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Assessing Biosolids Treatment Processes on Pollutant Environmental Fate and Plant Uptake following Land Application

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Trainees: Harley Curtis[1], Qianqian Dong[1], Geoff Rhodes[1], Yifei Wang[2], and Zhiliang Xu[1]

Collaborators: Katherine Bell[5] and Shubha Oza[5]

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2024 Midwest Biosolids Conference, West Lafayette, IN March 26, 2024

EPA Project: Assessing Biosolids Treatment Processes on Pollutant Environmental Fate and Plant Uptake following Land Application

Hui Li

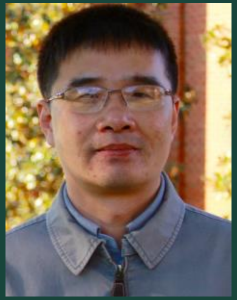
pollutant sorption and bioavailability, plant uptake, PPCP and PFAS analysis

Courtney Carignan

exposure assessment, community engagement, research translation

Wei Zhang

sorption and transport processes in soils, soil-water-plant relationship



Jack Huang

fate and transport of PFAS, PFAS remediation, PFAS analysis

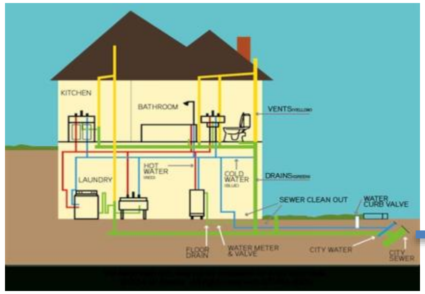
James Ippolito

land application of biosolids, biogeochemistry of nutrients and heavy metals

John Norton Jr.

wastewater treatment, biosolids processing, community engagement

PPCPs and PFAS in biosolids and potential impact



Land application of biosolids

Irrigation with treated wastewater

Li and Koosaletse-Mswela, 2023, *Current Opinion in Environ Sci & Health*, 34: 100487.

EPA Project Research and Extension Tasks

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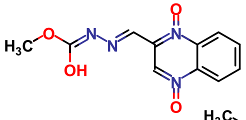
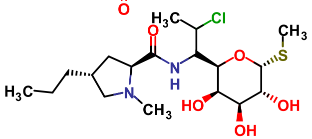
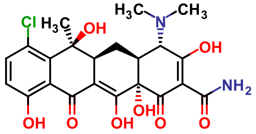
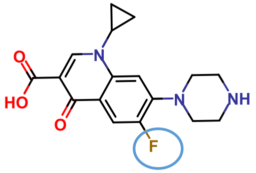
1. Surveillance of impacts of treatment processes on PPCP and PFAS concentration in biosolids.
2. Sorption and transport of PPCP and PFAS in soils
3. Accumulation of PPCP and PFAS in agricultural crops from biosolids-amended soils and relation with their presence in soil pore water
4. Conduct field experiments to measure the accumulation of PPCP and PFAS in food crops from land-applied biosolids
5. Modeling human exposure to PPCP and PFAS through biosolids land-application pathway
6. Community engagement and communication through education and extension activities

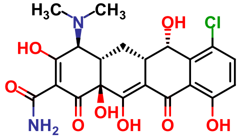
Pharmaceuticals and Personal Care Products (34)

