

PFAS in soil - forever pollution, forever concern?

PFAS content occurring in agricultural top soils representative for rural areas in Germany

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Section II 2.6 / Soil Protection Measures

Introduction

Project funding

German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)



Bundesministerium
für Umwelt, Naturschutz, nukleare Sicherheit
und Verbraucherschutz

Sampling

Fraunhofer Institute (FhG IME) – 2021-2024

- Grassland and arable land top soils in rural areas,
- Exclusion of areas: e.g. known contaminated sites, floodplains,
- Safty measures for a PFAS free soil sampling (as far as possible)



Fraunhofer
IME

Analytics

German Federal Institute for Material Research and Testing (BAM)

- 2021-2025
- Quantification of soil content for 30 PFAS (modified DIN 38414-14)
- Additionally: Quantification of PFAS leachat, TOP-Assay for PFAA precursor analysis, other organic substances (e.g. TFA, PBDE, HBCD, Siloxane)



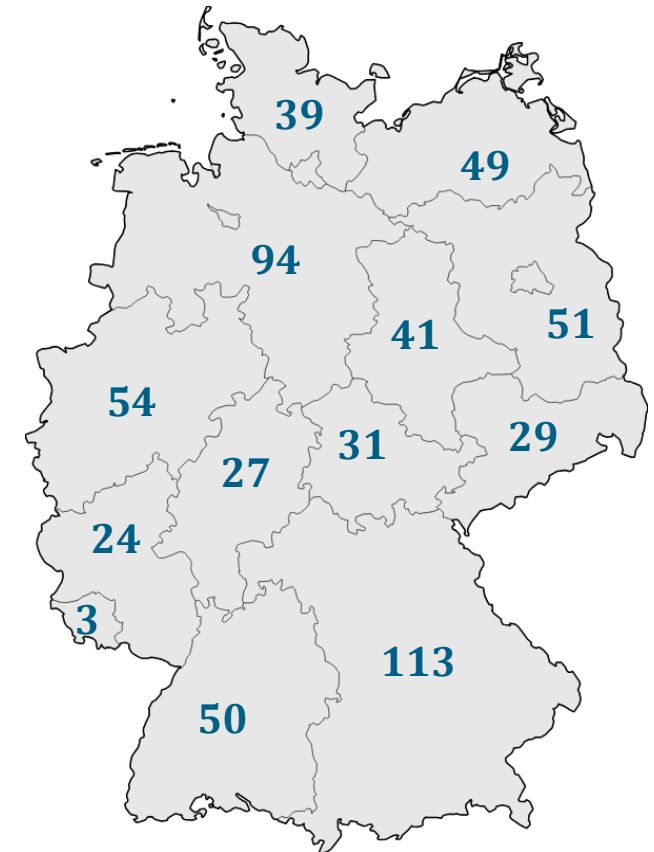
BAM
Bundesanstalt für
Materialforschung
und -prüfung

Evaluation

German Environment Agency (UBA)

**Umwelt
Bundesamt**

Number of sampling locations / federal state



Σ- sampling locations

GRASSLAND 204 (cleared 199)

ARABLE LAND 401 (cleared 382)

Introduction

Detection rate PFAS in top soils [%]

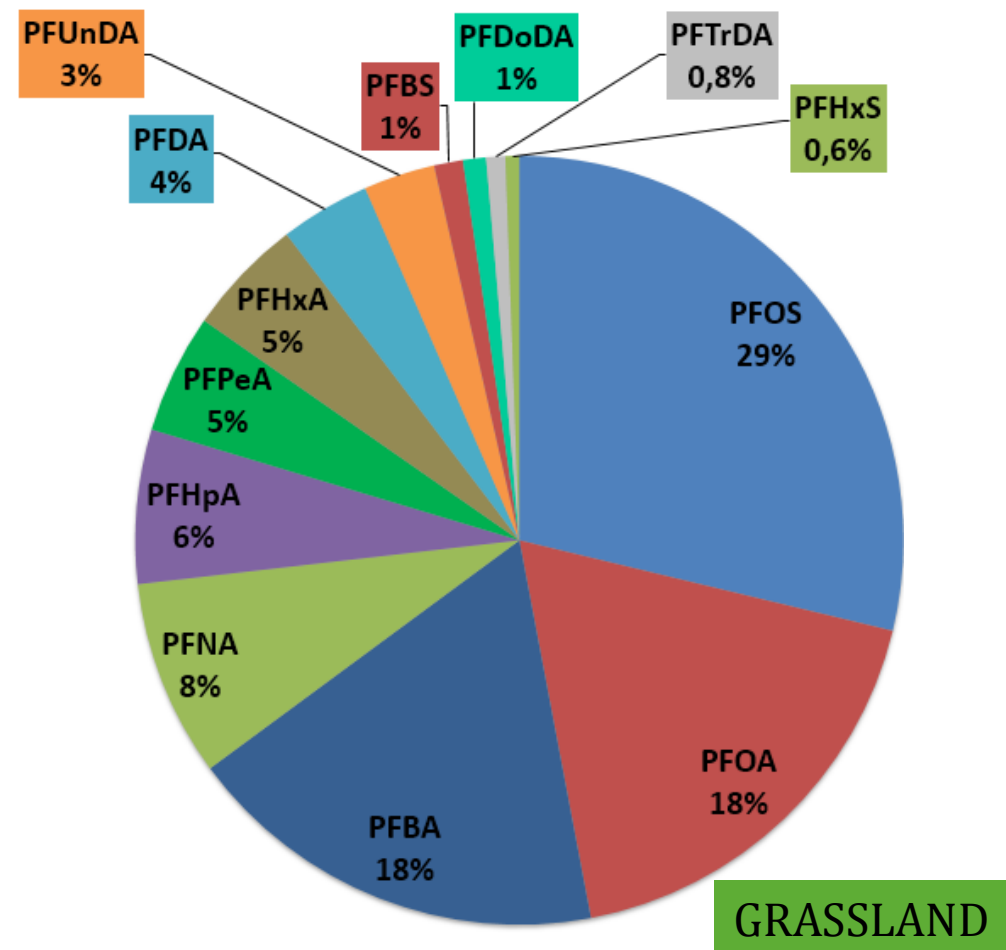
Limits of Detection: 0,002 – 0,011 µg/kg

