PFAS Effect on Agriculture Testimony: H.911

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Introduction

Dr. Hao Chen: Assistant Professor at the University of Vermont

Areas of expertise

1. Fate and transport of pollutants within soil and water systems
2. Interactions between pollutants and the environment with a focus on mitigating their effects through innovative and engineered methods

Current project: Our current project investigates how winter triticale takes up PFAS from contaminated soils collected from an organic farm in Maine.

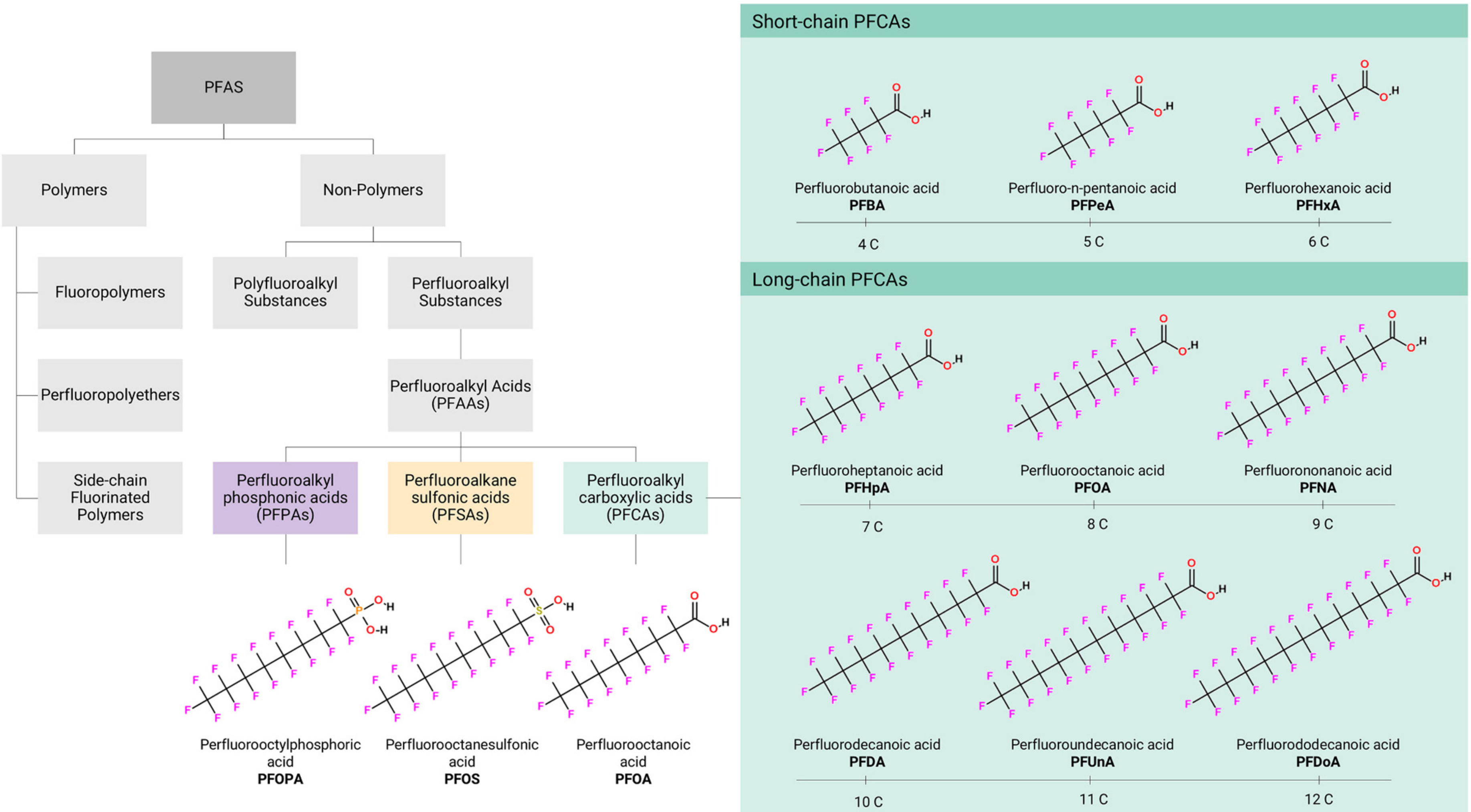
Why PFAS matter

PFAS unique behavior: they resist chemical breakdown, heat, and biological degradation.

Because of this stability, PFAS exist in millions of variations.