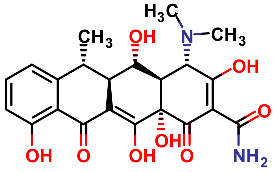
Carbadox 

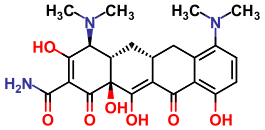
Clindamycin 

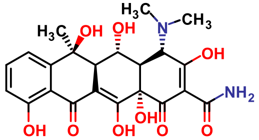
Chlortetracycline 

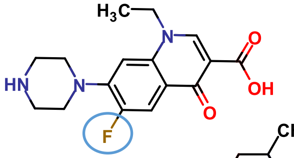
Ciprofloxacin 

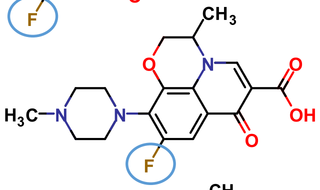
Demeclocycline 

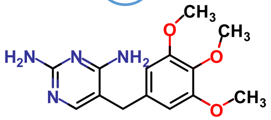
Doxycycline 

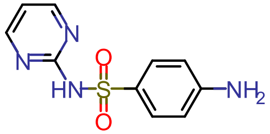
Minocycline 

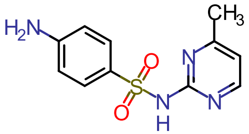
Oxytetracycline 

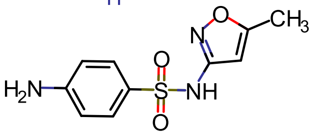
Norfloxacin 

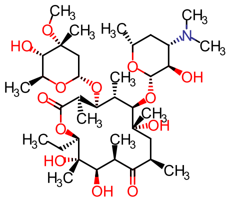
Ofloxacin 

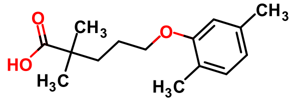
Trimethoprim 

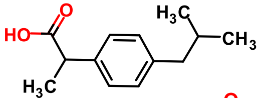
Sulfadiazine 

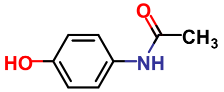
Sulfamerazine 

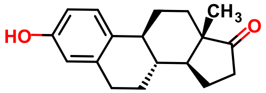
Sulfamethoxazole 

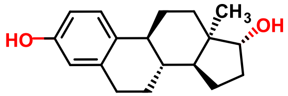
Erythromycin 

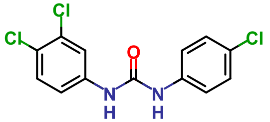
Gemfibrozil 

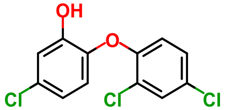
Ibuprofen 

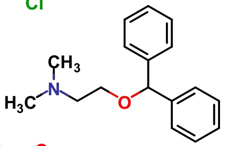
Acetaminophen 

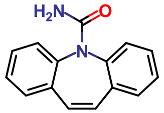
Estrone 

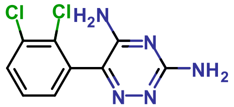
17α-estradiol 

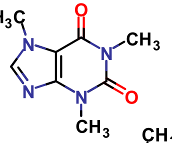
Triclocarban 

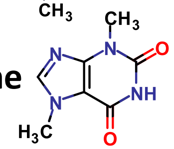
Triclosan 