	GRASSLAND	ARABLE LAND
perfluorocarboxylic acids		
PFBA (C4)	100	99
PFPeA (C5)	92	91
PFHxA (C6)	98	99
PFHpA (C7)	99	99
PFOA (C8)	100	100
PFNA (C9)	100	100
PFDA (C10)	100	100
PFUnDA (C11)	100	99
PFDoDA (C12)	87	81
PFTTrDA (C13)	75	45
PFTeDA (C14)	51	20
PFHxDA (C16)	5,1	4,3
PFODA (C18)	2,0	1,1
perfluorosulfonic acids		
PFBS (C4)	87	65
PFHxS (C6)	71	31
PFHpS (C7)	19	5,1
PFOS (C8)	100	100
PFDS (C10)	0,5	0,3

	GRASSLAND	ARABLE LAND
others		
PFOSA	1,5	3,7
N-MeFOSA	0,0	0,0
N-EtFOSA	5,6	1,1
N-MeFOSAA	1,0	0,5
N-EtFOSAA	3,6	4,0
6-2-FTS	0,5	0,8
8-2-FTS	0,5	0,8
9Cl-PF3ONS	0,0	0,3
8:2 FTUCA	0,0	0,3
8:2 diPAP	0,5	0,3
HFPO-DA (GenX)	0,0	0,0
ADONA	32	14

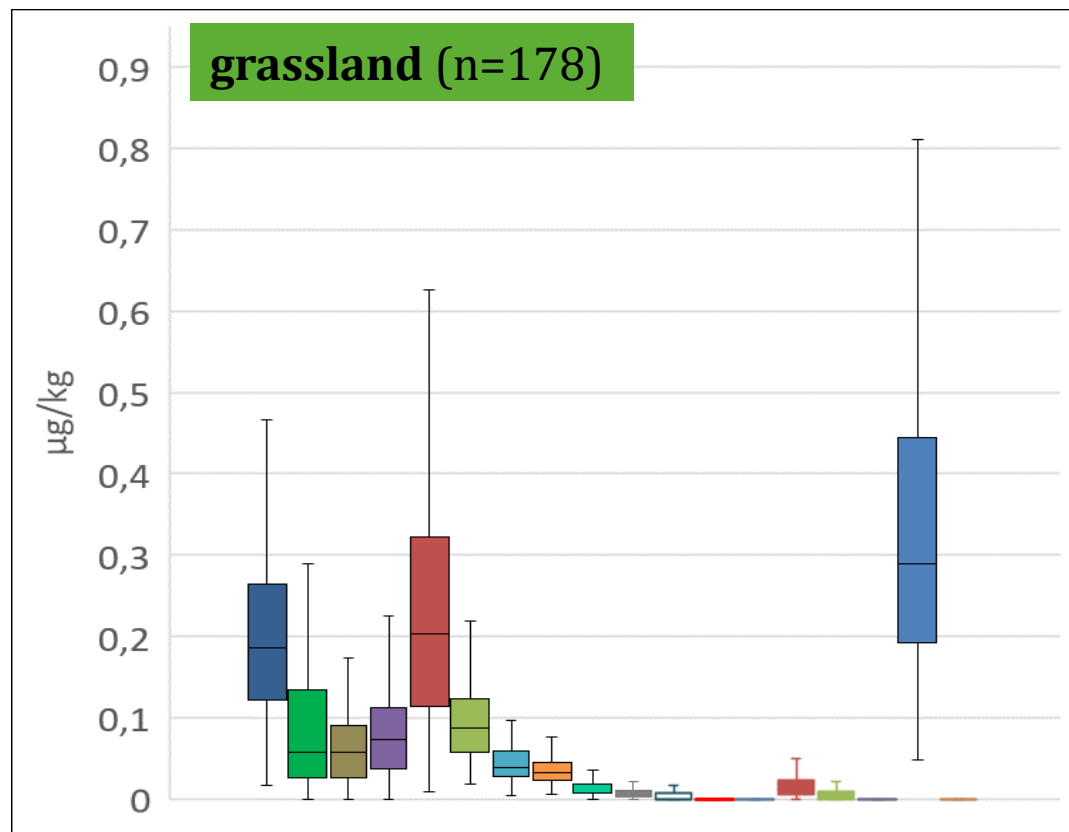
Average composition of PFAS in top soils (median)