The C–F bond is one of the strongest in chemistry

PFAS classification and structure



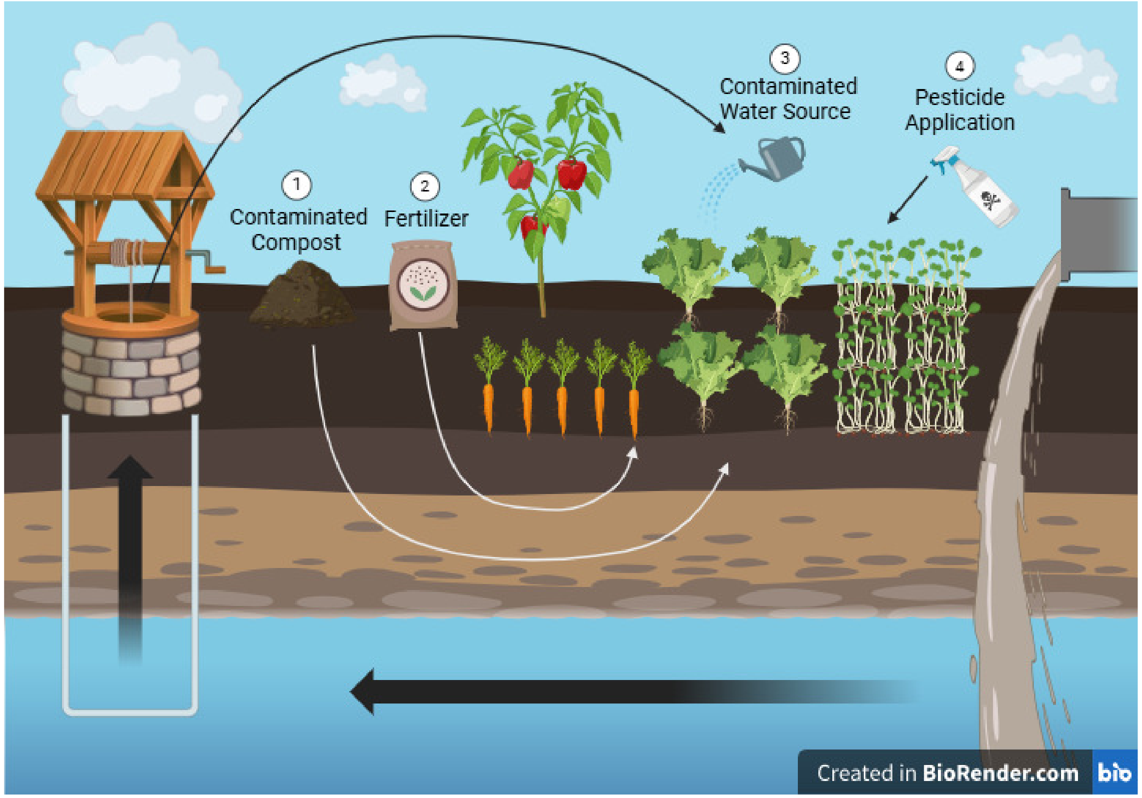
PFAS in soils

PFAS behavior in soils depends on:

- soil texture
- organic carbon content
- pore structure
- water retention
- sediment movement

These soil properties affect:

- how PFAS leach downward
- how long they remain in soil
- how they move into groundwater
- the shape of their environmental pathways



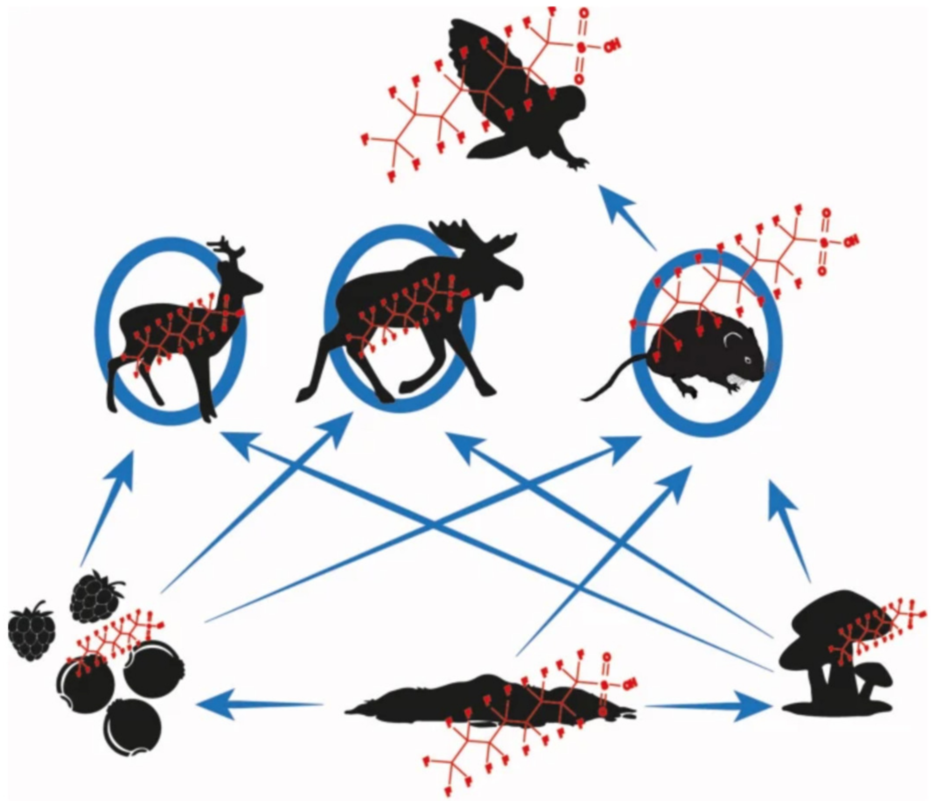
Fate and Accumulations of PFAS in the Food Chain

PFAS can move between environmental compartments, they can:

bioaccumulate (build up inside organisms)

biomagnify (increase in concentration as they move up the food chain)

