PFAS - Vermeidbar, ersetzbar, unverzichtbar ?!
Freie Universität Berlin, 7.–8. April 2025

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Significance of Perfluoroalkyl Substances (PFAS)

in Food and their Current Legal Regulation

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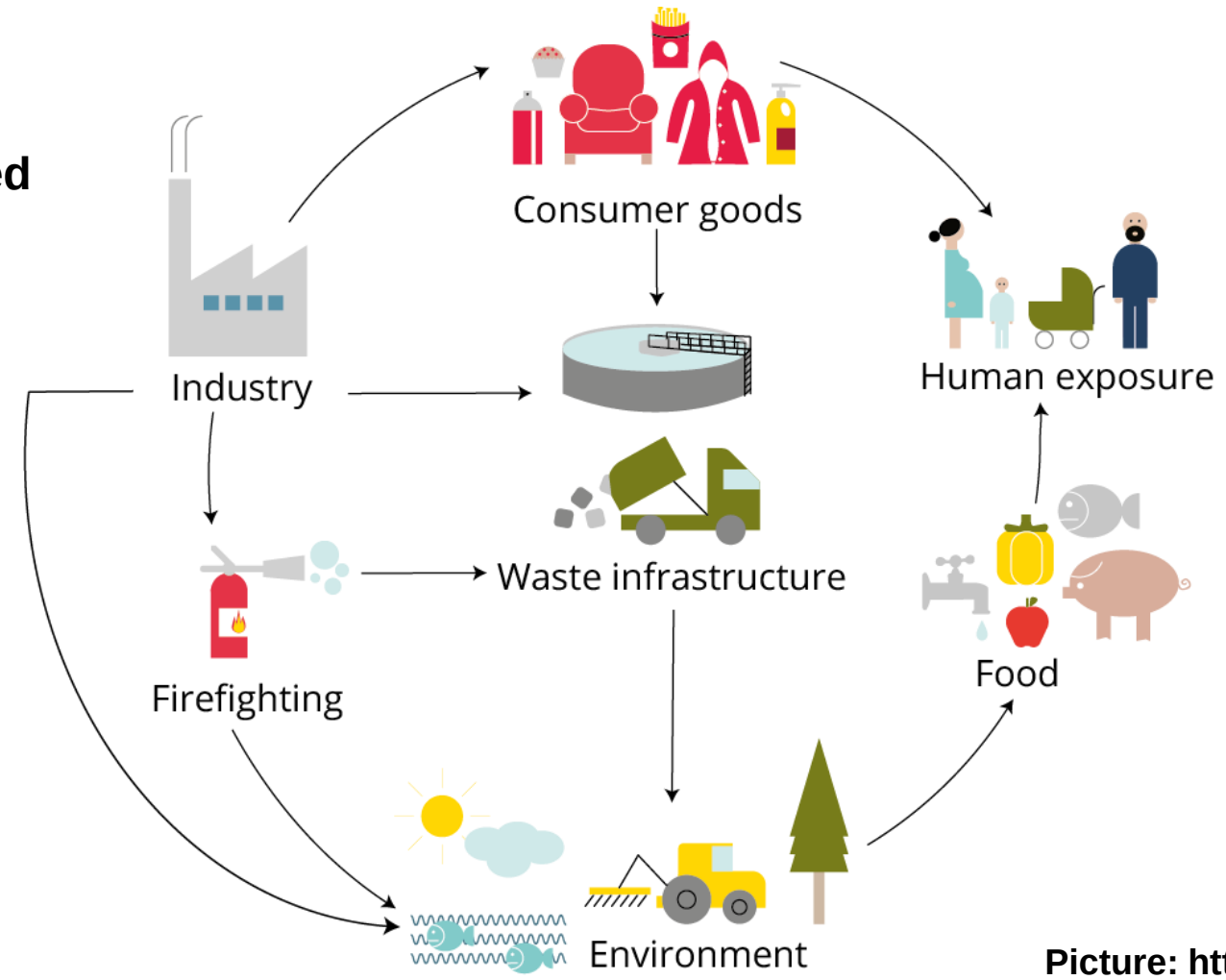
One Health Approach:
Almost everything is connected