Limits of quantification: 0,01-0,03 µg/kg

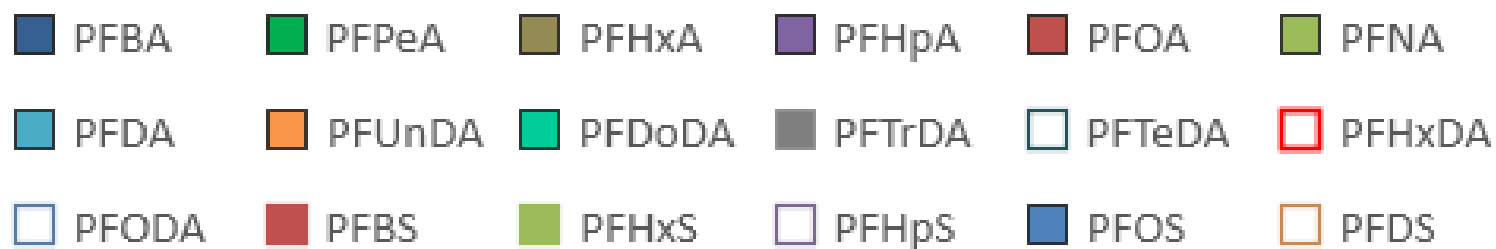
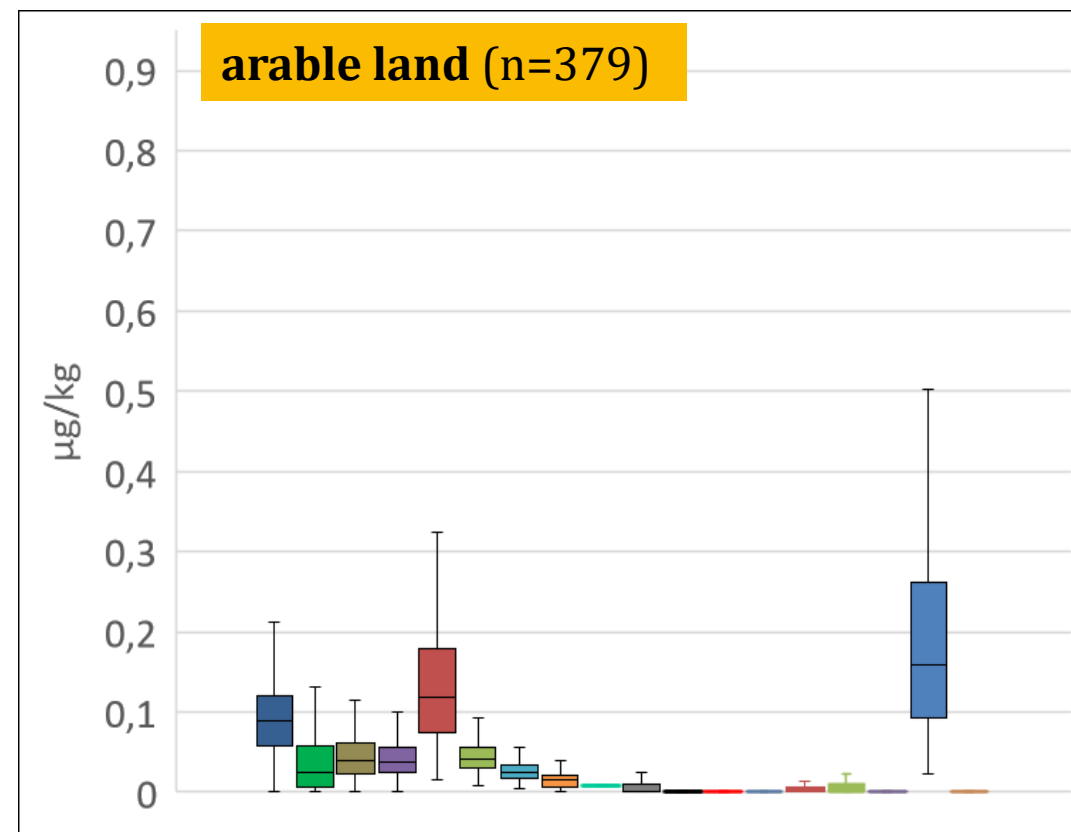


Distribution of quantified PFCA and PFSA in top soils (h1-h5)