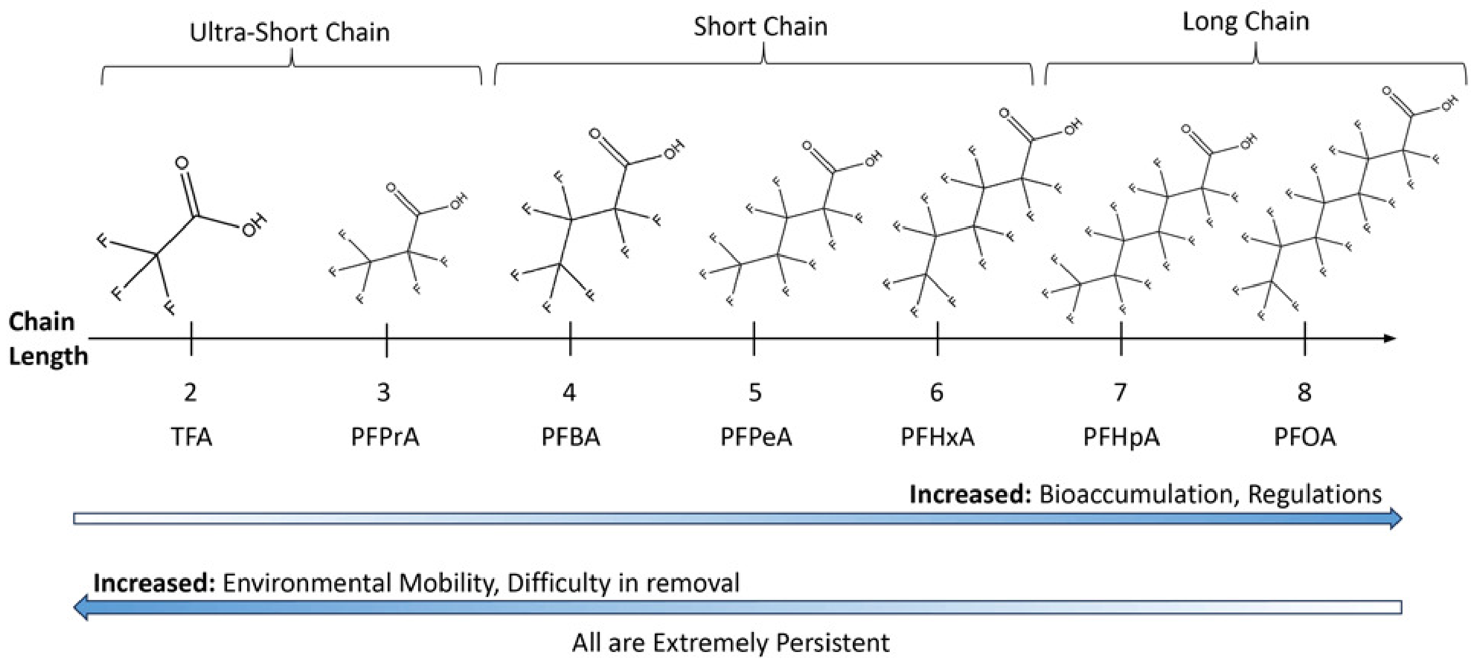
This means animals higher in the food chain (including humans) can end up with the **highest PFAS levels**, which can be dangerous.



Behavior of long-chain vs. short-chain PFAS in soil and water

Long-chain PFAS: stick more strongly to soil organic matter move more slowly but persist longer (because they don't leach away)

Short-chain PFAS: dissolve more easily in water move faster can reach groundwater more easily



Environmental PFAS concentrations vary widely

PFAS levels in the environment depend on where the contamination comes from.

Typical concentrations:

0.1–100 µg/kg in many contaminated soils

Up to 200 µg/kg in heavily polluted sites (e.g., military bases, fire stations using AFFF)

In Europe:

Average soil PFAS contamination is >5 µg/kg

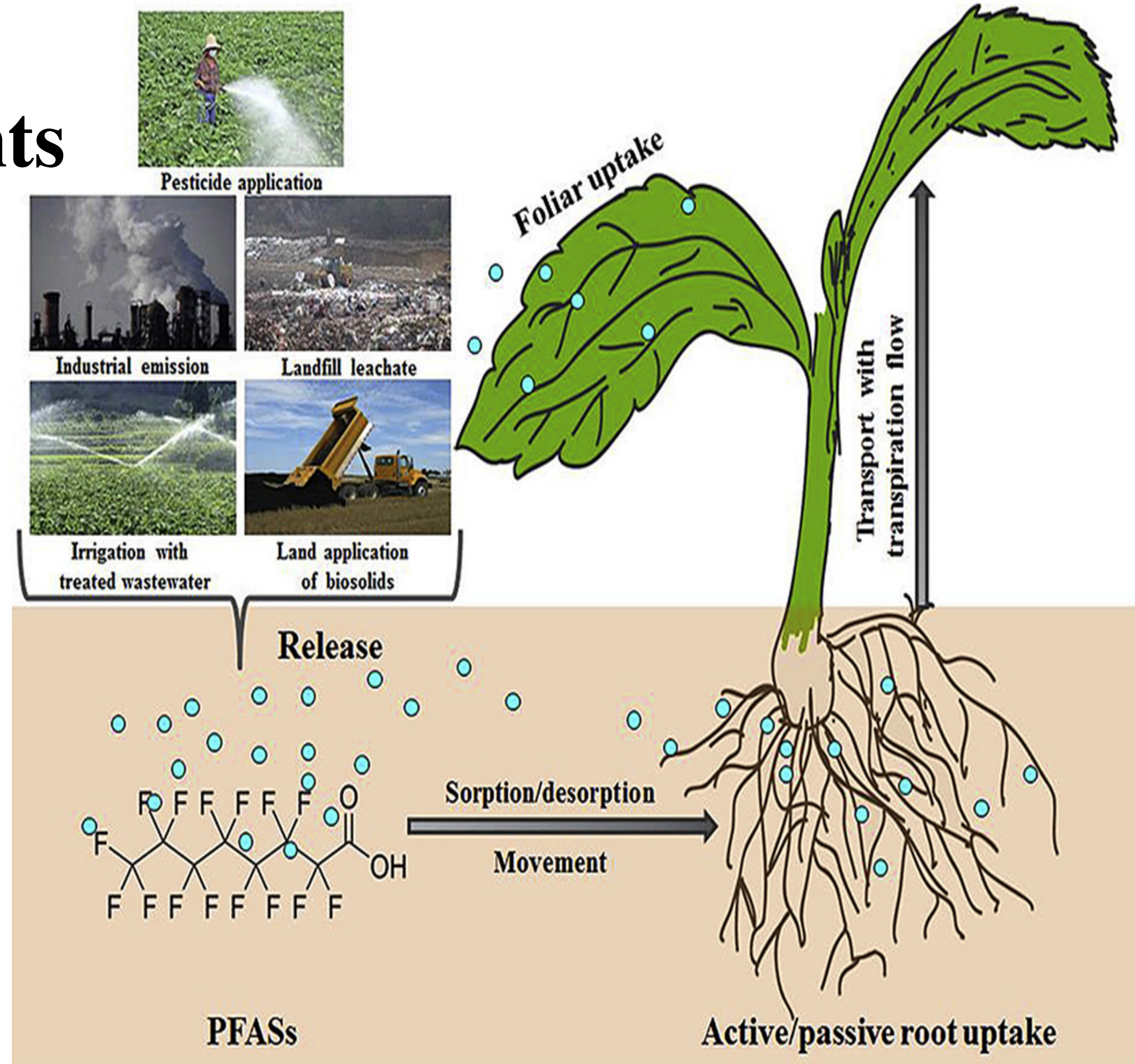
Some northern regions reach 40 µg/kg

PFAS uptake by plants

Plants can take up PFAS from soil or water. PFAS can move into edible plant parts (leaves, fruits, grains).

