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ASSESSMENT OF PFAS LEACHABILITY FROM BIOSOLIDS IN 3.1 SQUARE MILES AGRICULTURAL AREA

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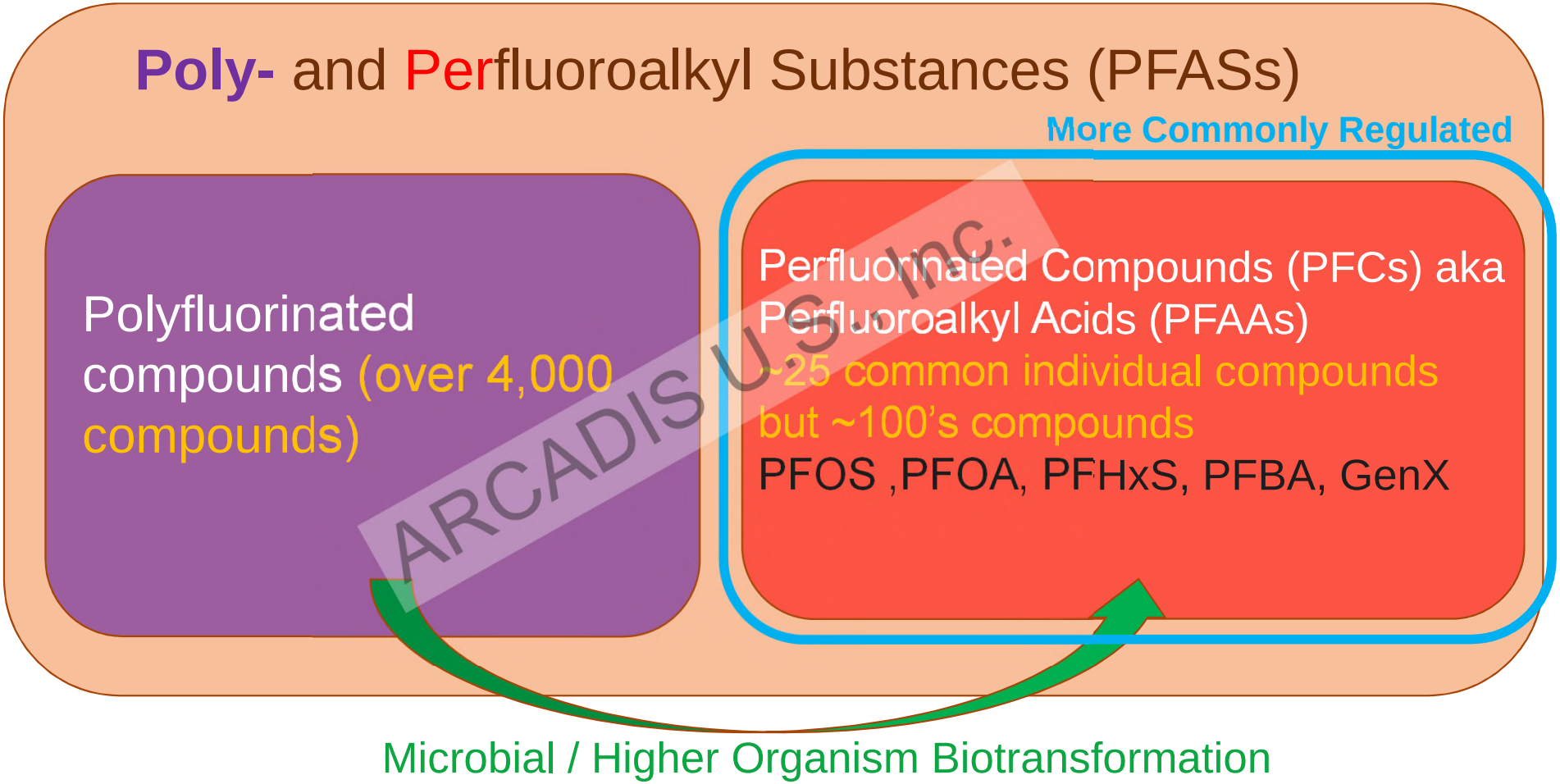
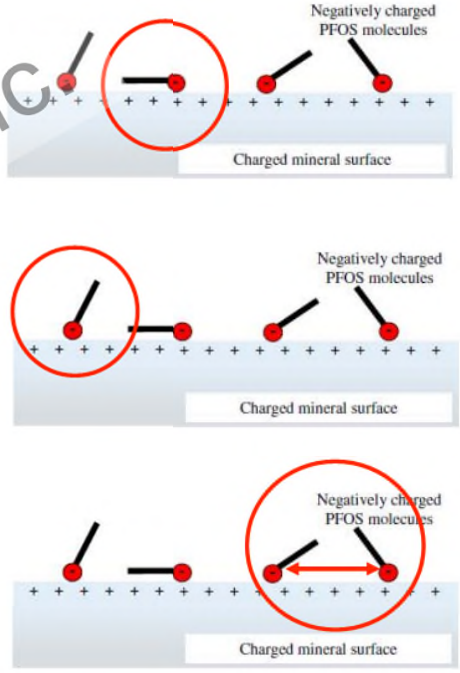
NEWEA Conference on Biosolids October 18, 2019

