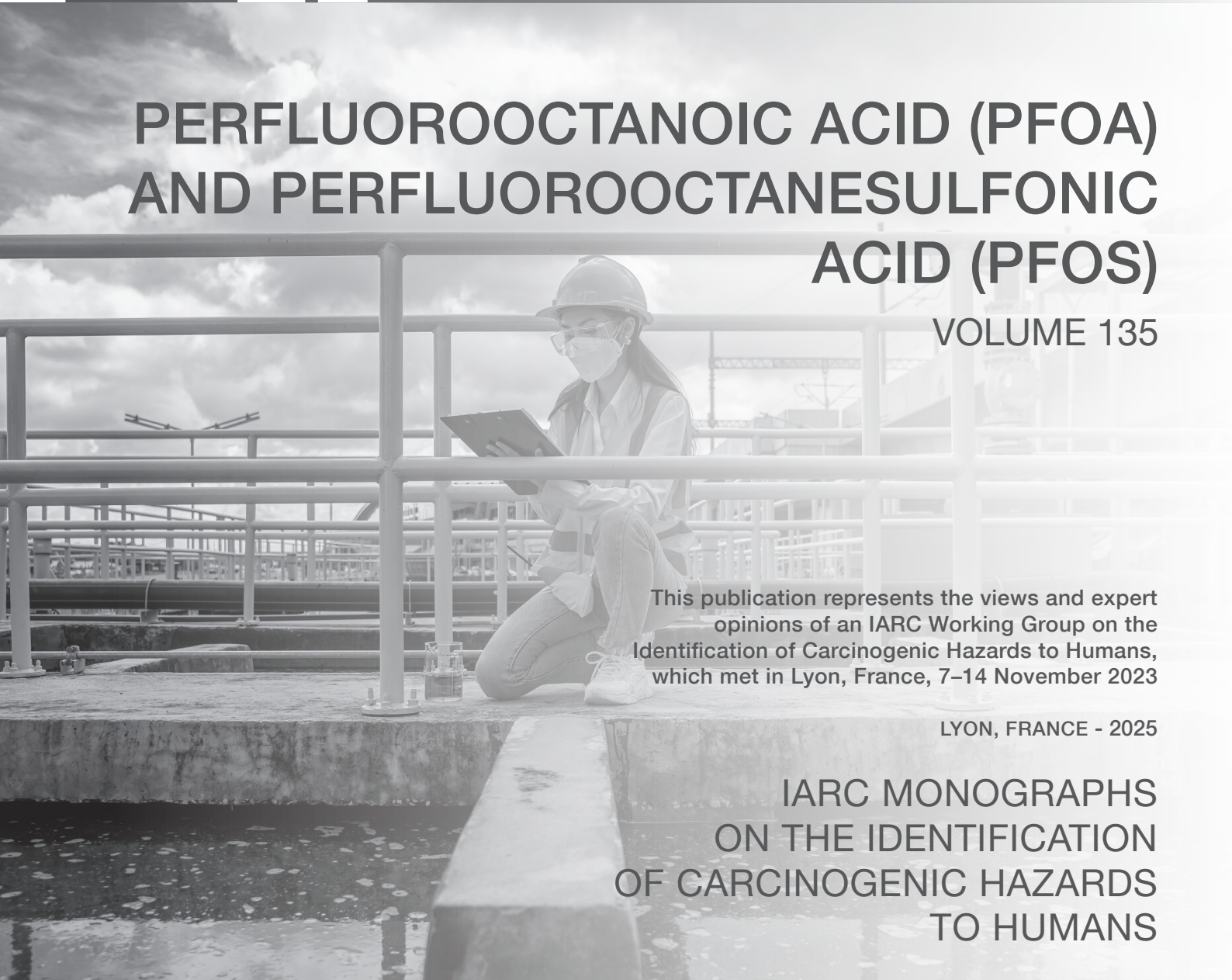


PERFLUOROOCTANOIC ACID (PFOA) AND PERFLUOROOCTANESULFONIC ACID (PFOS)

VOLUME 135



This publication represents the views and expert opinions of an IARC Working Group on the Identification of Carcinogenic Hazards to Humans, which met in Lyon, France, 7–14 November 2023