Picture: https://www.eea.europa.eu

Introduction – Routes of Entry, Toxicity, Elimination

Brunn *et al. Environmental Sciences Europe* 2023, **35**(1):20
https://doi.org/10.1186/s12302-023-00721-8

Environmental Sciences Europe

REVIEW Open Access

PFAS: forever chemicals—persistent, bioaccumulative and mobile. Reviewing the status and the need for their phase out and remediation of contaminated sites

Hubertus Brunn[1*], Gottfried Arnold[2], Wolfgang Körner[3], Gerd Rippen[4], Klaus Günter Steinhäuser[5] and Ingo Valentin[6]

> 500 References

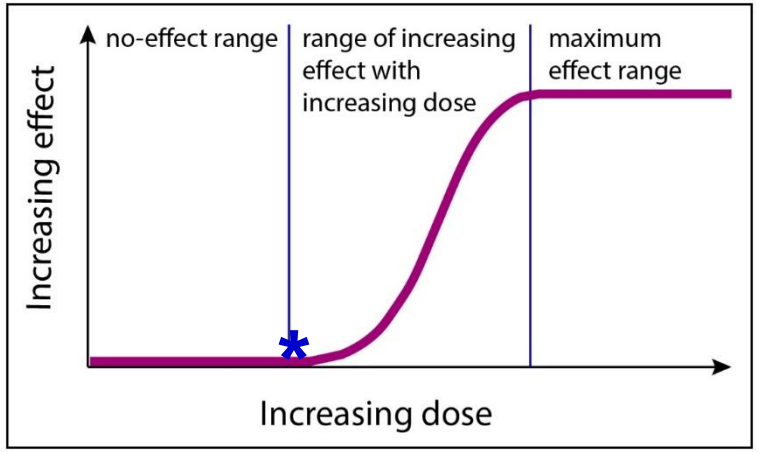
Introduction – Conclusions Relevant for Food Safety (Brunn et al. 2023)

- ✓ Best studied PFAS are **carboxylic and sulfonic acids C4 to C14**
- ✓ PFOA and PFOS harmful to aquatic fauna, insects, and amphibians at **a few µg/L or less**
- ✓ **Accumulation** in organisms, **biomagnification** in food webs
- ✓ Humans are subjected to PFAS uptake primarily through **food and drinking water**
- ✓ PFAS are a major **challenge for analysis**: single-substance analyses capture only a fragment of PFAS
- ✓ The high mobility of per- and polyfluorinated carboxylic and sulfonic acids makes soil and groundwater pollution at contaminated sites a problem (**hot spots**)
- ✓ In general **short-chain PFAS are more mobile than long-chain ones**
- ✓ **Recycling** of PFAS-containing products such as paper and food packaging **leads to carryover of the contaminants**
- ✓ **The switch to short-chain representatives**, per- and polyfluorinated oxo carboxylic acids, telomeric alcohols and acids **leads to increased environmental concentrations of them**

Introduction – Risk Assessment

If it is possible to derive a NO(A)EL* for a non directly acting genotoxic contaminant, you divide this concentration by a safety factor to obtain e.g., TDI or TWI.

Tolerable daily/weekly intake (TDI / TWI) indicates the amount of a pollutant or group of pollutants, which, according to current knowledge, can be ingested weekly over the entire lifetime without posing a health risk to humans.

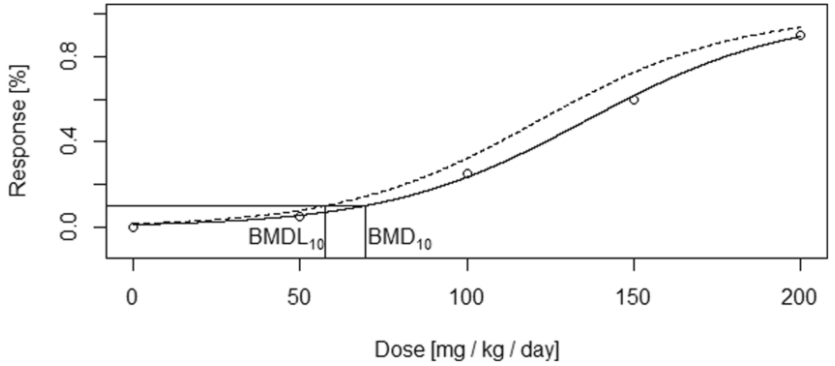


https://toxedfoundation.org/basics-of-dose-response/

Setting of maximum levels:

Evaluation of a toxicological reference value (TDI /TWI or $BMDL_{10}$) is one important factor:

Based on: *in-vitro studies*, animal studies, human data (e.g., via biomarker, body burden)



Yoshii et al. 2020

Other considerations relevant, e.g. the **ALARA** principle ("As Low As Reasonably Achievable")

EFSA – Scientific Opinions (2008–2020)

First Opinion 2008

TDI PFOA: 1500 ng/kg/bw

TDI PFOS: 150 ng/kg bw

(Animal studies)

Second Opinion 2018

TWI PFOA: 6 ng/kg/bw

TWI PFOS: 13 ng/kg bw

(Human data: increase of LDL cholesterol)

EFSA Journal

SCIENTIFIC OPINION

ADOPTED: 9 July 2020

doi: 10.2903/j.efsa.2020.6223

Risk to human health related to the presence of perfluoroalkyl substances in food

EFSA Panel on Contaminants in the Food Chain (EFSA CONTAM Panel),
Dieter Schrenk, Margherita Bignami, Laurent Bodin, James Kevin Chipman, Jesús del Mazo,
Bettina Grasl-Kraupp, Christer Hogstrand, Laurentius (Ron) Hoogenboom,
Jean-Charles Leblanc, Carlo Stefano Nebbia, Elsa Nielsen, Evangelia Ntzani, Annette Petersen,
Salomon Sand, Christiane Vleminckx, Heather Wallace, Lars Barregård, Sandra Ceccatelli*,
Jean-Pierre Cravedi, Thorhallur Ingi Halldorsson, Line Småstuen Haug, Niklas Johansson,
Helle Katrine Knutsen, Martin Rose, Alain-Claude Roudot, Henk Van Loveren, Günter Vollmer,
Karen Mackay, Francesca Riolo and Tanja Schwerdtle

422 References

The 4 EFSA PFAS – Sum Value, Similar Mode of Action

- ✓ Perfluorooctane sulfonic acid (PFOS, ban 2011)
- ✓ Perfluorooctanoic acid (PFOA, ban 2021)
- ✓ Perfluorononanoic acid (PFNA, ban 2022)
- ✓ Perfluorohexane sulfonic acid (PFHxS, ban 2022)

- Contamination of food via **bioaccumulation** in aquatic and terrestrial food chains
- **Diet** including drinking water is the major source of PFAS exposure
- Food contact materials containing PFAS is likely to contribute to human exposure
- Probably cosmetics (PFAS are used in mascara, make-up and lipsticks) and personal care products with minor relevance
- No accumulation in fat, but **binding to proteins and storage and accumulation in blood, liver and kidneys**

Toxicological Outcomes

- **Impairment of the immune system: PFAS can impair the immune response, which can lead to a reduced effectiveness of vaccinations.**

- Elevated cholesterol levels: Exposure is associated with higher total and LDL cholesterol levels, which may increase the risk of cardiovasculardisease.

- Delayed development: PFAS may affect fetal and infant development,including the risk of lower birth weight.

- Impairment of liver function: Exposure may cause elevated liver enzyme levels, indicating liver damage or dysfunction.

- There are concerns about an increased risk of kidney and testicular cancer. No evidence for a direct genotoxic mode of action for PFOS and PFOA was identified.

efsa EUROPEAN FOOD SAFETY AUTHORITY

The Most Sensitive Toxicological Endpoint

Lower number of antibodies after vaccination in infants who had been breastfed for a longer period of time

(1) From a human study, a **lowest $BMDL_{10}$ of 17.5 ng/mL for the sum of the four PFASs** in serum was identified for 1-year-old children.

(2) Using PBPK (Physiologically-based pharmacokinetic) modelling, this serum level of 17.5 ng/mL in children was estimated to **correspond to longterm maternal exposure of 0.63 ng/kg bw per day**.

(3) Since accumulation over time is important, **a tolerable weekly intake (TWI) of 4.4 ng/kg bw** was established.