Some studies in model plants (like *Allium cepa*, onion) show PFAS can: damage DNA; affect cell division, effects depend on:

- the specific PFAS
- the plant species
- the exposure time



PFAS in crops and the need for regulation

Research has found PFAS in:

- cereals
- fruits
- vegetables

PFAS can accumulate in edible tissues, which raises concerns for human consumption. This shows:

- the need for better regulation
- the urgency to prevent PFAS spread
- the importance of understanding how plants take up PFAS

(Wen et al., 2013)

PFOA Movement into Roots

- Energy Dependent Active Process

OR Passive Process

(Zhang et al. (2019)

PFOA Movement into Roots

- Energy Dependent Active Process

Quantify plant's PFAS uptake ability

metrics to evaluate plant performance:

A. BAF / BCF (Bioaccumulation / Bioconcentration Factor)

These measure how much PFAS accumulates in the plant compared to soil or water.

BCF > 1 → plant accumulates PFAS well

BCF is calculated for both: shoots roots

B. TF (Translocation Factor)

TF = PFAS concentration in shoots ÷ PFAS concentration in roots

TF > 1 means the plant can move PFAS from roots to leaves/stems

TF > 1 indicates hyperaccumulator behavior

30 day experiment for fern PFAS fern uptake

1.PFAS Chemicals

The authors selected 11 PFAS compounds

Short-chain PFAS (PFBA, PFPeA, PFHxA…)

Long-chain PFAS (PFOA, PFOS)

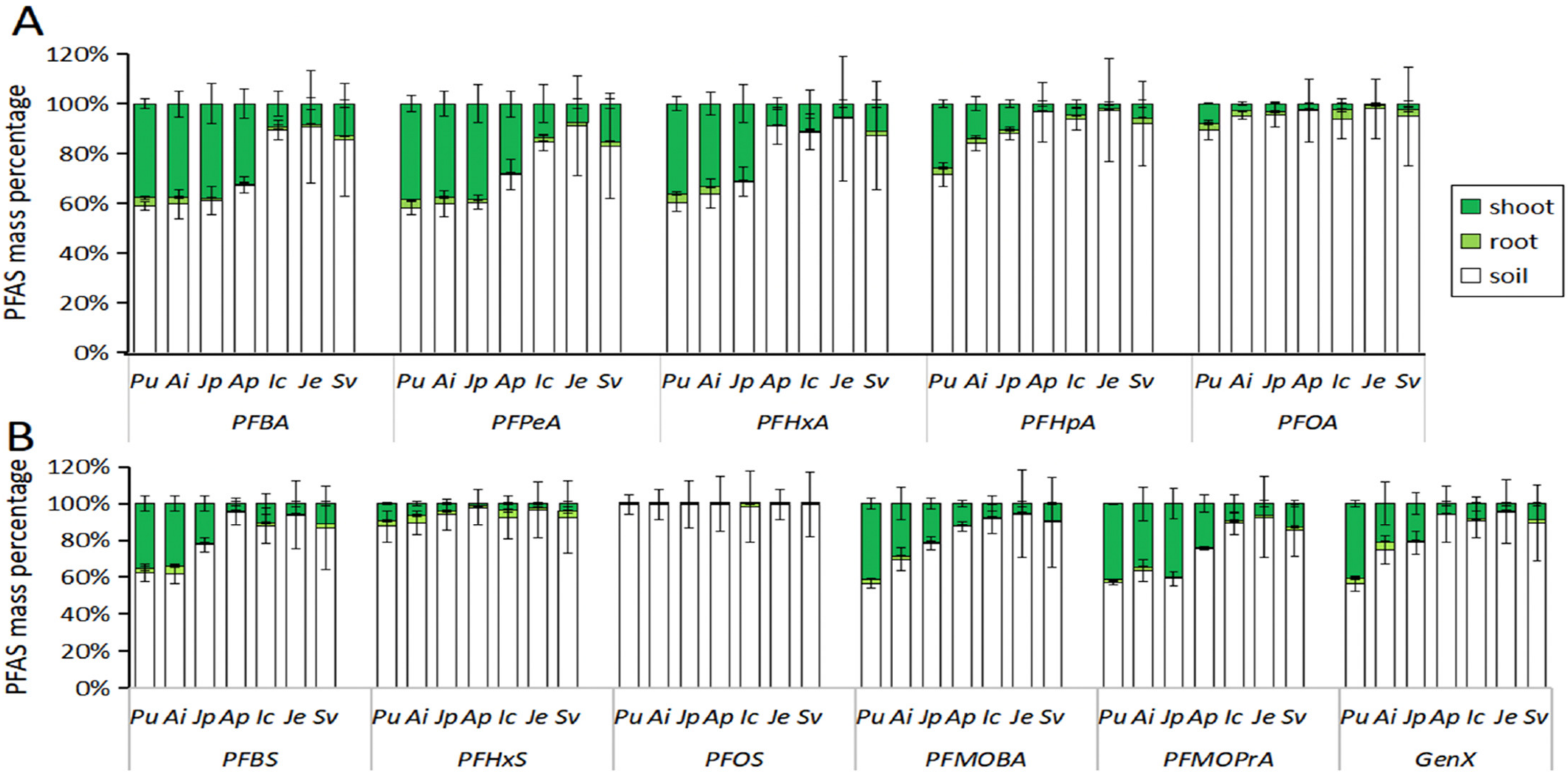
Ether PFAS / GenX (PFMOPrA, PFMOBA, HFPO-DA)

