Supplementary information

Recent advances and challenges of analytical methods for detection of perfluoroalkyl and polyfluoroalkyl substances

Linh Q. Phan,[1,2] Kien G. Nguyen,[1,2] Thuan V. Tran[1,2*]

[1] Center for Hi-Tech Development, Nguyen Tat Thanh University, Saigon Hi-Tech Park, Ho Chi Minh City, Vietnam.

[2] Institute of Applied Technology and Sustainable Development, Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam.

*Corresponding author. Tel: (+84) 0902 298 300

Email: tranvt@ntt.edu.vn (Thuan V. Tran)

Nguyen Tat Thanh University, Ho Chi Minh City, Vietnam.

Table S1. The occurrence of PFAS in various sources.

Compound	Source	Nation	Measured concentration	Ref.
24 types of PFAS	Groundwater	USA	1–1000 ng L^{-1}	1
19 types of PFAS	Besòs River Delta	Spain	9–1007 ng L^{-1}	2
29 types of PFAS	Groundwater, stream water	USA	Groundwater: 20–4773 ng L^{-1}, stream water: 426–3617 ng L^{-1}	3
8 types of PFAS	Santa Cruz River	USA	5–500 ng L^{-1}	4
38 types of PFAS	Bogotá River	Colombia	60–520 ng L^{-1}	5
43 types of PFAS	Surface water, groundwater, sediment	Fluorochemical industrial parks in China	Surface water; 0.4–765 μg L^{-1}, Groundwater: 0.6–306 μg L^{-1}, Sediment: 2.0–1231 μg g^{-1}	6
10 types of PFAS	Groundwater	China	1.1–34.3 ng L^{-1}	7
18 types of PFAS	Soil	China	0.03–58.3 μg kg^{-1}	8

17 types of PFAS	Biosolid	USA	0.84–146.3 µg kg^{-1}	9
3 types of PFAS	Soil	Italy	1405–3756 ng g^{-1}	10
9 types of PFAS	Irrigation water	Italy	98–9867 ng L^{-1}	10
24 types of PFAS	Soil	Germany	2–150 µg kg^{-1}	11
20 types of PFAS	Paper-based food package	Spain	0.002–6.53 µg kg^{-1}	12
27 types of PFAS	Fast food: ice cream, instant noodles, bubble tea	China	0–2.09 ng g^{-1}	13
17 types of PFAS	Eggs	Belgium	0–241 ng g^{-1}	14
13 types of PFAS	Ready-to-eat food, frozen food, fresh food	Italy	Ready-to-eat food: 0.014–0.391 ng g^{-1}, frozen food: 0.009–0.166 ng g^{-1}, fresh food: 0.007–0.296 ng g^{-1}	15
39 types of PFAS	Breast milk	USA	52–1850 pg mL^{-1}	16
38 types of	Blood serum	USA	0–32.9 ng mL^{-1}	17

PFAS

26 types of PFAS	Human cerebrospinal fluid	China	0–11761 pg mL^{-1}	18
20 types of PFAS	Blood serum, postmortem brain	Australia	Blood serum: 0.01–18 ng mL^{-1}, Postmortem brain: 0.002–1.7 ng g^{-1}	19
17 types of PFAS (13 PFA + 4 PFS)	Freshwater fish species in West Lake and Yen So Lake	Vietnam	Liver samples: 2.7–6.6 ng g^{-1} wet weight Muscle samples: 0.51–2.6 ng g^{-1} wet weight	20
17 types of PFAS (13 PFCAs + 4 PFSs)	Food packaging samples in Vietnamese markets	Vietnam	Mochi paper tray samples: 372–624 ng g^{-1}	21
7 types of PFAS	Groundwater samples at industrial waste disposal site areas	Thailand	PFOA up to 34.96 ng L^{-1} and PFOS up to 25.88 ng L^{-1}	22
PFOS and PFOA	Marine species in Rayong, Samut Sakhon, and Bangkok	Thailand	PFOS: from less than 24 ng kg^{-1} to 623 ng kg^{-1} wet weight, PFOA: from less than 48 ng kg^{-1} to 419 ng kg^{-1}	23