Sampling depth ~0–10 cm

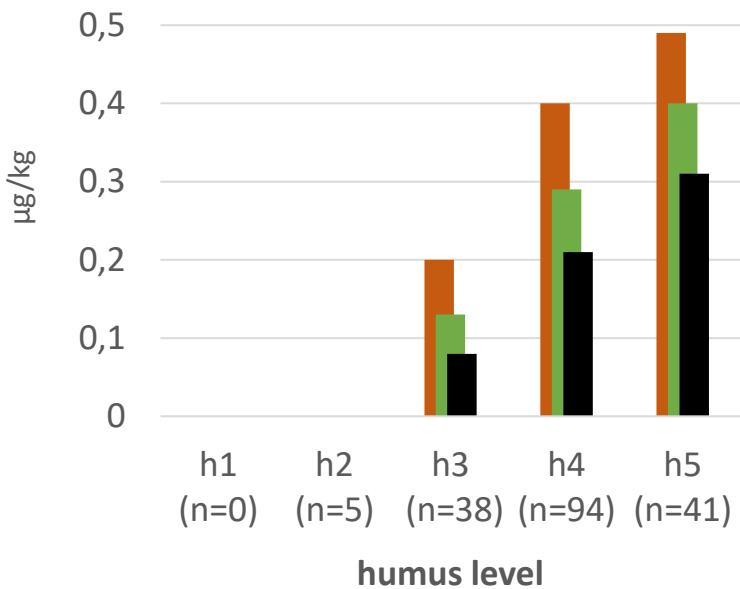


Sampling depth ~0–30 cm



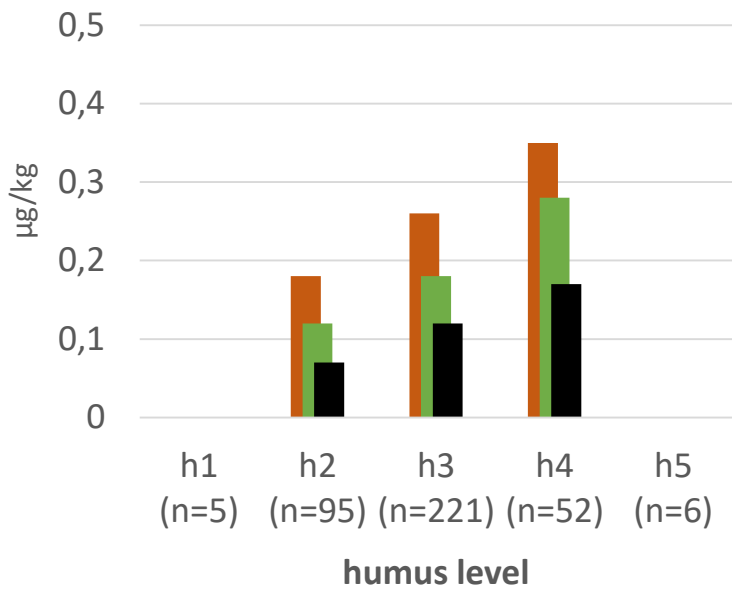
PFOA content in top soil

PFOA: grassland



humus levels	n	PFOA (µg/kg)		
		50th	75th	90th
h2-h5	178	0,2	0,3	0,41

PFOA: arable land



humus levels	n	PFOA (µg/kg)		
		50th	75th	90th
h1-h5	379	0,11	0,17	0,27

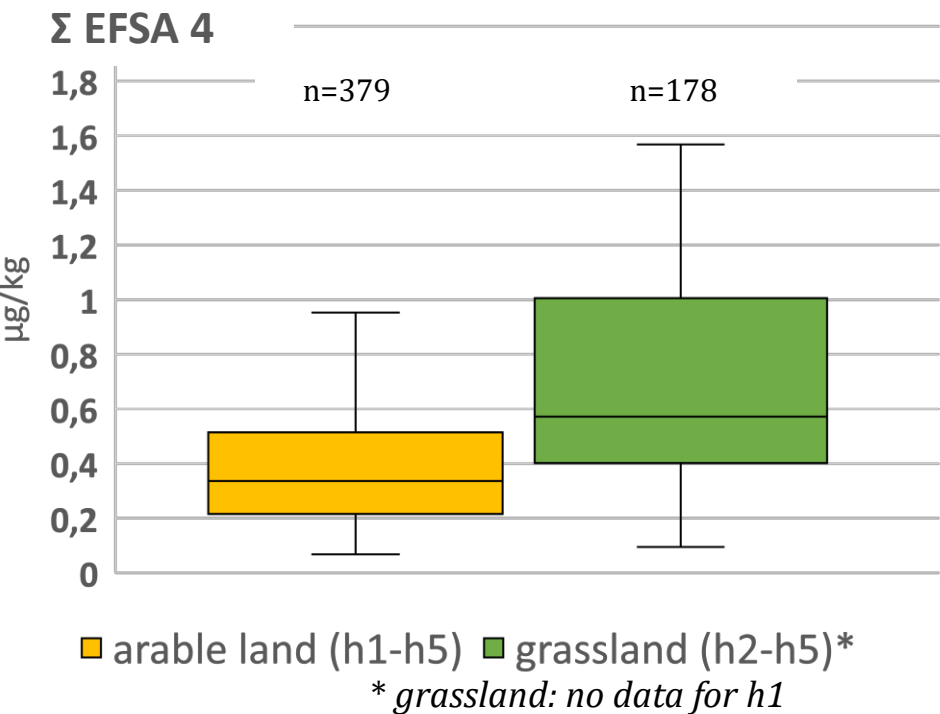
Percentiles

■ ≤ 50th Percentile ■ ≤ 75th Percentile ■ ≤ 90th Percentile

humus levels

h1 < 1%, h2 < 2%, h3 < 4%, h4 < 8%, h5 < 15%

Content of EFSA4-PFAS in top soil



Number of samples

humus content	< 1%	< 2%	< 4%	< 8%	< 15%	< 30%	≥ 30%
humus levels	h1	h2	h3	h4	h5	h6	h7
n-arable land	5	95	221	52	6	3	---
n-grassland	---	5	38	94	41	9	12