2. Soil PFAS concentration: ~200 ng/g (environmentally relevant).

Phytoextraction of per- and polyfluoroalkyl substances (PFAS) by weeds: Effect of PFAS physicochemical properties and plant physiological traits

Qiang He [a], Zheng Yan [a], Shenhua Qian [a], Tiantian Xiong [b], Khara D. Grieger [c,d], Xiaoming Wang [a], Caihong Liu [a], Yue Zhi [a,*]

{He, 2023 #1}



Mass percentage of PFAS in soil and plant root and shoot after 30-day exposure. Seven plant species were investigated, i.e., Phyllanthus urinaria (Pu), Aster indicus(Ai), Justicia procumbens(Jp), Alternanthera philoxeroides(Ap), Imperata cylindrica(Ic), Juncus effusus(Je), and Setaria viridis(Sv).

Summary

PFAS uptake depends strongly on chain length

- Short chain: higher uptake
  Long chain : minimal uptake

Shoots only contain short-chain PFAS

- Translocation (root to shoot) is limited to **small PFAS.**

Plant species matter, but less than PFAS chemistry

- Some plants are slightly better accumulators, but none remove much long-chain PFAS.

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

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

Accumulation and effects of perfluoroalkyl substances in three hydroponically grown *Salix* L. species

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ABSTRACT

The potential of young rooted cuttings of three *Salix* L. species plants to accumulate a mixture of eleven perfluoroalkyl substances (PFASs), in particular, perfluoroalkyl acids (PFAAs), from the nutrient solution and their effects on plant growth and photosynthesis were assessed in an 8-day experiment. The growth rate of the willow plants exposed to the PFAA mixture was not much affected except for *S. triandra*. Regarding photosynthesis, the gas exchange parameters were affected more than those related to chlorophyll fluorescence, with significant increase of the net CO_2 assimilation rate and parameters related to stomatal conductance. A decreasing trend in the PFAA concentration in leaves with increasing carbon chain length was observed, whereas long-chain PFAAs showed higher concentrations in roots. Accordingly, the foliage to root concentration factor highlighted that PFAAs with shorter carbon chain length ($C \leq 7$) translocated and accumulated relatively more in leaves compared to roots. Removal efficiency of individual PFAAs for leaves and roots were comparatively higher with *S. eleagnos* and *S. purpurea* than *S. triandra*, with mean removal values at the whole plant level ranging around 10% of the amount initially spiked, suggesting their potential for phytoremediation of PFASs.

Hydroponic study

Woody plant : Willows in hydroponic

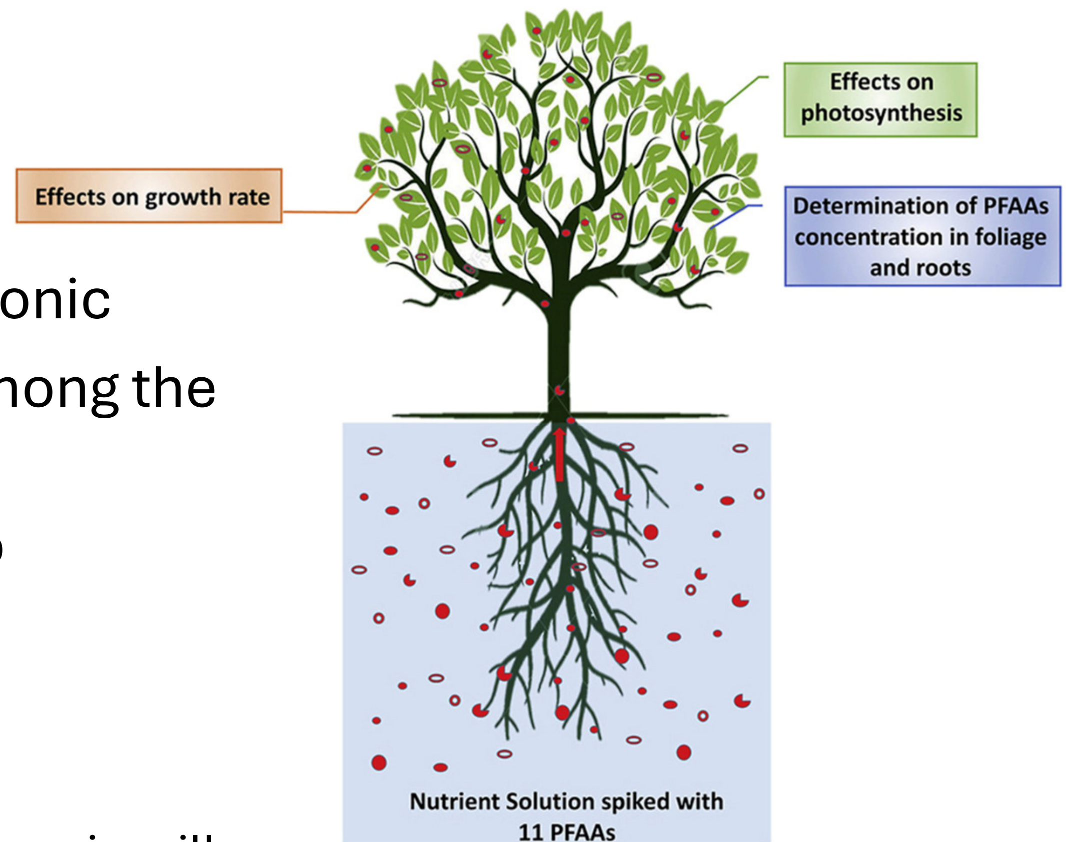
Removal efficiencies differed among the willow species