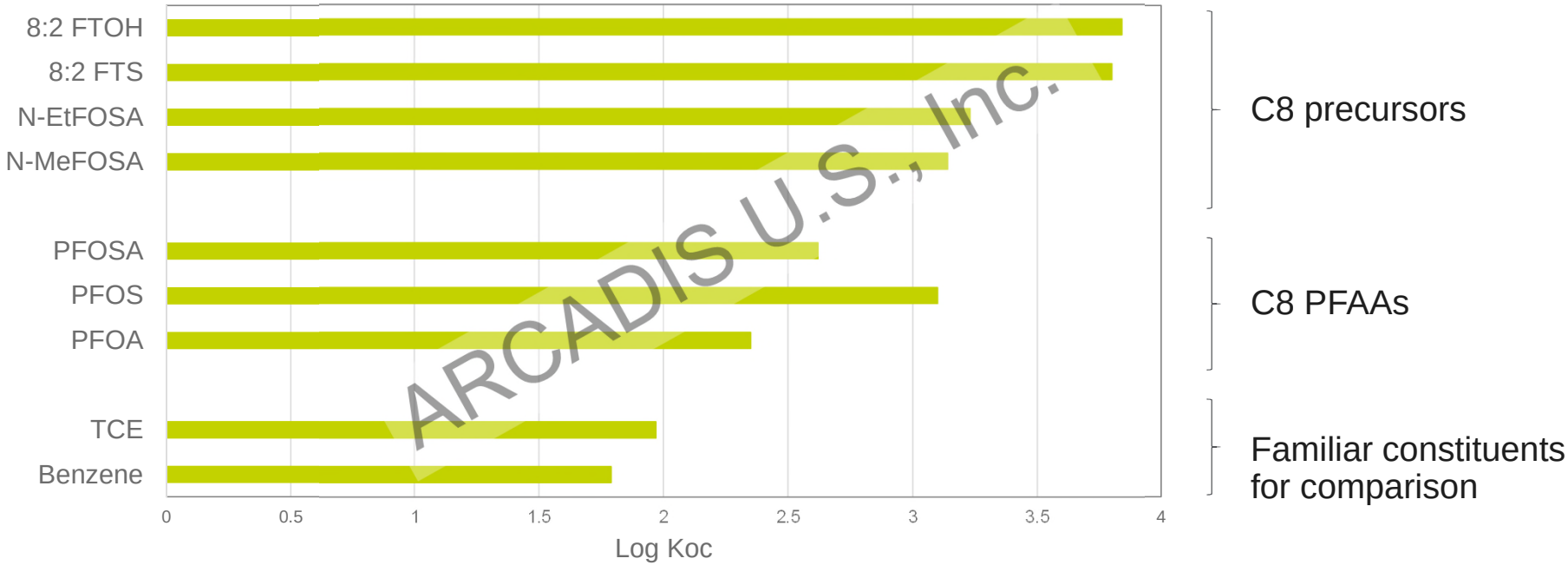


Retardation of PFAS

- Hydrophobic interaction
  - Predominant sorption mechanism for long chain PFAS
  - ~0.5 log Koc increase for each CF_2 group (Higgins & Luthy 2006, ES&T)
  - Organic rich soils retard movement of PFAS
  - f_{oc} increases -> K_d increases
  - Oil and other organics may also increase sorption
- Electrostatic effects
  - Positively charged PFAS (*i.e.*, some precursors) sorb to negatively charged minerals
  - Negatively charged PFAS sorb to positively charged minerals
  - Electrostatic repulsion can decrease PFAS sorption
  - High ionic strength dulls electrostatic repulsion and attraction



Comparison of Log Koc



Source: After Guelfo & Higgens, 2013 and references therein.