Resulting percentiles after statistical analysis

EFSA4 - grassland

	humus levels	n	Percentiles (µg/kg)		
			50th	75th	90th
PFOA	h2-h5	178	0,2	0,3	0,41
PFNA			0,09	0,12	0,18
PFHxS			< 0,018*	< 0,018*	< 0,018*
PFOS			0,29	0,44	0,65

* 0,006-0,018

Σ EFSA 4 - arable land

Σ EFSA 4	humus levels	n	Percentiles (µg/kg)		
			50th	75th	90th
Σ EFSA 4	h1-h5	379	0,33	0,48	0,7

Lessons learned

- Shown data is a first insight into the determination of German background levels
- After last steps of quality assurance background values representative for rural German agricultural top soils will be published soon (in 2025)
- Background values are an important part in the derivation of regulatory soil values
- To determine PFAS content in rural, uncontaminated soils limits of quantification had to be lowered compared to available standardized methods
- Determined background contents are in good agreement with published background levels of neighboring countries
- Regional background levels may differ



PFAS background content of topsoils in rural areas of North-Rhine Westphalia

PFAS in soil - forever pollution, forever concern?
International Conference - 25 March 2025

Mareike Mersmann - Section 32: Soil Protection and Contaminated Sites

North Rhine Westphalian Office for Nature, Environment and Consumer Protection (LANUV NRW)

Project „PFAS background content of topsoils in rural areas of North-Rhine Westphalia (NRW)“

- **Project Funding:** Ministry of the Environment, Nature and Transport of the State of North Rhine-Westphalia
- **Project Management:** LANUV NRW
- **Soil Sampling:** Geological Survey NRW
 - mineral topsoil layer on grassland (0-10 cm) and arable land (0-30 cm) in rural areas of NRW (2020-2021)
 - exclusion of areas: e.g. known contaminated sites, floodplains, ...
 - *additionally: sampling of subsoils and forest soils*
- **Soil Analytics:** German Water Centre, TZW
 - *Quantification of soil content for 26 PFAS (DIN 38414-14)*
 - Quantification of leachates of batch tests from topsoils (DIN 19529, L/S-ratio 2:1) for 26 PFAS (DIN 38407-42).
 - *additionally: TOP-Assay for PFAA precursor analysis and analysis of ultrashortchain PFAS in selected soil samples*
- **Evaluation and Report:** LANUV NRW

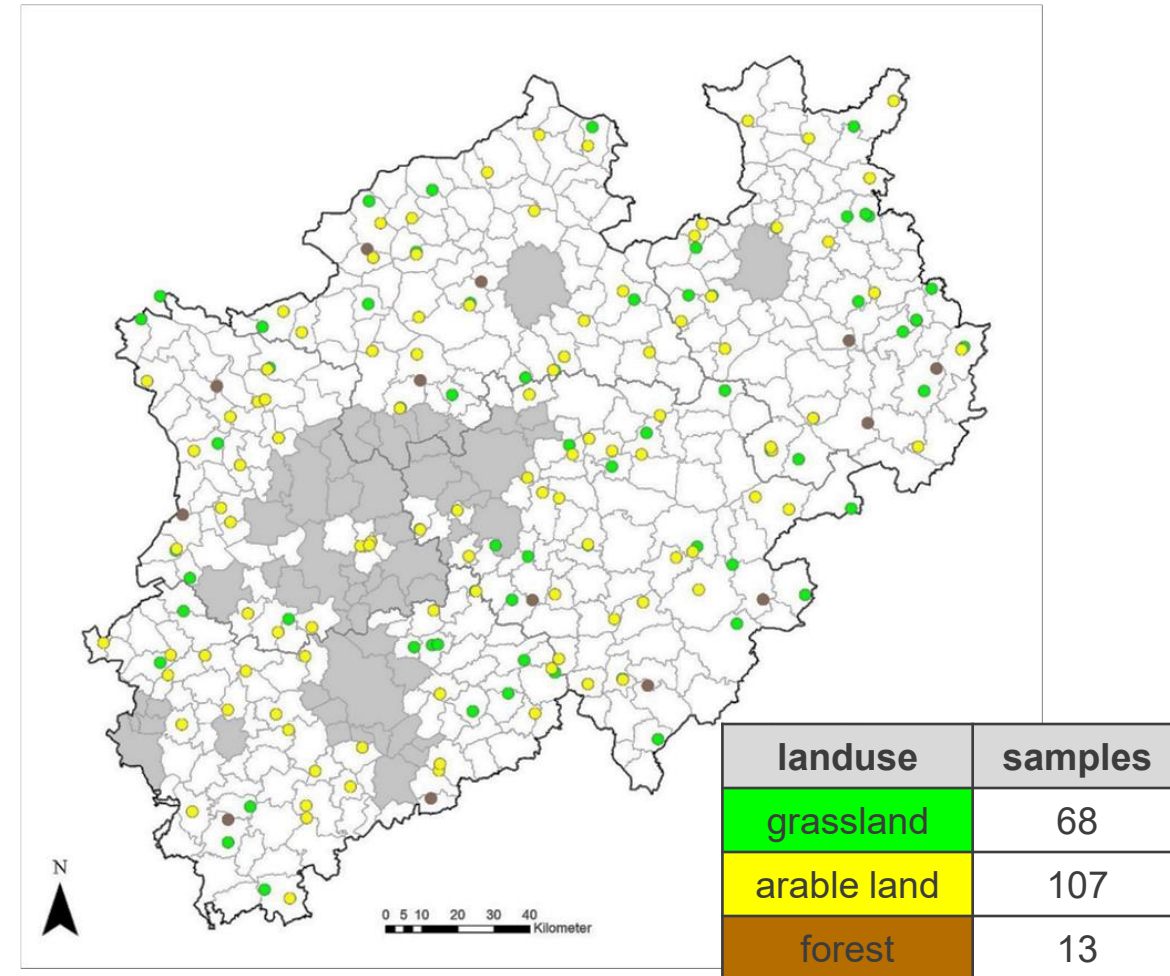


Fig. 2 soil sampling locations in NRW
[LANUV-technical report 150](#)