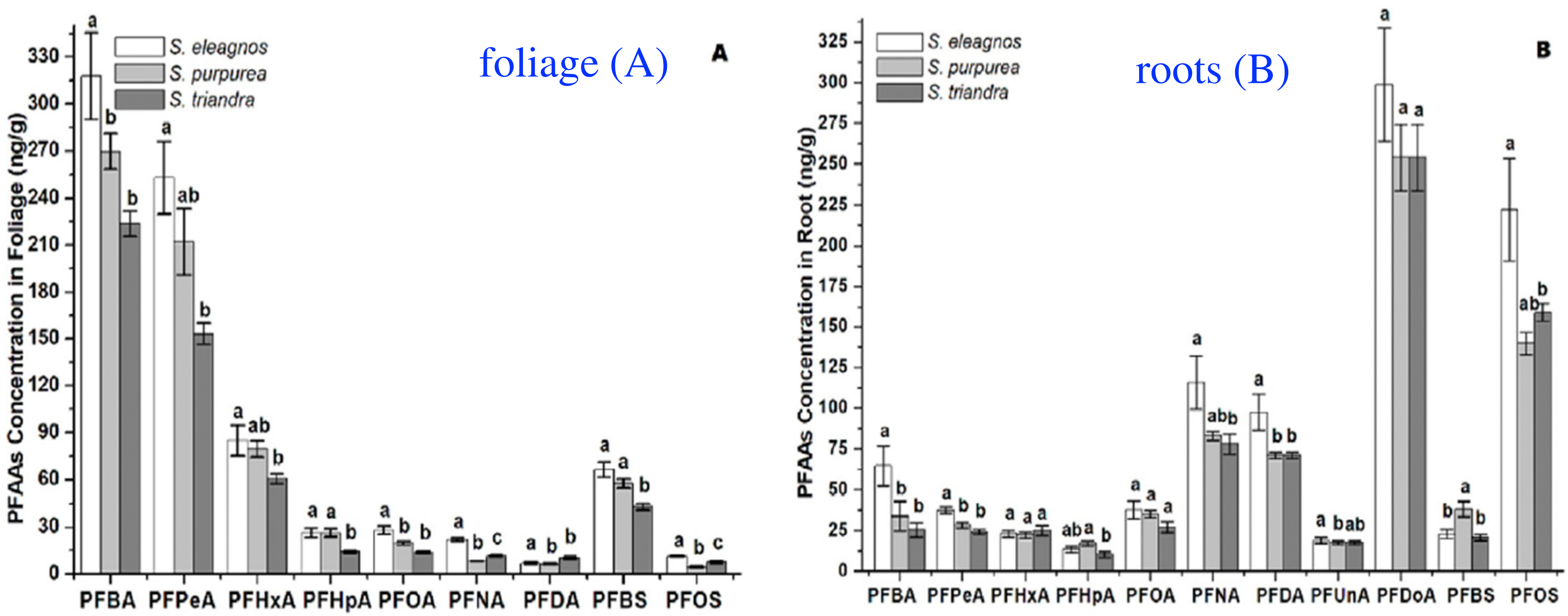
S. purpurea removed about 11%

S. eleganos removed about 9%

S. triandra removed about 6%

PFAS exposure causes mild or no stress in willows.





Concentration of PFAAs in foliage (A) and roots (B) of three willow species, on FW basis. Error bars represent standard error of the mean (n=5). Different letters indicate significant differences within the three willow species, as determined by Tukey's HSD test at $p < 0.05$.

conclusion

- PFAS exposure caused almost no visible stress.
- All 11 PFAS were taken up by roots and moved to shoots.
- Short-chain PFAS ($C \leq 7$) accumulated more in leaves; Long-chain PFAS ($C \geq 9$) stayed mostly in roots.
- Willows—especially *S. purpurea*—have meaningful potential for PFAS phytoremediation, although field soils still need to be tested.

Herbaceous Plants: Fern

Bioaccumulation of Per- and Polyfluoroalkyl Substances (PFAS) in Ferns: Effect of PFAS Molecular Structure and Plant Root Characteristics

Shenhua Qian, Hongying Lu, Tiantian Xiong, Yue Zhi,* Gabriel Munoz, Chuhui Zhang, Zhengwei Li, Caihong Liu, Wei Li, Xiaoming Wang, and Qiang He

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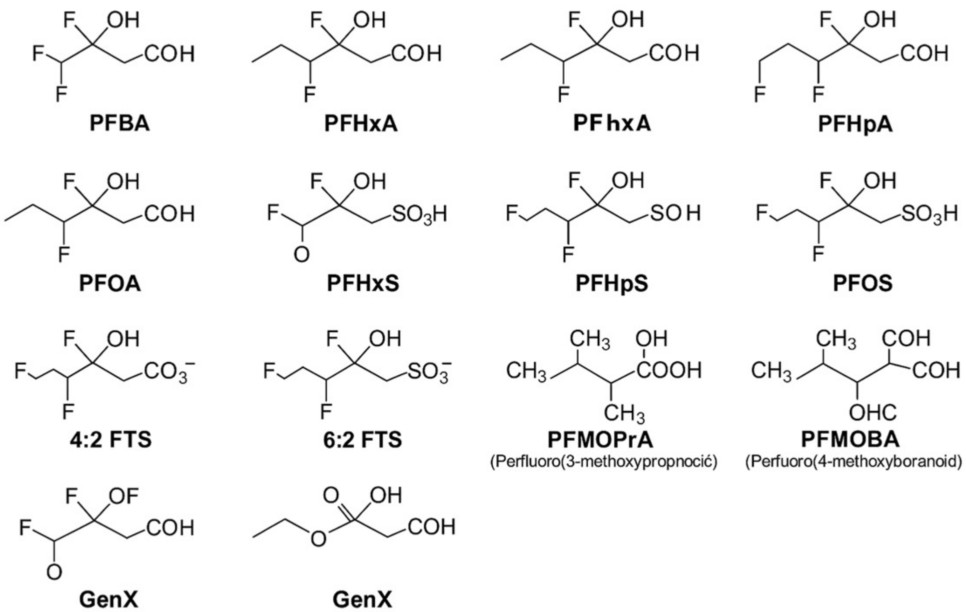


Concentrations were approx. 200–300 μg/L for each PFAS.
Each plant sat in 300 mL of this PFAS mixture for 30 days.