Some precursors may more readily sorb to soil

ADD References

PFAA Precursor Transformation Rates

PFAA Precursor		Media	Temperature	Inferred Transformation Half Life	Dead End Transformation Product	
EtFOSE	N-Ethyl perfluorooctan sulfonamideothanol	Marine Sediments Batch Slurry	4°C	44 d		PFOS
		Aerobic biosolids - bottle test	30°C	0.71 d		
SAmPAP Diester	Sulfonamid-based Polyfluoroalkyl Phosphate diester	Marine Sediments - Batch Slurry	4°C	>379 d		PFOS
6:2 FTOH	6:2 Fluorotelmeralcohol	Aerobic contaminated Soil Column	--	1.3 d	PFBA, PFPeA, PFHxA	
		Anaerobic Soil Column	--	>> 200 d	PFHxA	
8:2 FTOH	8:2 Fluorotelmeralcohol	Anaerobic Soil Column	--	145 *d*	PFOA	

After Held & Reinhard, 2016 and references therein.

Review of Surficial Soil data

- Vermont background study indicated widespread detection of PFAS in urban areas;

Widespread detections of PFAS indicate complex input from local and remote sources, including bio-solids.

	Vermont Soil Study [1]
Minimum PFOA	0.052
Average PFOA	0.52
Median PFOA	0.4
Maximum PFOA	4.9
Minimum PFOS	0.106
Average PFOS	1.1
Median PFOS	0.68
Maximum PFOS	9.7

[1]Source: Zhu, et al. PFAS Background in Vermont Shallow Soils. February 8, 2019.

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Evolving understanding of toxicology

Evolving tolerable daily intake

Source	PFOS (ng/kg bw/day)	PFOA (ng/kg bw/day)
EFSA, 2008	150	1500
EPA, 2009	80	190
Denmark, 2015	30	100
EPA, 2016 (RfD)	20	20
RIVM, 2016	-	12.5
Australia, 2017	20	160
ATSDR 2018 (proposed RfD)	2	3
EFSA 2018 (proposed)	1.8	0.86
RIVM, 2019 (tox. max. allowed risk level)	(6.25)	12.5

JANUARY 30, 2019

Scientists just cut the tolerable intake of PFAS by 99,9%

https://chemsec.org/scientists-just-cut-the-tolerable-intake-of-pfas-by-999/

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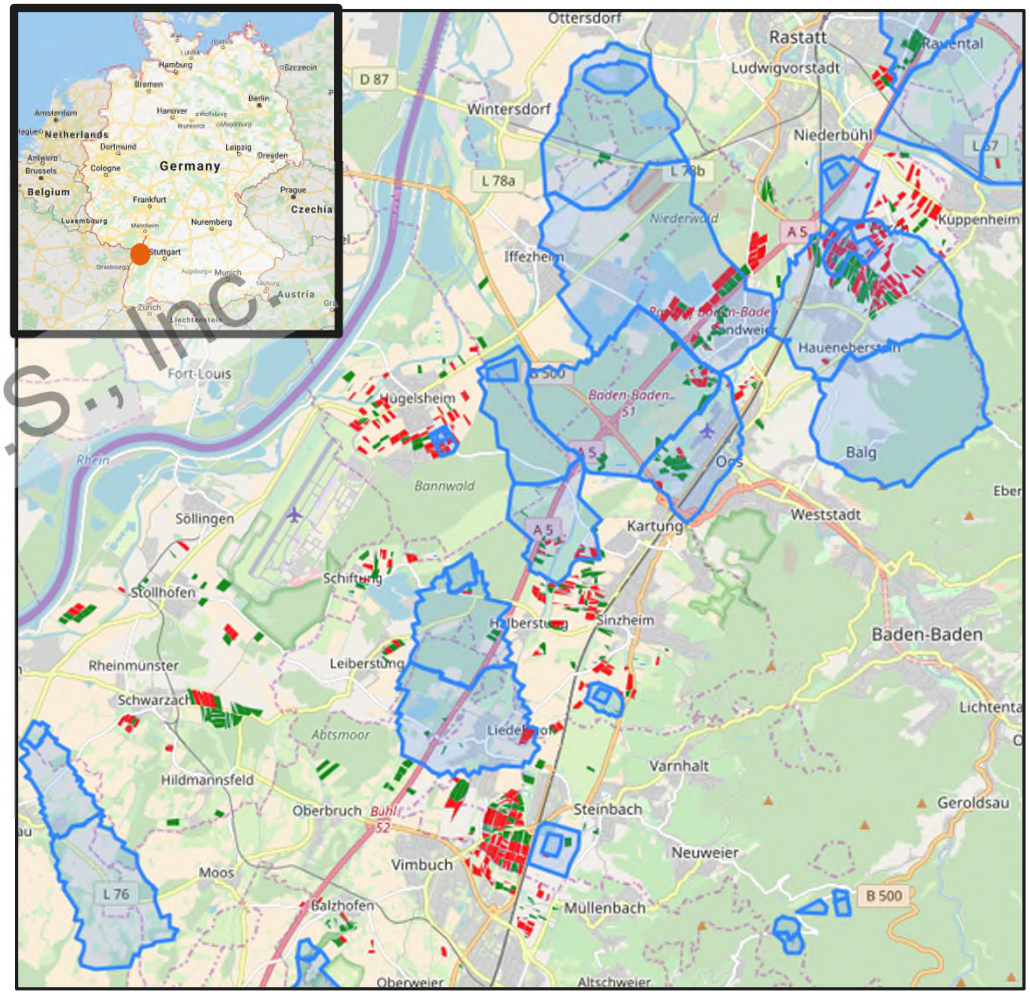
German Bio-solids Site