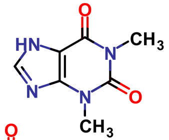
Diphenhydramine 

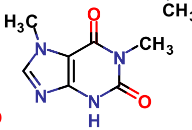
Carbamazepine 

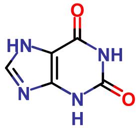
Lamotrigine 

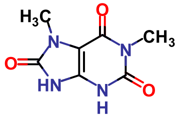
Caffein 

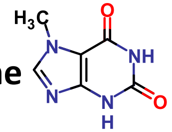
Theobromine 

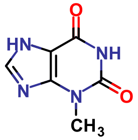
Theophylline 

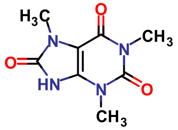
Paraxanthine 

Xanthine 

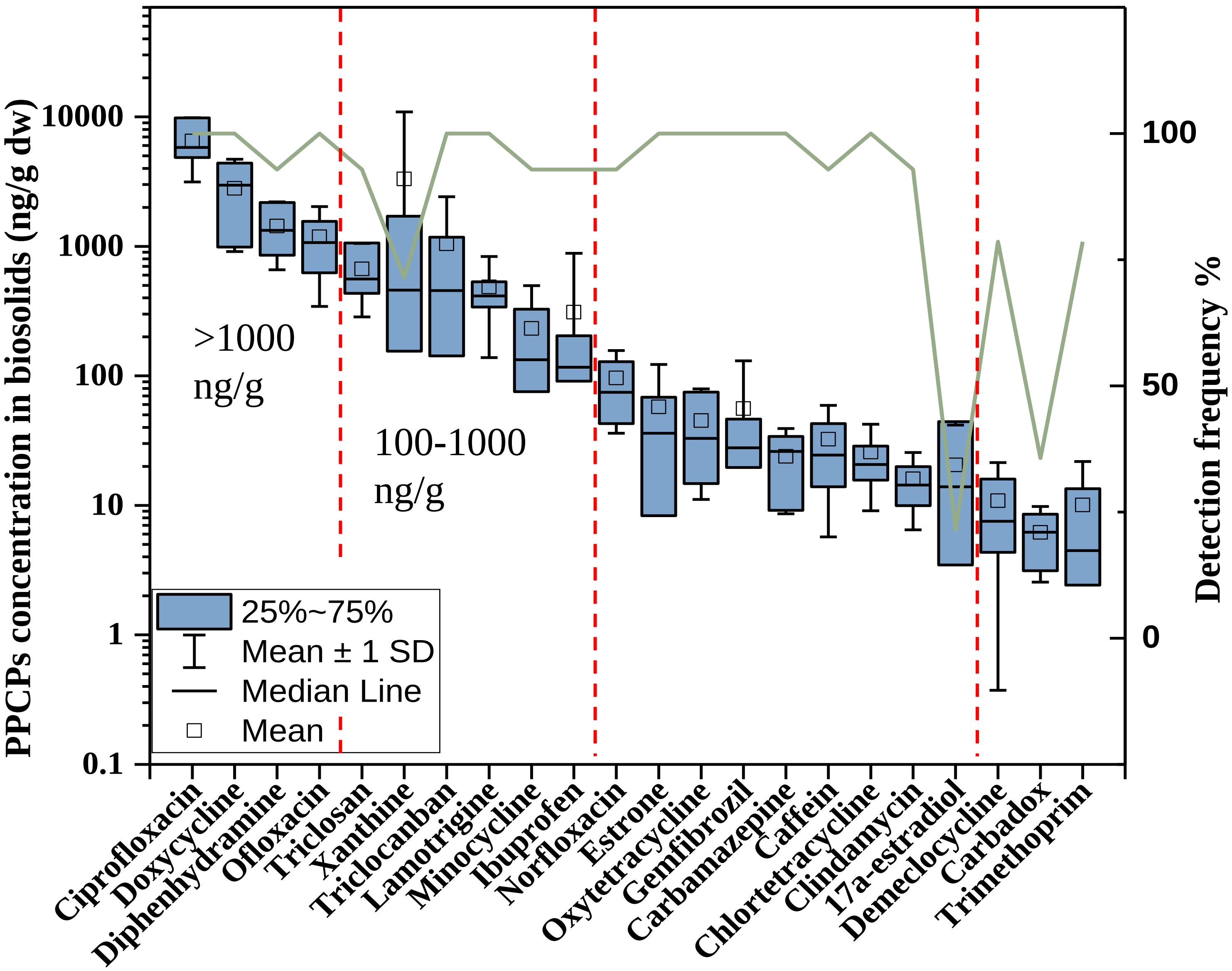
1,7-Dimethyluric Acid 

7-Methylxanthine 

3-Methylxanthine 

1,3,7-Trimethyluric Acid 

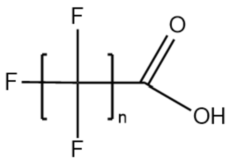
PPCP concentration and detection frequency in biosolids



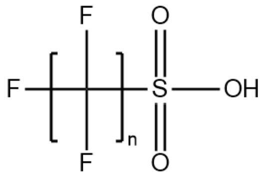
- >1000 ng/g:
  Ciprofloxacin, Doxycycline, Diphenhydramine, Ofloxacin
- 100 to 1000 ng/g:
  Triclosan , Xanthine, Triclocarban , Lamotrigine, Minocycline and Ibuprofen
- 3 to 100 ng/g:
  Remaining PPCPs

PFAS in Biosolids and Potential Impact

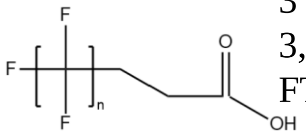
Target Analysis of 43 PFAS in Biosolids Samples across the nation



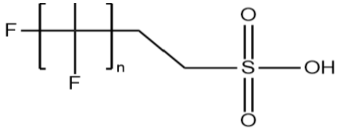
11 perfluoroalkyl carboxylic acid (PFCA): n = 3-13, PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFNA, PFDA, PFUnA, PFDoA, PFTrDA, and PFTeDA