EUROPEAN FOOD SAFETY AUTHORITY

The Most Sensitive Toxicological Endpoint – Quality Control

(1) EFSA (2020) **Outcome of a public consultation on the draft risk assessment of perfluoroalkyl substances in food**. EFSA supporting publication 2020: EN-1931. 202 pp. DOI:10.2903/sp.efsa.2020.EN-1931

(2) Immunological adverse effects confirmed by animal experiments

(3) BfR, Opinion 020/2021

“The overall view of the results of the external and internal exposure estimates shows that parts of the popular-tion in Germany are exposed to PFOS, PFOA, PFNA and PFHxS at levels are exposed to PFOS, PFOA, PFNA and PFHxS at a level that is associated with a lower concentration of vaccine antibodies in the blood serum. **This is also possible in children between 1 and 9 years of age with high PFAS exposure via their diet**.”

Legislation – Maximum Levels for the Sum of 4 PFAS

COMMISSION REGULATION (EU) 2023/915

of 25 April 2023

on maximum levels for certain contaminants in food and repealing Regulation (EC) No 1881/2006

4.2	**Perfluoroalkyl substances**	Maximum level (µg/kg)					Remarks
		PFOS	**PFOA**	**PFNA**	**PFHxS**	**Sum of PFOS, PFOA, PFNA and PFHxS**	The maximum level applies to the wet weight. PFOS: perfluorooctane sulfonic acid PFOA: perfluorooctanoic acid PFNA: perfluorononanoic acid PFHxS: perfluorohexane sulfonic acid For PFOS, PFOA, PFNA, PFHxS and their sum, the maximum level refers to the sum of linear and branched stereoisomers, whether they are chromatographically separated or not. For the sum of PFOS, PFOA, PFNA and PFHxS, maximum levels refer to lower bound concentrations, which are calculated on the assumption that all the values below the limit of quantification are zero.
4.2.1	Meat and edible offal (2)						
4.2.1.1	Meat of bovine animals, pig and poultry	0,30	0,80	0,20	0,20	1,3	
4.2.1.2	Meat of sheep	1,0	0,20	0,20	0,20	1,6	
4.2.1.3	Offal of bovine animals, sheep, pig and poultry	6,0	0,70	0,40	0,50	8,0	
4.2.3	Eggs	1,0	0,30	0,70	0,30	1,7	

Food Monitoring in Germany (Overview in BfR, Opinion 020/2021)

Lebensmittelhauptgruppe	Summe (PFHxS, PFNA, PFOA, PFOS)			
	Anzahl Proben	Anteil bestimmbarer Werte[a]	Mittelwert Gehalte [µg/kg]	95. Perzentil Gehalte [µg/kg]
Getreide und Produkte auf Getreidebasis	21	4,8 %	0,07	0[b]
Gemüse und Gemüseprodukte	184	17,4 %	0,18	1,29
Stärkehaltige Wurzeln oder Knollen und Erzeugnisse	95	1,1 %	0,01	0[b]
Obst und Obstprodukte	108	0,9 %	0,01	0[b]
Fleisch und Fleischerzeugnisse	762	41,3 %	52,90	339,87
Fisch und Fischerzeugnisse	904	45,0 %	5,38	30,00
Milch und Milchprodukte	379	13,7 %	0,01	0,04
Eier und Eiprodukte	26	23,1 %	0,36	1,60
Zucker, Süßwaren und wasserbasierte süße Desserts	34	0 %	0	0
Wasser und wasserbasierte Getränke[c]	554	14,4 %	0,001	0,004
Produkte für Säuglinge und Kleinkinder	61	0 %	0	0

[a] Ein Wert wurde als bestimmbar gezählt, wenn in der Probe mindestens eine der vier PFAS bestimmbar gewesen ist.
[b] Anteil bestimmbarer Werte <5 %, daher im 95. Perzentil 0
[c] ohne Trinkwasser

Food Monitoring in Germany (Overview in BfR, Opinion 020/2021)