German Case Study

- Industrial Slude was applied on agricultural land ~ 2002-2008.
- Multiple water-well protectionzones – groundwater the primary source of drinking water.
- Groundwater and soil impacts were first discovered after AFFF application associated with a 2011 storage facility fire.
- Arcadis involved in 2015.



PFAS in Groundwater

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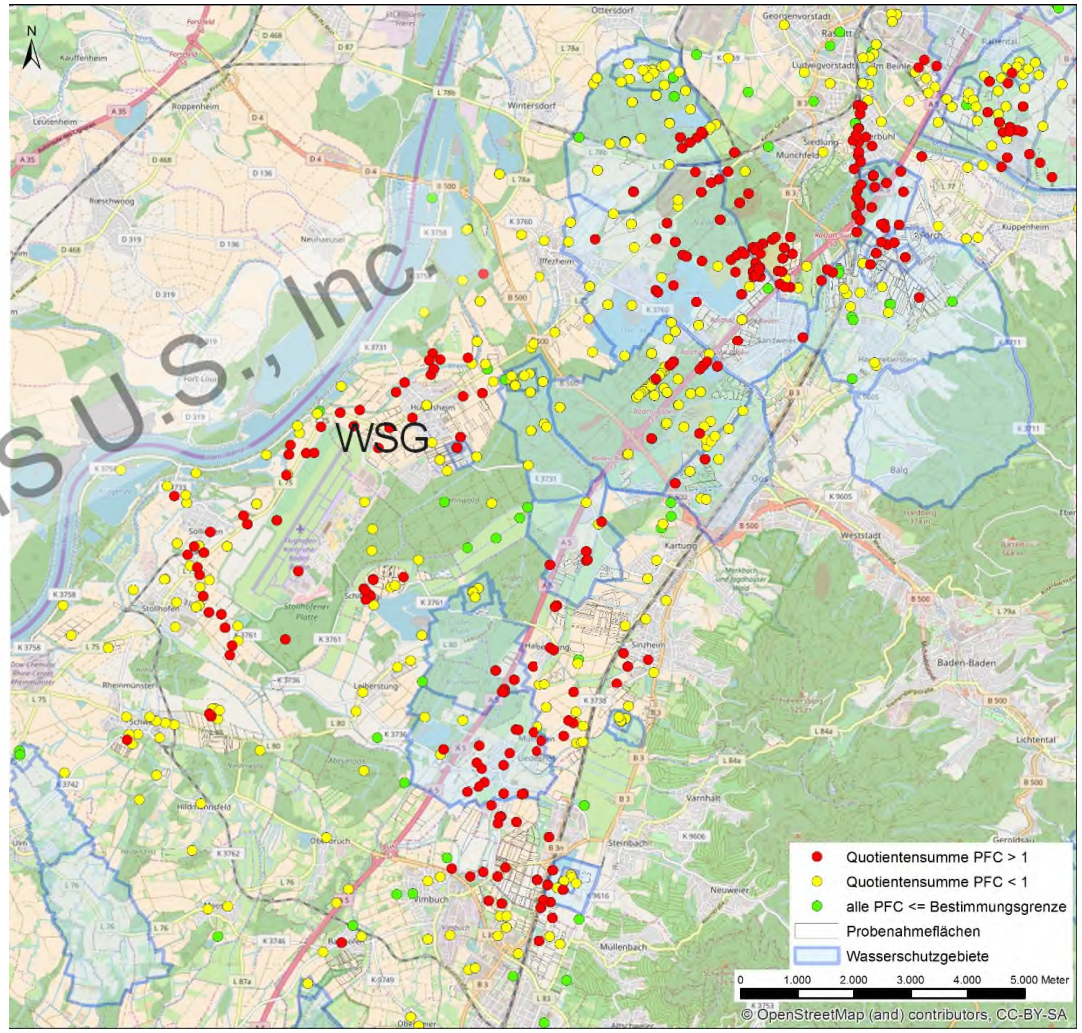
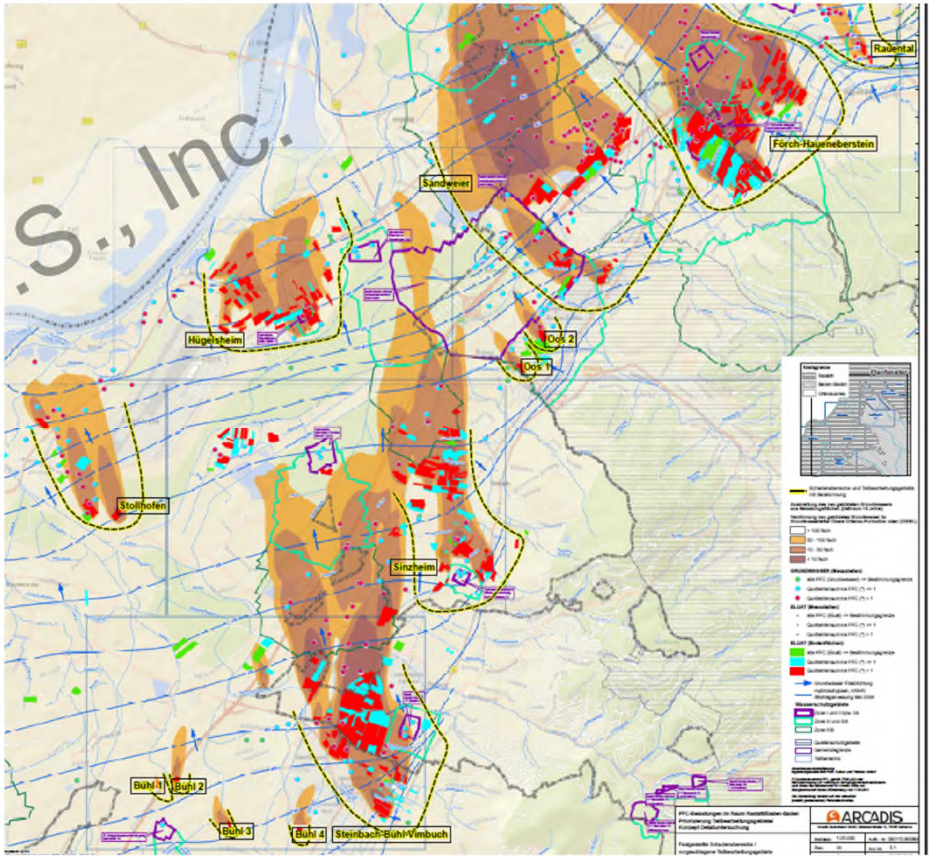
1	2	3	4
Nr.	Stoff	GFS[3] [µg/l]	vorläufige GFS [µg/l]
1	Perfluorbutansäure PFBA	10,0 [1]	
2	Perfluorpentansäure PFPeA		3,0 [2]
3	Perfluorhexansäure PFHxA	6,0 [1]	
4	Perfluorheptansäure PFHpA		0,3 [2]
5	Perfluoroctansäure PFOA	0,1 [1]	
6	Perfluornonansäure PFNA	0,06 [1]	
7	Perfluordecansäure PFDA		0,1 [2]
8	Perfluorbutansulfonsäure PFBS	6,0 [1]	
9	Perfluorhexansulfonsäure PFHxS	0,1 [1]	
10	Perfluorheptansulfonsäure PFHpS		0,3 [2]
11	Perfluoroctansulfonsäure PFOS	0,1 [1]	
12	1H,1H,2H,2H-Perfluoroctansulfonsäure 6:2 FTSA, H_4PFOS		0,1 [2]
13	Perfluoroctansulfonamid PFOSA = FOSA		0,1 [2]
14	Weitere PFC z.B. GenX, ADONA, u.a.[4]		1,0 [2]

1) Humantoxikologische Ableitung durch LAWA-LABO-Kleingruppe (LAWA, 2017)
2) GOW aus GFS-Bericht (LAWA, 2017)
3) Für die Bildung der Quotientensumme nach der Additionsregel werden ausschließlich die Werte in Spalte 3 herangezogen
4) R1-$(CF_2)_n$-R2, mit n > 3