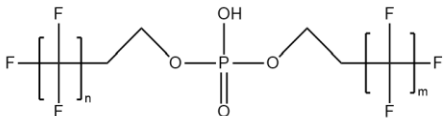
8 perfluorosulfonic acids (PFSA): n = 4-10, and 12. PFBS, PFPeS, PFHxS, PFHpS, PFOS, PFNS, PFDS and PFDoS



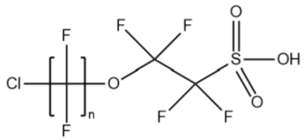
3 fluorotelomer carboxylic acids: n = 3,5, and 7, 3:3 FTCA, 5:3 FTCA, 7:3 FTCA



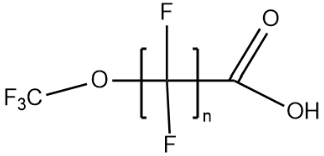
3 fluorotelomer sulfonic acids: n = 4,6, and 8, 4:2 FTS, 6:2 FTS, 8:2 FTS



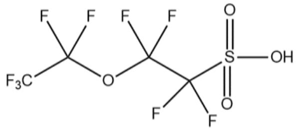
3 polyfluoroalkyl phosphate dieaster: m= n=6 6:2 diPAP; m= n=8 8:2 diPAP; m= 6, n=8 6:2/8:2 diPAP



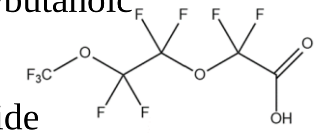
2 polyfluoroether sulfonic acids n =6, 9ClPF3ONS; n =8, 11ClPF3ONS



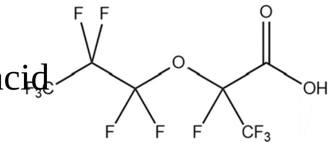
n = 2, perfluoro-3-methoxypropanoic acid (PFMPA), n= 3, perfluoro-4-methoxybutanoic acid (PFMBA)



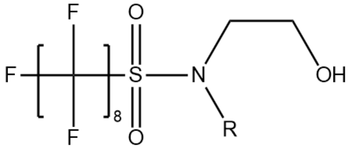
Perfluoro(2-ethoxyethane)sulfonate (PFEESA)



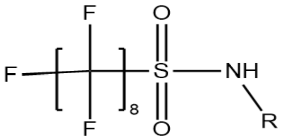
Perfluoro-3,6-dioxaheptanoic acid (NFDHA)



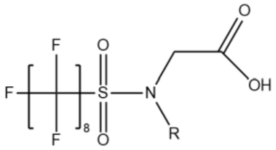
HFPO-DA (Gen X)



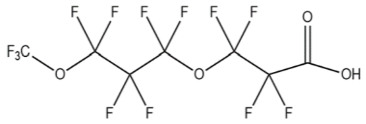
2 perfluorooctane sulfonamide ethanols: R=-CH3, N-MeFOSE; R=-CH_2CH_3, N-EtFOSE



3 perfluorooctane sulfonamides: R=H, PFOSA; R=-CH_3, N-MeFOSA; R=-CH_2CH_3, N-EtFOSA