	Summe (PFHxS, PFNA, PFOA, PFOS)			
Lebensmittelgruppe	**Anzahl Proben**	**Anteil bestimmbare Werte[m]**	**Mittelwert Gehalte [µg/kg]**	**95. Perzentil Gehalte [µg/kg]**
Fleisch mehrerer Tiere[a]	28	0 %	0	0
Fleisch Rind/Kalb	11	72,7 %	1,34	2,95
Fleisch Schaf/Lamm	1	0 %	0	0
Fleisch Schwein	39	25,6 %	0,05	0,01
Fleisch sonstige Säuger nicht-Wild[b]	43	0 %	0	0
Fleisch Wildschwein	68	73,5 %	33,77	236,93
Fleisch Reh Fleisch	38	2,6 %	0,03	0[l]
Fleisch Hirsch	12	0 %	0	0
Fleisch sonstige Säuger Wild[c]	4	0 %	0	0
Fleisch Huhn	38	10,5 %	0,19	1,49
Fleisch Pute	39	15,4 %	<0,01	0,02
Fleisch sonstiges Geflügel nicht-Wild[d]	6	16,7 %	2,37	10,65
Fleisch Geflügel Wild	8	62,5 %	4,17	16,23
Leber Rind/Kalb	136	56,6 %	3,67	11,08
Leber Schwein Leber	89	14,6 %	0,81	5,56
Leber Schaf/Lamm	8	62,5 %	3,83	11,46

Domestic pig

Wild boar

Rapid Alert System for Food and Feed

Reference	Category	Type	Subject	Date	Origin	Notifying	Classification	Decision
2025.2407	Crustaceans and products thereof	food	PFAS and PFNA in crab from China	1 APR 2025	China	Netherlands	alert notification	serious
2025.1372	Fish and fish products	food	Excessive PFAS compounds detected in horse mackerel	26 FEB 2025	Ireland	Ireland	information notification for attention	potential risk

Items per page: 25
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Sampling	Hazard	Category	Analytical results	Maximum
16 SEP 2024	**Perfluoroalkyl substances (PFAS) - environmental pollutants**	Environmental pollutants	50.487 ± 4.372 µg/kg - ppb	8 µg/kg - ppb

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Showing 1–1 of 1

Sampling	Hazard	Category	Analytical results	Maximum
26 FEB 2025	**Perfluorooctanoic acid (PFOA) - environmental pollutants**	Environmental pollutants	6.0 µg/kg - ppb	0.70 µg/kg - ppb
26 FEB 2025	**Perfluorononanoic acid (PFNA) - environmental pollutants**	Environmental pollutants	1.5 µg/kg - ppb	1.0 µg/kg - ppb

https://food.ec.europa.eu/food-safety/rasff_en

Dramatic Adverse Toxicological Effect of PTFE (1975)

Thermal degradation leads to toxic gasses and ultrafine particles …

Picture: Wikipedia

Vet. Rec. **1975**, 96(8):175-178.

A case of polytetrafluoroethylene poisoning in cockatiels accompanied by polymer fume fever in the owner

T B Blandford, P J Seamon, R Hughes, M Pattison, M P Wilderspin

Five cocatiels (*Nymphicus hollandicus*) died within 30 minutes following exposure to fumes from a frying pan coated with the "non-stick" plastic polytetrafluoroethylene (PTFE) that had accidentally overheated. **Within an hour the owner developed symptoms of "polymer fume fever" but recovered in the next 24 hours**. Clinical signs and post mortem lesions of the cockatiels are described and reference is made to the unusual susceptibility of parakeets to the pyrolysis products of frying pans coated with PTFE.

Dramatic Adverse Toxicological Effect of PTFE (1982)

ACUTE TOXICOSIS OF BUDGERIGARS (*MELOPSITTACUS-UNDULATUS*) CAUSED BY PYROLYSIS PRODUCTS FROM HEATED POLYTETRAFLUOROETHYLENE - MICROSCOPIC STUDY

WELLS, RE; SLOCOMBE, RF

AMERICAN JOURNAL OF VETERINARY RESEARCH 1982
Volume 43, Issue7, Page1243-1248

Picture: Wikipedia

An ultrastructural study was performed on the respiratory system of budgerigars (including 6 controls) which were acutely affected by inhalation of toxic fumes from heated polytetrafluoroethylene (PTFE pyrolysis products) or had survived for 24 h after a sublethal exposure. The controls were exposed to fumes from heated plain Al (not coated with PTFE). The microanatomy of lungs of the controls was described and compared with that of lungs of birds exposed to PTFE pyrolysates. **The PTFE pyrolysates caused extensive, severe necrotizing and hemorrhagic pneumonitis.** These lesions were associated with amorphous elongate conglomerates of particles which were similar to those isolated on membrane filters from fumes generated from heated PTFE. This supported the hypothesis that the toxic principle in PTFE pyrolysates was related to generated particulates.