LYON, FRANCE - 2025

IARC MONOGRAPHS
ON THE IDENTIFICATION
OF CARCINOGENIC HAZARDS
TO HUMANS

Table S1.14 Occurrence of PFOS in food

Sample type	Location and collection date	No. of samples	PFOS concentration (pg/g)		Analytical method (LOD)	Comments	Reference
			Mean (range)	Median (IQR)			
Vegetables	26 developing countries ^a , 2018–2019	10	2.45 (< LOQ to 9.53)	2.06 (NR)	HPLC-MS/MS (LOQ: <i>n</i> -PFOS, 6.2 pg/g; <i>br</i> -PFOS, 1.2 pg/g; <i>n</i> -PFOS + <i>br</i> -PFOS, 7.4 pg/g)	DF, 70% Concentrations below the LOQ were set at zero	Fiedler et al. (2022)
Vegetables and vegetable products	Europe, 2000–2016 ^b	477	NR (3–150)	NR	NR	Includes fungi DF, 5 % Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Vegetables	China, 2003–2019 ^b	NR	42 (NR)	NR	NR	DF, NR	Fan et al. (2021)
Cranberries	USA, 2021	42	NR	NR	LC-HRMS (MDL, 28 pg/g cereal)	DF, 0%	US FDA (2022a)
Fruit and fruit products	Europe, 2007–2016 ^b	143	NR (27–250)	NR	NR	DF, 23% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Fruits	China, 2003–2019 ^b	NR	0.82 (NR)	NR	NR	DF, NR	Fan et al. (2021)
Grains and grain-based products	Europe, 2000–2016 ^b	93	< LOQ (NR)	NR	NR	DF, 0% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Grains and grain-based products	China, 2003–2019 ^b	NR	120 (NR)	NR	NR	DF, NR	Fan et al. (2021)

Table S1.14 Occurrence of PFOS in food

Sample type	Location and collection date	No. of samples	PFOS concentration (pg/g)		Analytical method (LOD)	Comments	Reference
			Mean (range)	Median (IQR)			
Grains and grain-based products	USA, 2021	17	NR	NR	LC-HRMS (MDL, 33 pg/g)	DF, 0%	US FDA (2022a)
Fish and other seafood	26 developing countries ^a , 2018–2019	76	124 (< LOQ to 1650)	30.0	HPLC-MS/MS (LOQ: <i>n</i> -PFOS, 6.2 pg/g; <i>br</i> -PFOS, 1.2 pg/g; <i>n</i> -PFOS + <i>br</i> -PFOS, 7.4 pg/g)	DF, 95% Concentrations below the LOQ were set at zero	Fiedler et al. (2022)
Fish and other seafood (fish meat)	Europe, 2000–2016 ^b	2637	580	NR	NR	DF, 51% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Fish and other seafood (fish offal)	Europe, 2000–2016 ^b	612	3379	NR	NR	DF, 16% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Fish and other seafood (fish and shrimp)	China, 2003–2019 ^b	NR	2760	NR	NR	DF, NR	Fan et al. (2021)
Fish and shrimp products	USA, 2021	7	[56] (< MDL to 216)	[28]	LC-HRMS (MDL, 28 pg/g)	DF, 20%	US FDA (2022a); Barbo et al. (2023)
Fish and other seafood	Washington (DC), USA 2021–2022	81	NR (< MDL to 1235)	NR	LC-MS/MS (MDL, 39–45 pg/g)	DF, 35%	Young et al. (2022)
Meat and meat products	26 developing countries ^a ,	9	37.6 (< LOQ to 84.4)	30.5	HPLC-MS/MS	DF, 89%	Fiedler et al. (2022)

Table S1.14 Occurrence of PFOS in food

Sample type	Location and collection date	No. of samples	PFOS concentration (pg/g)		Analytical method (LOD)	Comments	Reference
			Mean (range)	Median (IQR)			
(beef)	2018–2019				(LOQ: <i>n</i> -PFOS, 6.2 pg/g; br-PFOS, 1.2 pg/g; <i>n</i> -PFOS + br-PFOS, 7.4 pg/g)	Concentrations below the LOQ were set at zero	
Meat and meat products (sheep)	26 developing countries ^a , 2018–2019	2	39.6 (24.0–55.1)	39.6	HPLC-MS/MS (LOQ: <i>n</i> -PFOS, 6.2 pg/g; br-PFOS, 1.2 pg/g; <i>n</i> -PFOS + br-PFOS, 7.4 pg/g)	DF, 100% Concentrations below the LOQ were set at zero	Fiedler et al. (2022)
Meat and meat products (chicken)	26 developing countries ^a , 2018–2019	14	5.80 (< LOQ to 32.0)	< LOQ	HPLC-MS/MS (LOQ: <i>n</i> -PFOS, 6.2 pg/g; br-PFOS, 1.2 pg/g; <i>n</i> -PFOS + br-PFOS, 7.4 pg/g)	DF, 36% Concentrations below the LOQ were set at zero	Fiedler et al. (2022)
Meat and meat products (livestock meat)	Europe, 2000–2016 ^b	461	28	NR	NR	DF, 7% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Meat and meat products (poultry)	Europe, 2000–2016 ^b	169	9	NR	NR	DF, 1% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Meat and meat products (game mammals)	Europe, 2000–2016 ^b	574	940	NR	NR	DF, 29% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Meat and meat products	China, 2003–2019 ^b	NR	300	NR	NR	DF, NR	Fan et al. (2021)