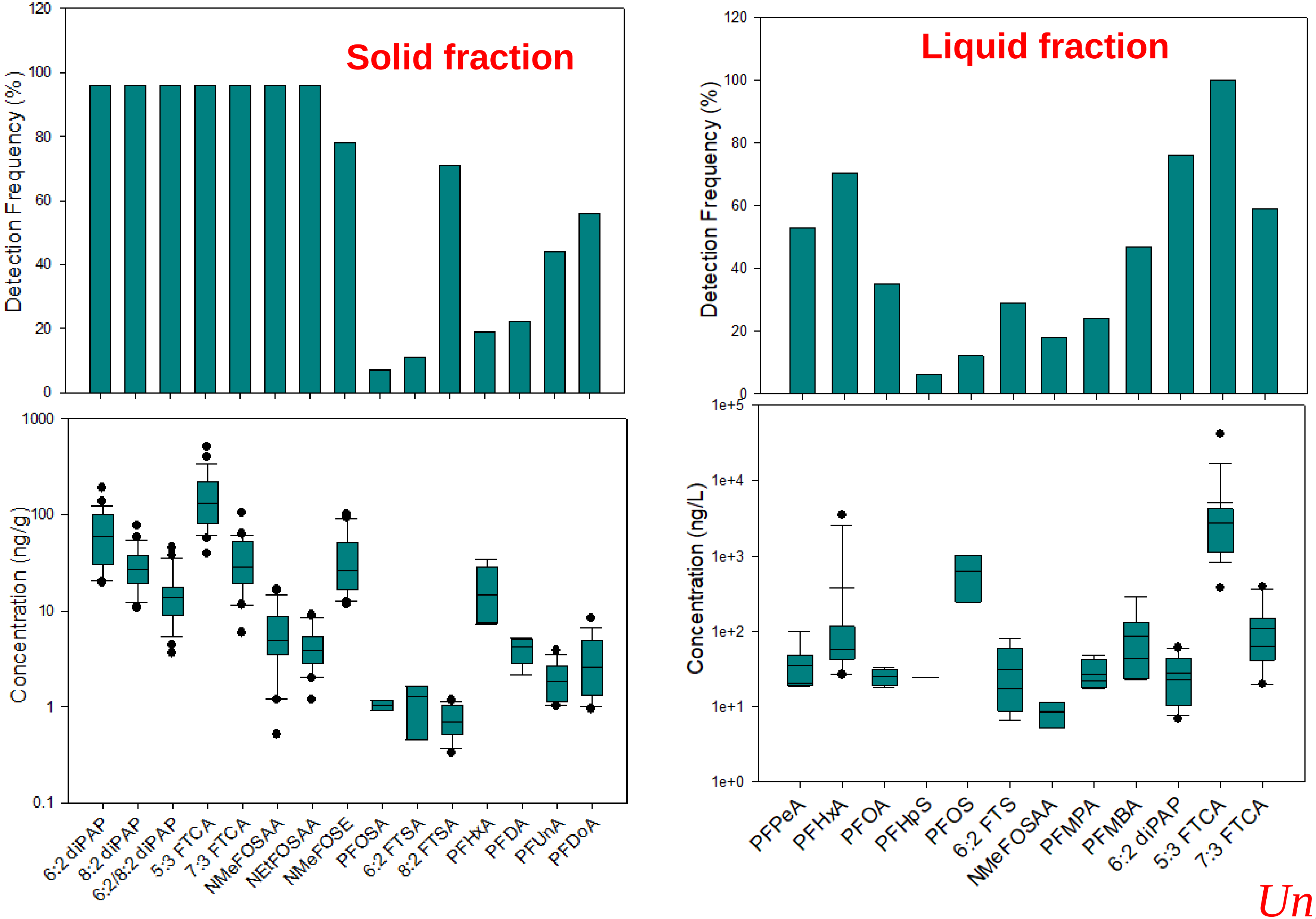


2 perfluorooctane sulfonamidoacetic acids: R=-CH_3, N-MeFOSAA; R=-CH_2CH_3, N-EtFOSAA



Perfluoroether carboxylic acids (ADONA)

PFAS concentration and detection frequency in solid and liquid fraction in biosolids