All PFAS enter roots AND shoots

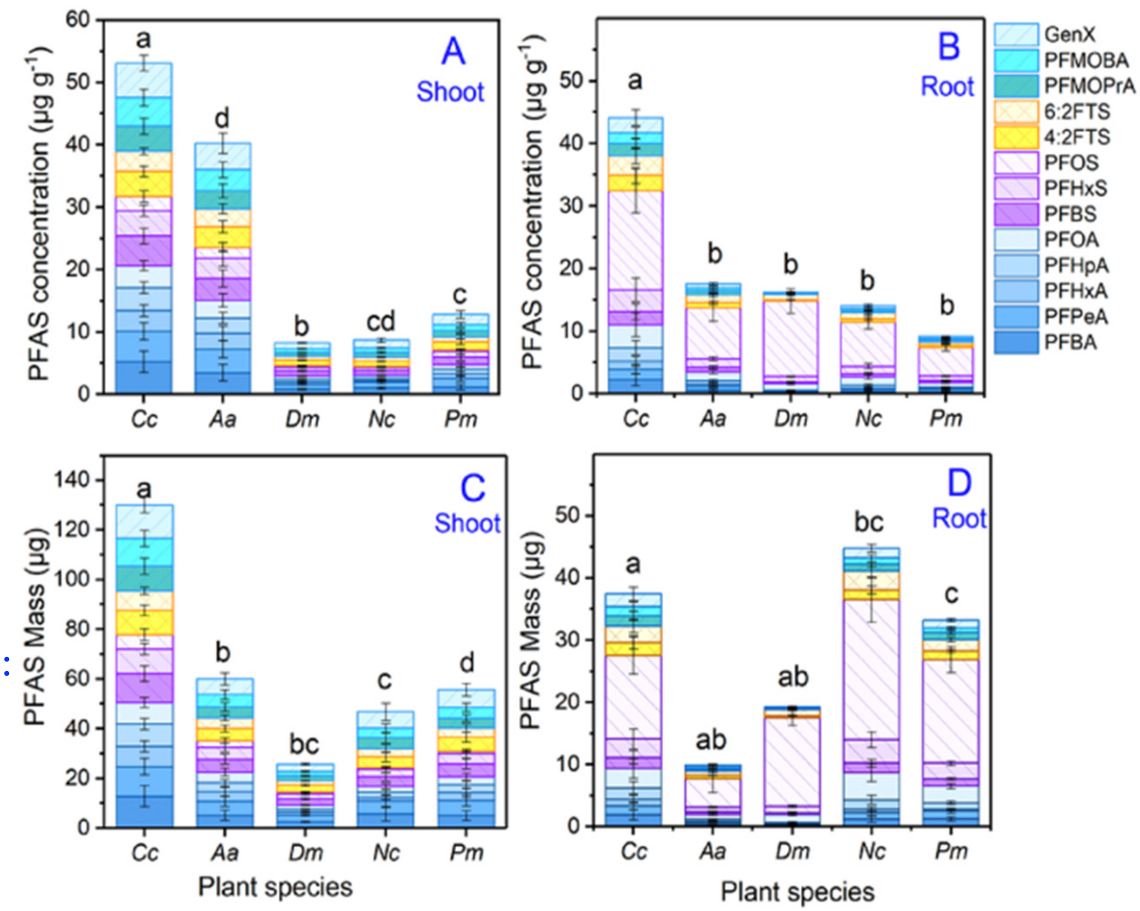
Short-chain PFAS TF > 1
Long-chain PFAS TF < 1

After 30 days, **all 13 PFAS** were found in both roots and shoots.

Concentration ranges:

Shoots: 7.0–53.1 µg/g

Roots: 9.1–44.1 µg/g



Root traits showing *positive correlation* with root PFAS:

- Total root length
- Surface area
- Surface area per length
- Projected area

Herbaceous plants in soil

Phytoextraction of per- and polyfluoroalkyl substances (PFAS) and the influence of supplements on the performance of short–rotation crops☆

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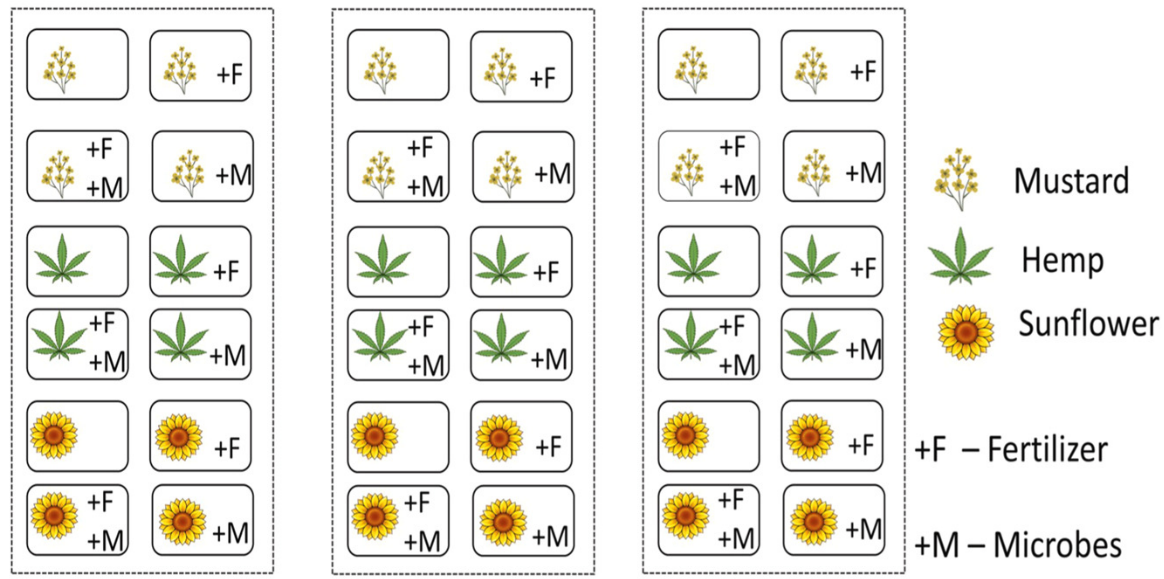
PFAS uptake performance of short-rotation crops