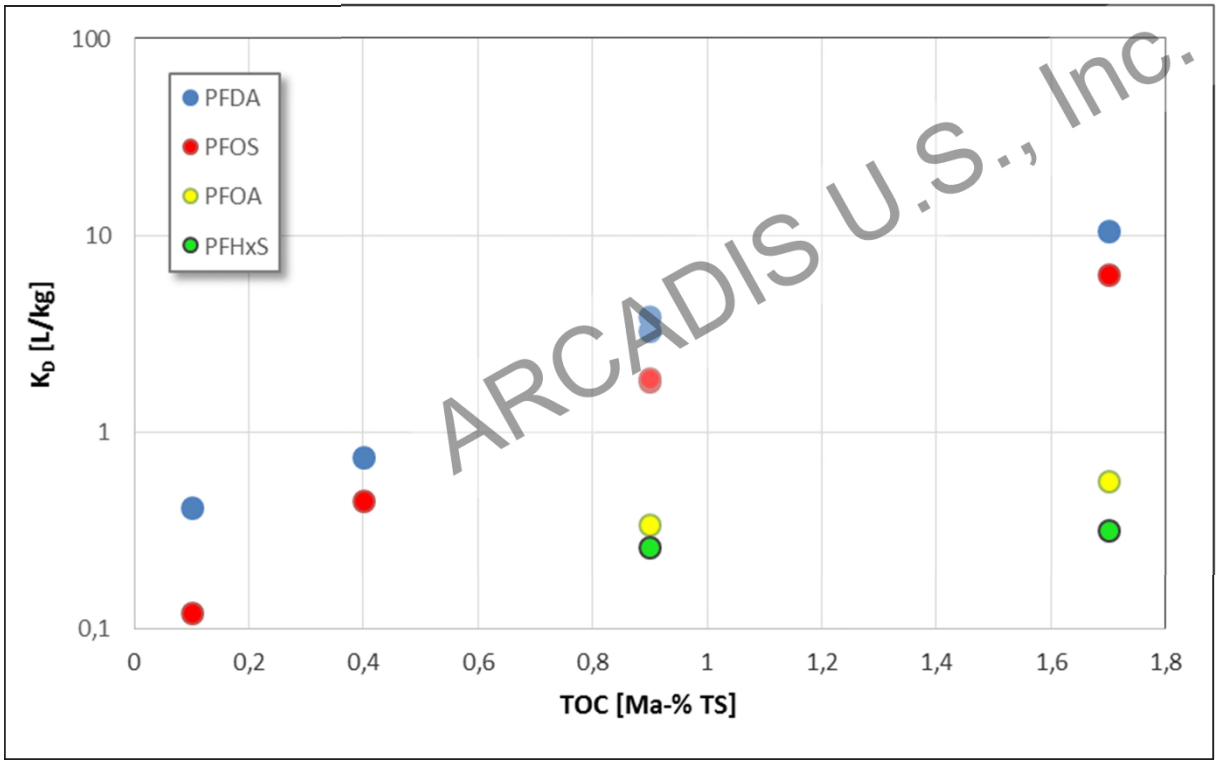
Fate & Transport

- Complex cluster of plumes;
- Modeling plume evolutions and area of impacts;
- Identifying priority areas.



Site Specific Sorption Data

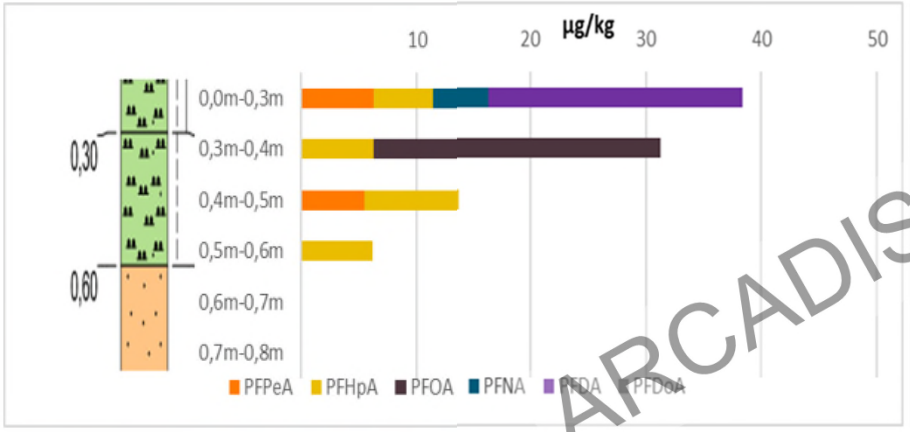
Surficial Soil Samples (Upper 50 cm)