Table S1.14 Occurrence of PFOS in food

Sample type	Location and collection date	No. of samples	PFOS concentration (pg/g)		Analytical method (LOD)	Comments	Reference
			Mean (range)	Median (IQR)			
Meat and meat products	USA, 2021	13	< MDL	< MDL	LC-HRMS (MDL, 28 pg/g)	DF, 0%	US FDA (2022a)
Milk and dairy products (butter)	26 developing countries ^a , 2018–2019	13	18.4 (< LOQ to 103)	8.77	HPLC-MS/MS (LOQ: <i>n</i> -PFOS, 6.2 pg/g; <i>br</i> -PFOS, 1.2 pg/g; <i>n</i> -PFOS + <i>br</i> -PFOS, 7.4 pg/g)	DF, 54% Concentrations below the LOQ were set at zero	Fiedler et al. (2022)
Milk and dairy products (milk)	26 developing countries ^a , 2018–2019	7	22.1 (< LOQ to 74.3)	13.2	HPLC-MS/MS (LOQ: <i>n</i> -PFOS, 6.2 pg/g; <i>br</i> -PFOS, 1.2 pg/g; <i>n</i> -PFOS + <i>br</i> -PFOS, 7.4 pg/g)	DF, 71% Concentrations below the LOQ were set at zero	Fiedler et al. (2022)
Milk and dairy products (milk)	Europe, 2000–2016 ^b	235	0.77	NR	NR	DF, 4%, Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Milk and dairy products (cheese)	Europe, 2000–2016 ^b	115	2.9	NR	NR	DF, 0.5%, Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Milk and dairy products	China, 2003–2019 ^b	NR	21.6 pg/mL	NR	NR	DF, NR	Fan et al. (2021)
Milk	USA, 2021	10	[194] (< MDL to 640)	[< MDL]	LC-HRMS (MDL, 24 pg/g)	DF, 40% Samples from two farms near an air force base with contaminated groundwater	US FDA (2022a)
Eggs	26 developing countries ^a ,	36	45.6 (< LOQ to 326)	26.0	HPLC-MS/MS	DF, 75%	Fiedler et al. (2022)

Table S1.14 Occurrence of PFOS in food

Sample type	Location and collection date	No. of samples	PFOS concentration (pg/g)		Analytical method (LOD)	Comments	Reference
			Mean (range)	Median (IQR)			
	2018–2019				(LOQ: <i>n</i> -PFOS, 6.2 pg/g; br-PFOS, 1.2 pg/g; <i>n</i> -PFOS + br-PFOS, 7.4 pg/g)	Concentrations below the LOQ were set at zero	
Eggs and egg products	Europe, 2000–2016 ^b	174	267	NR	NR	DF, 8% Concentrations below the LOQ were set at zero	Schrenk et al. (2020)
Eggs and egg products	China, 2003–2019 ^b	NR	150	NR	NR	DF, NR	Fan et al. (2021)
Eggs	USA, 2021	174	NR	NR	LC-HRMS (MDL, 82 pg/g)	DF, 0%	US FDA (2022a)

DC, District of Columbia; DF, detection frequency; HPLC, high-performance liquid chromatography; HRMS, high-resolution mass spectrometry; IQR, interquartile range; LC, liquid chromatography; LOD, limit of detection; LOQ, limit of quantification; MDL, method detection limit; MS/MS, tandem mass spectrometry; NR, not reported; PFOS, perfluorooctanesulfonic acid; br-PFOS, branched chain perfluorooctanesulfonic acid; *n*-PFOS, linear perfluorooctanesulfonic acid; USA, United States of America.

^a Twenty-six developing countries in Africa ($n = 10$), Asia ($n = 4$), Group of Latin America and the Caribbean countries (GRULAC; $n = 8$), and the Pacific Islands (PAC; $n = 4$).

^b Reported data from several studies.

1

References

- 2 Barbo N, Stoiber T, Naidenko OV, Andrews DQ (2023). Locally caught freshwater fish across the United States are likely a significant source of exposure to PFOS and other
3 perfluorinated compounds. *Environ Res.* 220:115165. <https://doi.org/10.1016/j.envres.2022.115165> PMID:36584847
- 4 Fan X, Wang Z, Li Y, Wang H, Fan W, Dong Z (2021). Estimating the dietary exposure and risk of persistent organic pollutants in China: a national analysis. *Environ Pollut.* 288:117764.
5 <https://doi.org/10.1016/j.envpol.2021.117764> PMID:34280741

- 6 Fiedler H, Sadia M, Baabish A, Sobhane S (2022). Perfluoroalkane substances in national samples from global monitoring plan projects (2017–2019). *Chemosphere*. 307(Pt 3):136038.
7 <https://doi.org/10.1016/j.chemosphere.2022.136038> PMID:35977568
- 8 Schrenk D, Bignami M, Bodin L, Chipman JK, Del Mazo J, Grasl-Kraupp B, et al. (2020). Risk to human health related to the presence of perfluoroalkyl substances in food. *EFSA J*.
9 18(9):e06223. <https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2020.6223> PMID:32994824
- 10 US FDA (2022a). Analytical results of testing food for PFAS from environmental contamination. Silver Spring (MD), USA: United States Food and Drug Administration. Available
11 from: <https://www.fda.gov/food/process-contaminants-food/analytical-results-testing-food-pfas-environmental-contamination>, accessed October 2024.
- 12 Young W, Wiggins S, Limm W, Fisher CM, DeJager L, Genualdi S (2022). Analysis of per- and poly(fluoroalkyl) substances (PFASs) in highly consumed seafood products from US
13 markets. *J Agric Food Chem*. 70(42):13545–53. <https://doi.org/10.1021/acs.jafc.2c04673> PMID:36251396