PFAS in batch test leachates of topsoils (L/S-ratio 2:1)

Tab. 1 Positive detects in % (LOQ: 1 ng/L)

landuse	grassland	arable land
n=	68	95
perfluorocarboxylic acids (PFCAs)		
PFBA (C4)	100	100
PFPeA (C5)	99	100
PFHxA (C6)	100	100
PFHpA (C7)	100	100
PFOA (C8)	100	100
PFNA (C9)	97	100
PFDA (C10)	46	62
PFUndA (C11)	1	1
PFDaA (C12)	1	0
PFTTrDA (C13)	0	0
perfluorosulfonic acids (PFSAs)		
PFBS (C4)	97	91
PFPeS (C5)	4	2
PFHxS (C6)	84	87
PFHpS (C7)	4	11
PFOS (C8)	97	99
PFNS (C9)	0	0
PFDS (C10)	0	0

landuse	grassland	arable land
n=	68	95
other PFAS		
4:2 FTS	0	0
6:2 FTS	3	2
8:2 FTS	0	0
HFPO-DA, Gen X	16	1
ADONA	13	3
PFOSA	0	0
PFOSAA	0	0
N-EtFOSA	0	0
N-Et-FOSAA	0	0

- water-soluble PFAS were detected in all batch test leachates of topsoils in rural NRW
- PFCAs (C4-C9) and PFSAs (C4, C6 and C9) were detected in almost all tested topsoil leachates
- GenX and ADONA were detected in over 10 percent of grassland topsoil leachates