Dramatic Adverse Toxicological Effect of PTFE (2012)

Comparative Medicine
Copyright 2012
by the American Association for Laboratory Animal Science

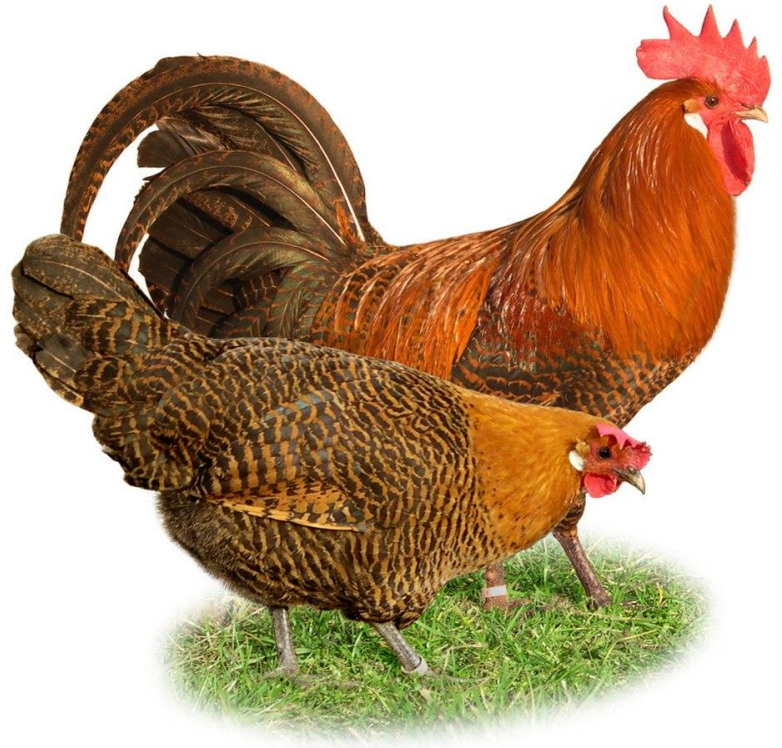
Vol 62, No 1
February 2012
Pages 49–52

Case Report

Polytetrafluoroethylene Toxicosis in Recently Hatched Chickens (*Gallus domesticus*)

Katherine A Shuster,[1,*] Kristie L Brock,[3] Robert C Dysko,[1] Victor J DiRita,[1,2] and Ingrid L Bergin[1]

Two groups of chickens (Gallus domesticus; White Leghorn; age, 4 d and 2 wk) housed in a university research vivarium **were found dead or moribund without prior signs of illness**. …Inspection of the animal room revealed that approximately 50% of the heat lamp bulbs in the brooder cage were coated with polytetrafluoroethylene (PTFE). Two published case reports detail similar experiences in birds exposed to PTFE-coated heat-lamp bulbs… **In the present case, the bulbs were replaced, and no similar problems subsequently have been noted.**



Picture: Wikipedia

Summary

- The possible **health effects of PFAS are manifold** and cannot be conclusively assessed today.
- Further **coordinated analyses of animal and plant-based foods** should be carried out to obtain comprehensive data on the PFAS contamination.
- Longer- and shorter-chain substitute products are not expedient from a food safety perspective.
- Even PTFE is not safe for each species per se …
- **The ALARA principle does not ignore social and economic factors**.

Entry and Elimination of PFAS into the Human Body (2024)

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Full length article

Kinetics of 15 per- and polyfluoroalkyl substances (PFAS) after single oral application as a mixture – A pilot investigation in a male volunteer

Klaus Abraham [a,*], Helena Mertens [a], Lennart Richter [a], Hans Mielke [b], Tanja Schwerdtle [a], Bernhard H. Monien [a]

[a] German Federal Institute for Risk Assessment (BfR), Department Food Safety, 10589 Berlin, Germany
[b] German Federal Institute for Risk Assessment (BfR), Department Exposure, 10589 Berlin, Germany

A very worth reading self-experiment:

Ingestion of a low-dose mixture of 15 PFAS. These compounds were labeled with carbon-13 (^{13}C).

Thank you for your attention !!!