Implications to beneficial use in the perspective of plant uptake of PFAS

Unpublished data, do not share

PPCP uptake by raddish at different concentration in soil pore water

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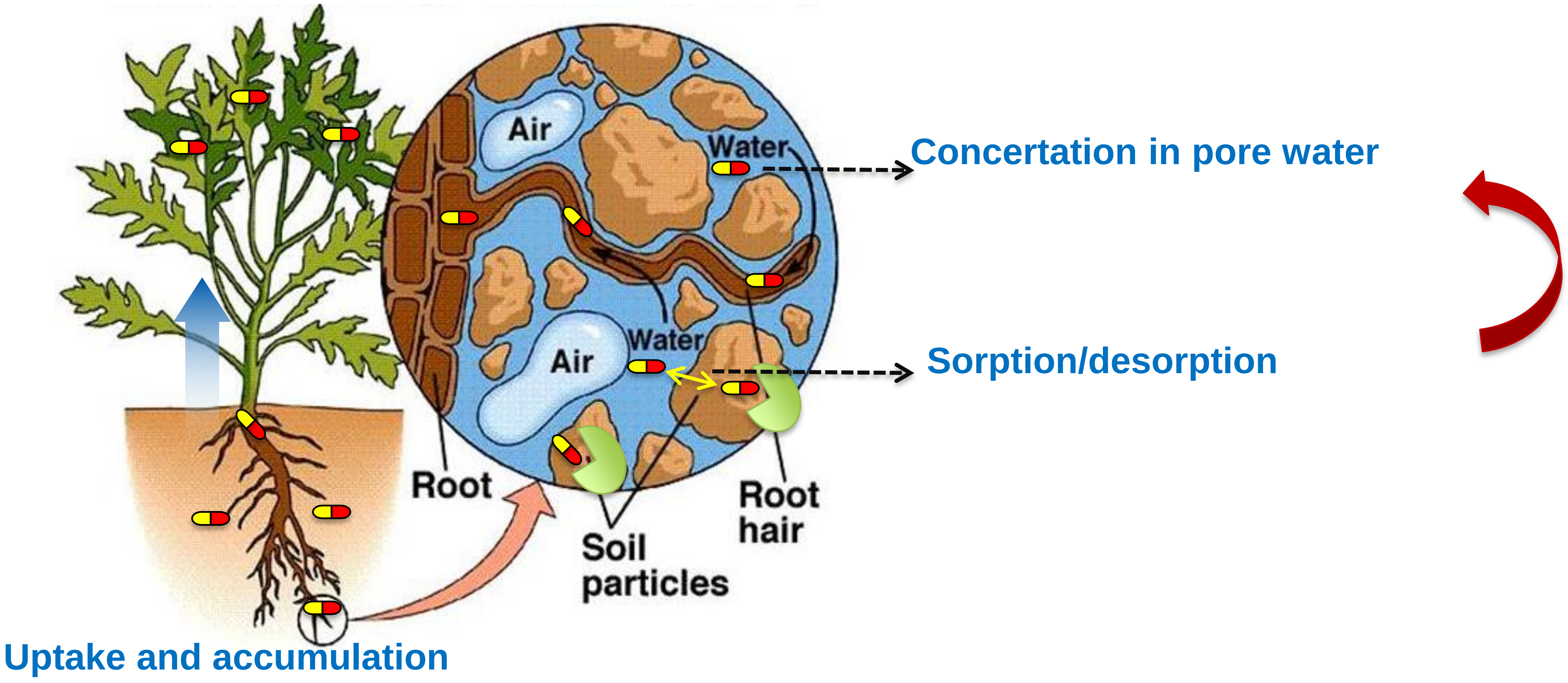
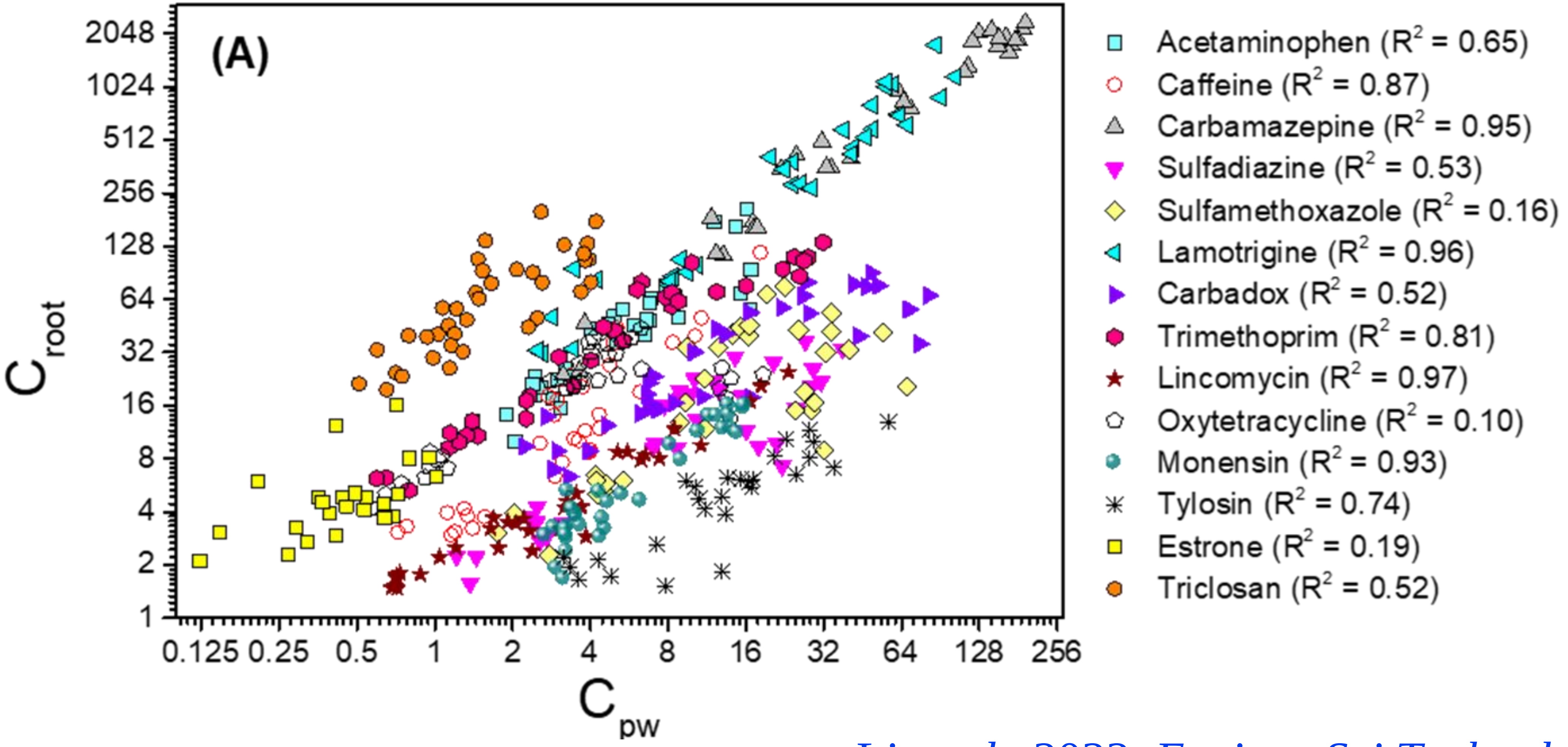
Soil No.	Type	pH	OC (%)	CEC (me/100g)	Clay	Silt	Sand
I	Sandy loam	7.2	1.3	7.0	8.9	17.2	73.9
II	Sandy clay loam	7.4	2.8	15.2	23.9	21.4	54.7
III	Loam	6.9	4.9	23.1	24.8	40.3	34.9