Distribution of PFAS in batch test leachates from topsoils

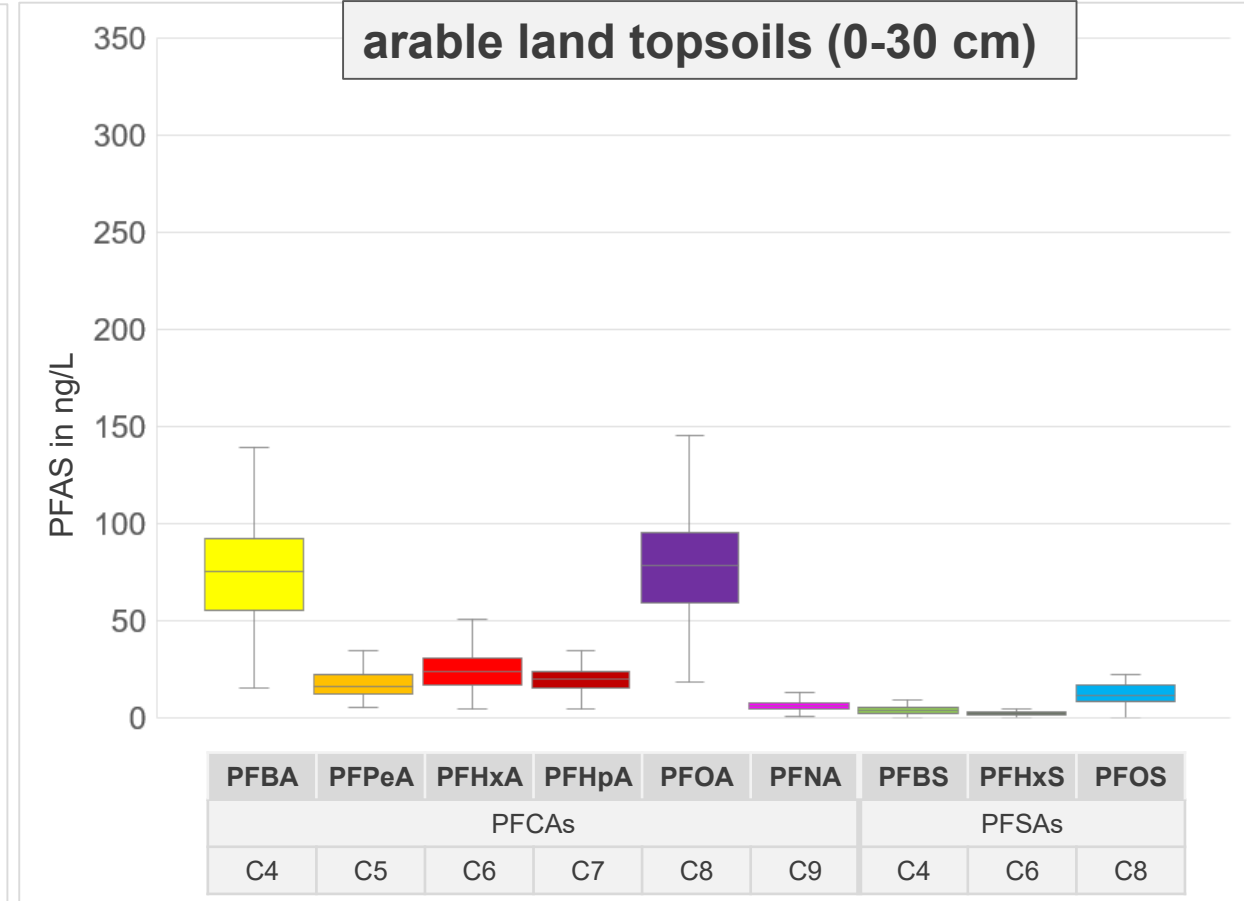
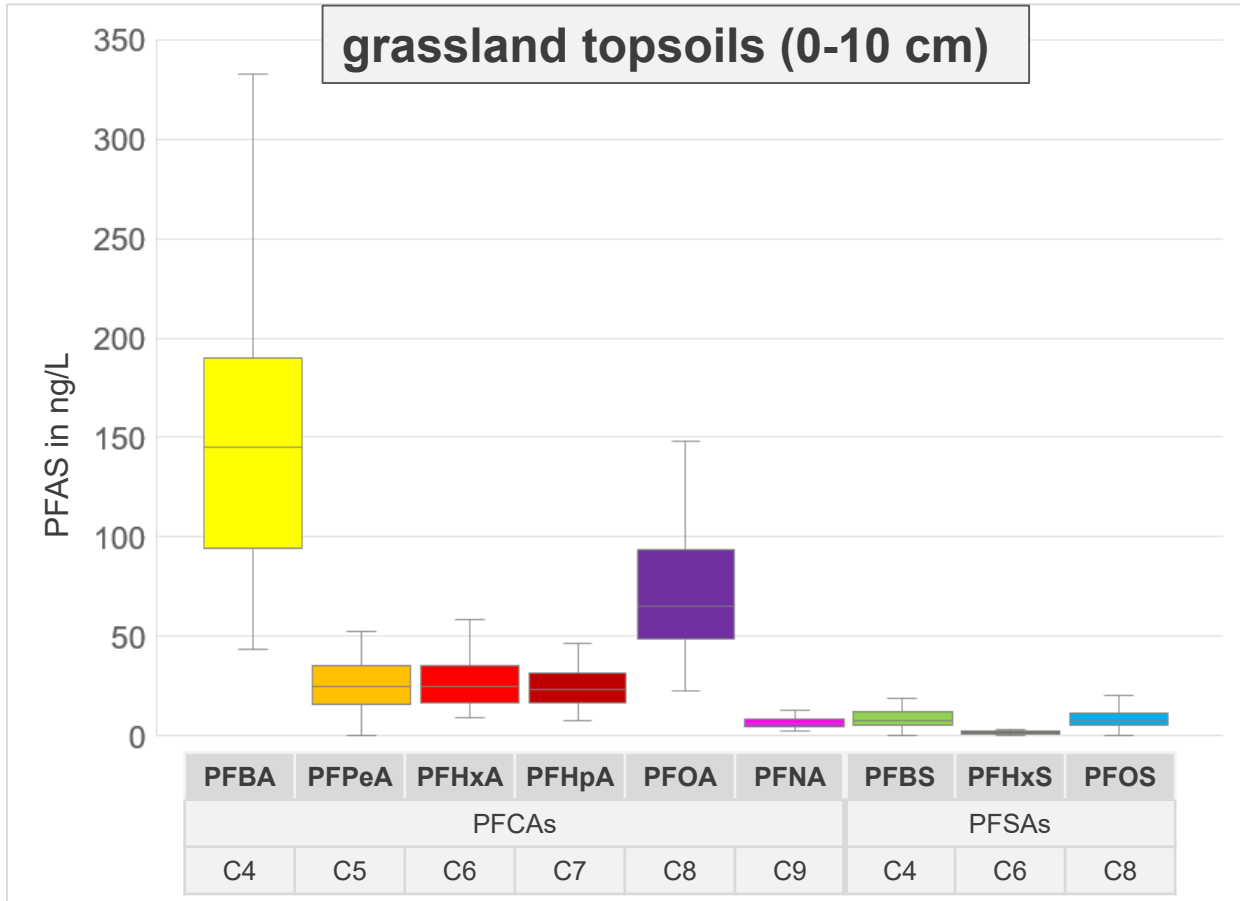


Fig. 3 grassland: PFAS in batch test leachates of topsoils

Fig. 4 arable land: PFAS in batch test leachates of topsoils

- PFAS pattern in batch tests leachates from topsoils is comparable between grassland and arable land (indication of ubiquitous input through deposition)
- PFBA and PFOA were detected at the highest levels in batch test leachates from topsoils

PFAS-Background values of topsoils

Tab. 2 Background values (90. Percentile) in batch test leachates from topsoils (L/S-ratio 2:1) in rural areas of NRW

		landuse	Grassland (0-10 cm)	Arable land (0-30 cm)
		substance	ng/L	
PFCAs	C4	PFBA	288	126
	C5	PFPeA	42	29
	C6	PFHxA	44	38
	C7	PFHpA	42	29
	C8	PFOA	118	113
	C9	PFNA	9	9
PFSAs	C4	PFBS	18	7
	C6	PFHxS	3	3
	C8	PFOS	16	19