10 types of PFAS	Kuantan River, Kim Kim River	Malaysia	- Kuantan River: PFBA has the highest concentration of 1.99 ± 0.44 ng L^{-1}; - Kim Kim River: PFPeA has the highest concentration of 35.8 ± 24.65 ng L^{-1}	24
15 types of PFAS	Fish, invertebrates, sediment and water	Vaal River, South Africa	- Sediment: below limit of detection, except for PFOS at Thabela Thabeng (2.36 ng g^{-1} dry weight). - Water: from below limit of detection to 38.5 ng L^{-1} - Invertebrates: from below limit of detection to 34.5 ng g^{-1} wet weight - Liver: from below limit of detection to 289 ng g^{-1} wet weight. - Muscle tissue: from	25

			below limit of detection to 34.0 ng g^{-1} wet weight.	
FTOHs, PFOS, PFOA, PFHxS and PFDS	Indoor dust and food packaging materials	Cairo, Egypt	FTOHs: 1.3–69 ng g^{-1} (dominant), PFOS and PFOA were detected at 58–79% of the samples, PFHxS and PFDS: below limit of detection.	26
23 types of PFAS	Groundwater of water wells, surface water	Porto Alegre, Brazil	Groundwater: 22–718 ng L^{-1}, surface water: 11–17 ng L^{-1}	27
17 types of PFAS	Aqueous film-forming foams in a petrochemical terminal in the Port of Santos	Brazil	500–9000 ng g^{-1}	28
4 types of PFAS	Surface water and feedstuff samples from aquaculture cages	Três Marias reservoir, Brazil	9.40–15.2 µg L^{-1}	29

Reference

1   P. B. McMahon, A. K. Tokranov, L. M. Bexfield, B. D. Lindsey, T. D. Johnson, M. A. Lombard and E. Watson, *Environ. Sci. Technol.*, 2022, **56**, 2279–2288.

2   C. Sáez, A. Bautista, O. Nikolenko, L. Scheiber, M. Llorca, A. Jurado, M. Farré and E. Pujades-Garnes, *Environ. Pollut.*, 2024, **358**, 124468.

3   M.-A. Pétré, D. P. Genereux, L. Koropeckyj-Cox, D. R. U. Knappe, S. Duboscq, T. E. Gilmore and Z. R. Hopkins, *Environ. Sci. Technol.*, 2021, **55**, 5848–5856.

4   T. T. Cáñez, B. Guo, J. C. McIntosh and M. L. Brusseau, *Sci. Total Environ.*, 2021, **791**, 147906.

5   A. Ramírez-Canon, A. Paola Becerra-Quiroz and F. Herrera-Jacquelin, *Environ. Adv.*, 2022, **8**, 100223.

6   D. Song, B. Qiao, Y. Yao, L. Zhao, X. Wang, H. Chen, L. Zhu and H. Sun, *J. Hazard. Mater.*, 2023, **460**, 132411.

7   J. Xingchun, Z. Wei, P. Jing, L. Guohui, C. Dian, Z. Zhaohe and Z. Yiran, *Sci. Total Environ.*, 2023, **901**, 165904.

8   B. Tansel, Y. Katsenovich, N. S. Quinete, J. Ocheje, Z. Nasir and M. M. Manzano, *J. Environ. Manage.*, 2024, **370**, 122395.

9   R. Alvarez-Ruiz, L. S. Lee and Y. Choi, *Sci. Total Environ.*, 2024, **954**, 176540.

10   I. Battisti, A. R. Trentin, E. Franzolin, C. Nicoletto, A. Masi and G. Renella, *Sci. Total Environ.*, 2024, **915**, 170032.

11   T. M. Melo, M. Schauerte, A. Bluhm, M. Slaný, M. Paller, N. Bolan, J. Bosch, A. Fritzsche and J. Rinklebe, *J. Hazard. Mater.*, 2022, **433**, 128771.

12   P. Vázquez Loureiro, K.-H. Nguyen, A. Rodríguez Bernaldo de Quirós, R. Sendón, K. Granby and A. A. Niklas, *Chemosphere*, 2024, **360**, 142360.