Organic potting soil was spiked with 14 PFAS, each at 1 mg/kg.
Plants used: Sunflower, mustard, hemp
Treatments (4 conditions)

1. Control (no supplement)
2. Microbial mixture
3. Fertilizer
4. Fertilizer + microbes

Greenhouse setup
Grown for 90 days (one crop cycle)



PFAS concentrations change in different parts

1. PFAS accumulate differently in plant tissues

Leaves have the highest PFAS

Stems are moderate

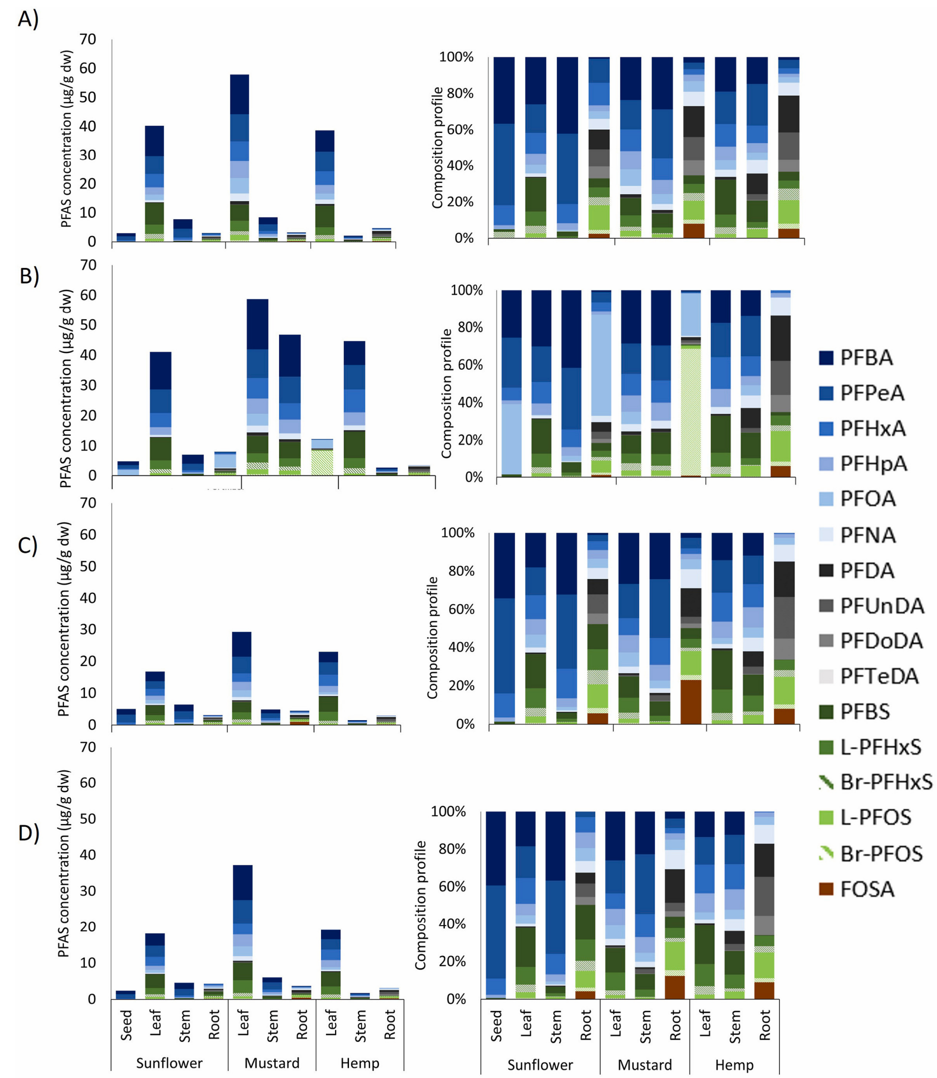
Roots are the lowest

2. Mustard has the highest PFAS concentrations

3. Different PFAS behave differently

Short-chain PFAS (PFBA, PFPeA) dominate leaves and stems.

Long-chain PFAS (PFOS, PFUnDA) show up more in roots.



A – Control (no fertilizer, no microbes); B – Microbes only
C – Fertilizer + microbes ; D – Fertilizer only

Summary

PFAS movement in plants is controlled by multiple interacting factors:

1. Chemical properties: chain length, hydrophobicity, molecular weight, van der Waals volume.
2. Root traits: diameter, fineness, protein/lipid content, anatomical barriers (endodermis, suberin).
3. Biological transporters: phosphate transporters (PHT family).

PFOS inhibits plant growth at moderate/high doses.

Reference

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4. Kim, Jun Hyeok, et al. "Perfluorooctanesulfonic acid alters the plant's phosphate transport gene network and exhibits antagonistic effects on the phosphate uptake." *Environmental Science & Technology* 58.12 (2024): 5405-5418.