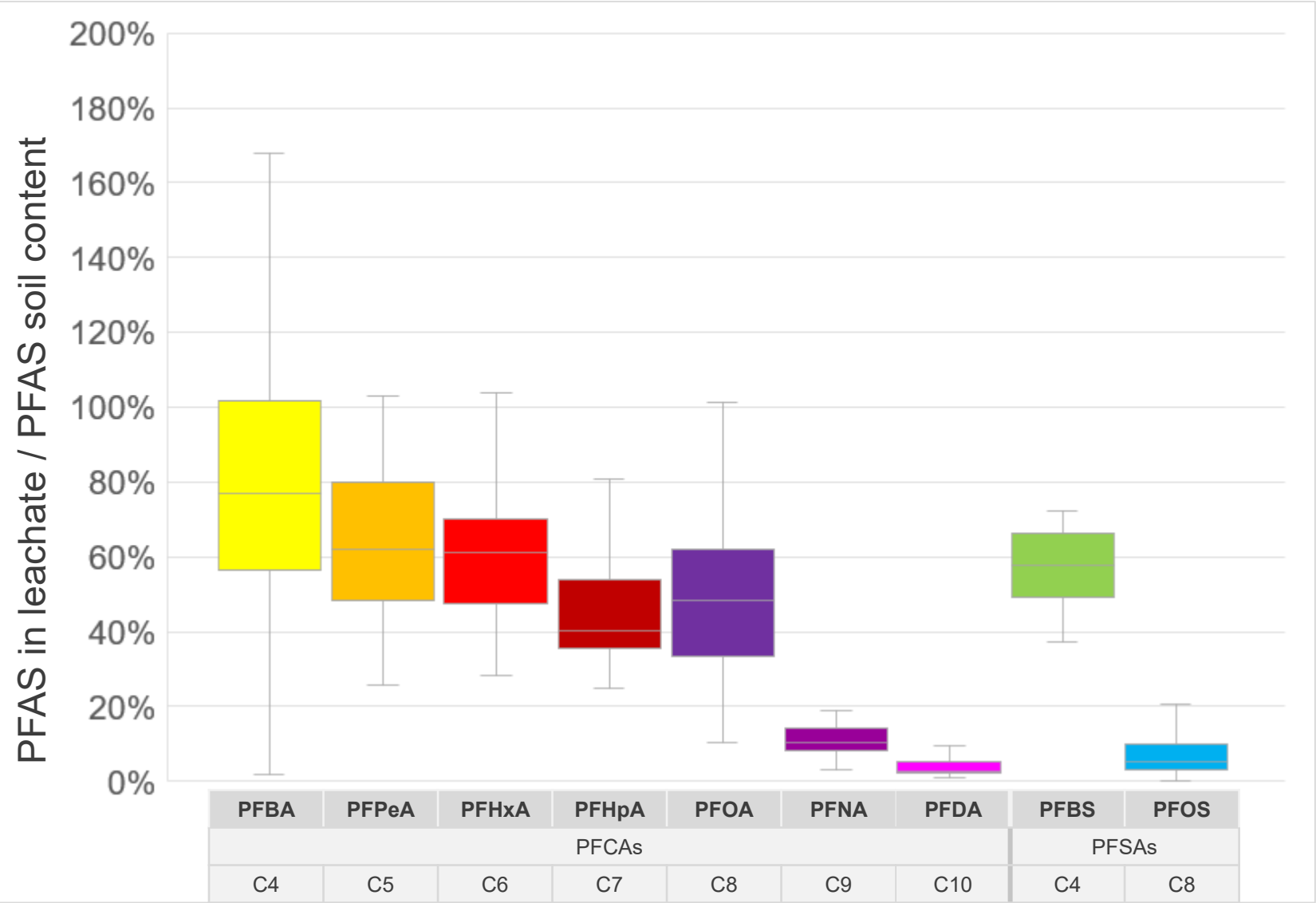
Background values (90. Percentile) could be derived for

- 6 PFCAs and
- 3 PFSAs

in batch test leachates of topsoils (L/S-ratio 2:1).



„Leachable fraction“ of PFAS in background topsoils



note: water solubility of PFAS in background topsoils depends on

- chain length of PFAS and
- functional group of PFAS.

Fig. 5 ratio of the mass fraction of each PFAS compound in the leachate (L/S-ratio 2:1) divided by the fraction of each PFAS compound in the soil content in background topsoils (grassland and arable land)

Conclusions

take home messages:

- PFAS content in agricultural topsoils is ubiquitous (soil content and water soluble PFAS)
- even precursors and substitutes were detected in some soil samples
- soils function as a sink and a source for PFAS
- indication that PFAS from background soils could enter groundwater via leachate (depending on the retention capacity and thickness of the unsaturated soil zone)

measures to be taken:

- inputs from diffuse sources must be quantified and measures must be taken to prevent or effectively reduce them

research needs:

- first tests show ultra-short-chain PFAS and precursors in background soils, what should be the subject of further research

Many thanks to...

Umwelt 
Bundesamt

...the German Federal States and local farmers
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...the Ministry of the Environment, Nature
and Transport of the State of North Rhine-
Westphalia

...our commissioned researchers from

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...the Geological Service NRW

...the German Water Centre, TZW Karlsruhe

...all of you for your kind attention

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