13   Z. Huang, X. Zhang, X. Wang, Z. Deji and H. K. Lee, *J. Agric. Food Chem.*, 2022, **70**, 10836–10846.

14   R. Lasters, T. Groffen, M. Eens, D. Coertjens, W. A. Gebbink, J. Hofman and L. Bervoets, *Chemosphere*, 2022, **308**, 136283.

15   E. Piva, P. Fais, P. Ioime, M. Forcato, G. Viel, G. Cecchetto and J. P. Pascali, *Food Chem.*, 2023, **410**, 135415.

16   G. Zheng, E. Schreder, J. C. Dempsey, N. Uding, V. Chu, G. Andres, S. Sathyanarayana and A. Salamova, *Environ. Sci. Technol.*, 2021, **55**, 7510–7520.

17   A. A. Schultz, N. Stanton, B. Shelton, R. Pomazal, M. A. Lange, R. Irving, J. Meiman and K. C. Malecki, *J. Expo. Sci. Environ. Epidemiol.*, 2023, **33**, 766–777.

18   W. Hu, M.-Y. Zhang, L.-Y. Liu, Z.-F. Zhang and Y. Guo, *J. Hazard. Mater.*, 2023, **442**, 130003.

19   M. Suzuki, S. Nilsson, C. E. Shepherd, I. Zammit, E. Suryana, N. Mueller, G. Halliday, X. Wang, C. Symeonides, S. Dunlop and J. F. Mueller, *Environ. Sci. Technol.*, 2025, **59**, 3366–3375.

20   N. T. Q. Hoa, T. T. Lieu, H. Q. Anh, N. T. A. Huong, N. T. Nghia, N. T. Chuc, P. D. Quang, P. T. Vi and L. H. Tuyen, *Environ. Sci. Pollut. Res.*, 2022, **29**, 52057–52069.

21   A. Q. Hoang, T. L. Tran, L. H. Tuyen, T. A. H. Nguyen, D. M. Pham, T. C. Nguyen, T. N. Nguyen, D. Q. Phan, M. K. Nguyen, V. Q. Tran, C. T. Pham, Q. Do Bui and T. Q. H. Nguyen, *Environ. Sci. Pollut. Res.*, 2023, **30**, 104181–104193.

22   C. Hongkachok, S. K. Boontanon, N. Boontanon, S. Sukeesan, C. Polprasert and S. Fujii, *Int. J. Environ. Sci. Technol.*, 2023, **20**, 12437–12448.

23   T. Lertassavakorn, N. Pholphana, N. Rangkadilok, T. Suriyo, S. Thaeopattha, P. Teeyapant and J. Satayavivad, *Environ. Monit. Assess.*, 2025, **197**, 1258.

24   M. R. Razak, D. E. M. Haron, M. Q. J. Roslan, N. A. binti A. Sabri and A. Z. Aris, *Ecotoxicol. Environ. Saf.*, 2025, **302**, 118739.

25   T. Groffen, V. Wepener, W. Malherbe and L. Bervoets, *Sci. Total Environ.*, 2018, **627**, 1334–1344.

26   T. Shoeib, Y. Hassan, C. Rauert and T. Harner, *Chemosphere*, 2016, **144**, 1573–1581.

27   P. H. P. Stefano, A. Roisenberg, R. D'Anna Acayaba, A. P. Roque, D. R. Bandoria, A. Soares and C. C. Montagner, *Environ. Sci. Pollut. Res.*, 2023, **30**, 6159–6169.

28   K. Pozo, L. B. Moreira, P. Karaskova, P. Přibylová, J. Klánová, M. U. de Carvalho, L. A. Maranho and D. M. de Souza Abessa, *Mar. Pollut. Bull.*, 2022, **182**, 113938.

29   D. A. da S. Rodrigues, M. C. V. M. Starling, A. L. C. de Barros, M. C. Santos, E. S. da Silva, G. C. C. Viana, L. F. da S. Ribeiro, M. F. Simcik and C. C. Amorim, *Chemosphere*, 2024, **352**, 141444.