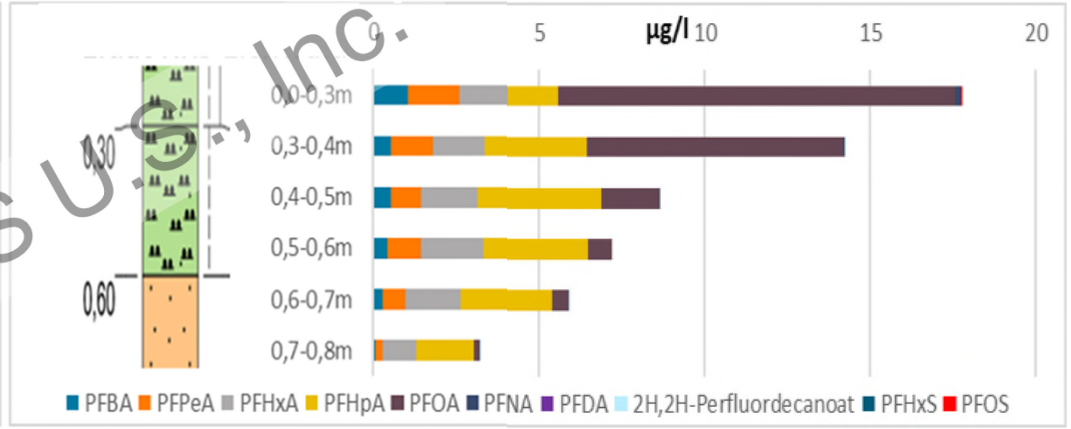
Water spiked with:

- PFBA
- PFHxA
- PFOA
- PFDA
- PFBS
- PFHxS
- PFOS

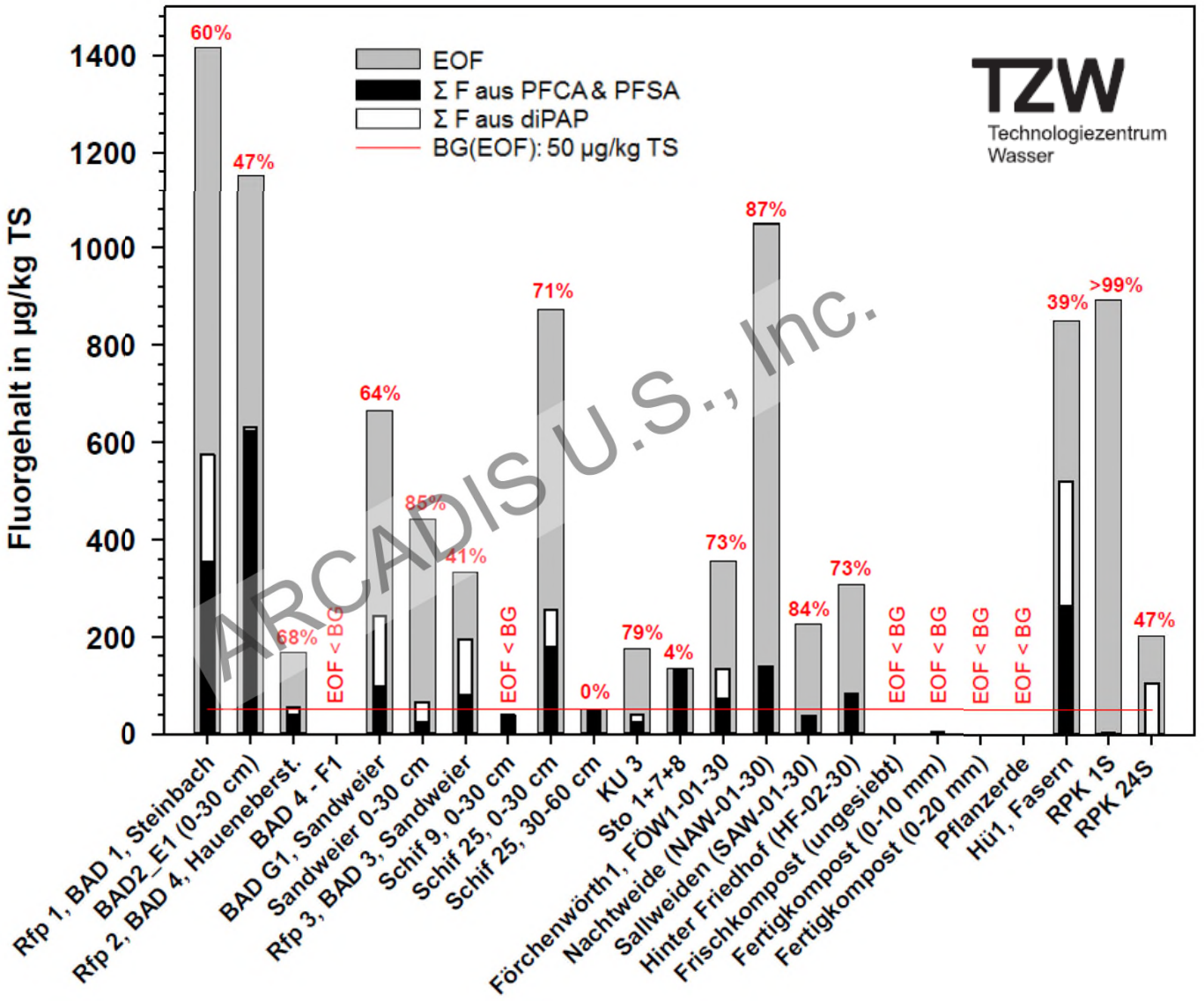
Soil Analysis



Soil Leachate Analysis



Leachate Analysis Reveals a More Complex PFAS Composition



Path Forward – Management Strategy

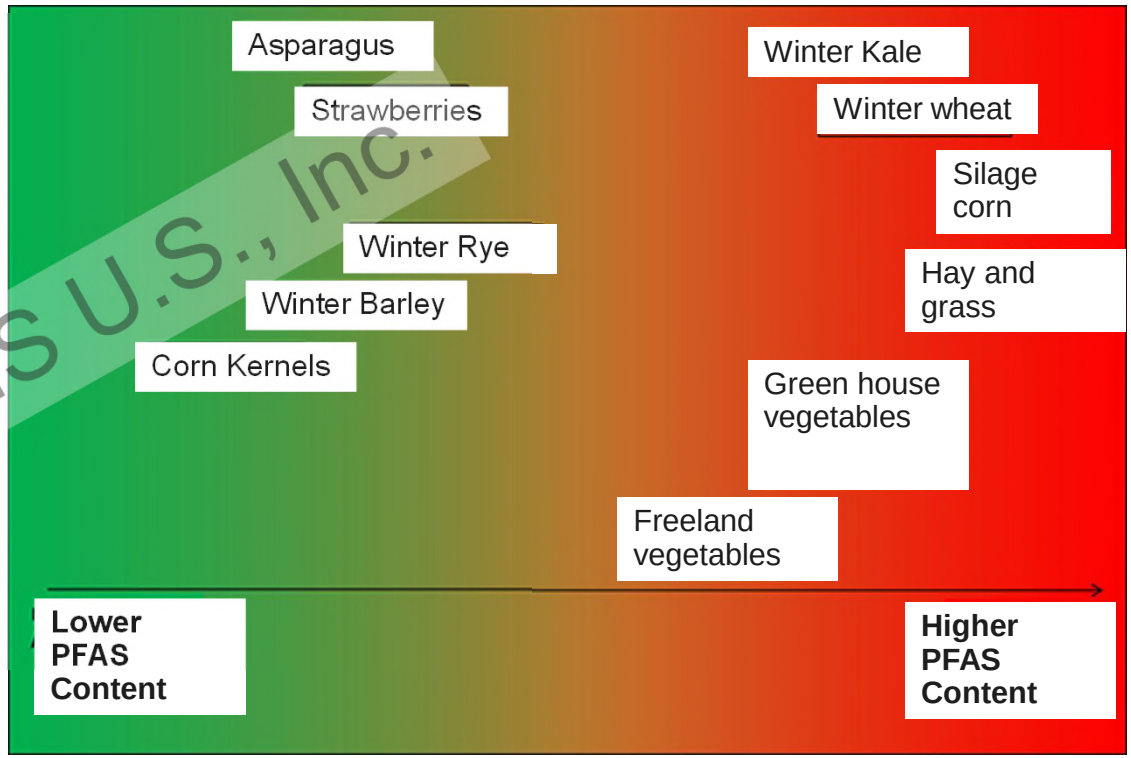
Guidance Values for Food Products - Germany

	[µg/kg]					
	PFBA	**PFPeA**	**PFHxA**	**PFHpA**	**PFBS**	**PFHxS**
Fruit/vegetables	9,4	2,8	5,7	< 2	5,7	< 1

	[mg/kg]					
	PFBA	**PFPeA**	**PFHxA**	**PFHpA**	**PFBS**	**PFHxS**
Meat & Fish	0,10	0,03	0,06	0,003	0,06	0,001

PFAS Plant Uptake

- Opportunity for managed and strategic agricultural use;
- Crop for e.g. Bio-fuel production presents the lowest risk – but lower economical insentive for farmers;
- Requires QA/QC program to manage risk to consumers.



Source:: Homepage Stabsstelle PFAS 17.11.2017

Summary

- Biosolid application has the potential to cause large area soil and groundwater PFAS impacts;
- Conventional soil analysis can significantly underestimate the PFAS mass
- Precursors represents a "hidden mass" with potential significant implications for fate and transport and risk;
- Large area impacts from biosolids can be managed - requires stakeholder collaboration and solid QA/QC program.

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