Positive relationship between pharmaceutical accumulation in roots and concentration in soil pore water



Li *et al.*, 2022, *Environ Sci Technol.* 56:9346.

Lettuce uptake of pharmaceuticals and personal care products

❖ **Sampling at 12, 24, 48, 72, 105, and 144 hours**

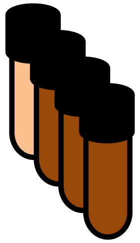
Measured lettuce growth, transpired water

Measured pH, EC and refilled/adjusted solution to 210 mL, pH back to 5-6 and EC back to 0.7-0.85 mS, then placed lettuce back into nutrient solution

Plant sample: QuEChERS

Solution: SPE

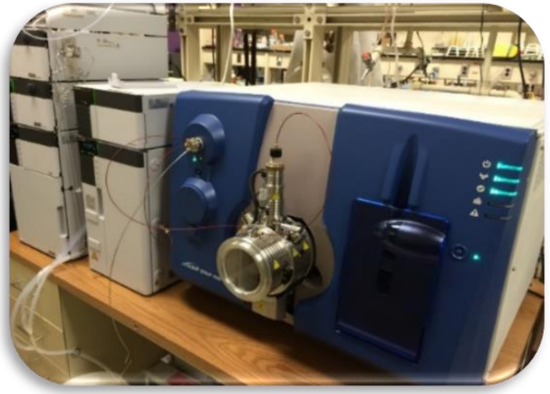
Sorption by roots



Batch experiment

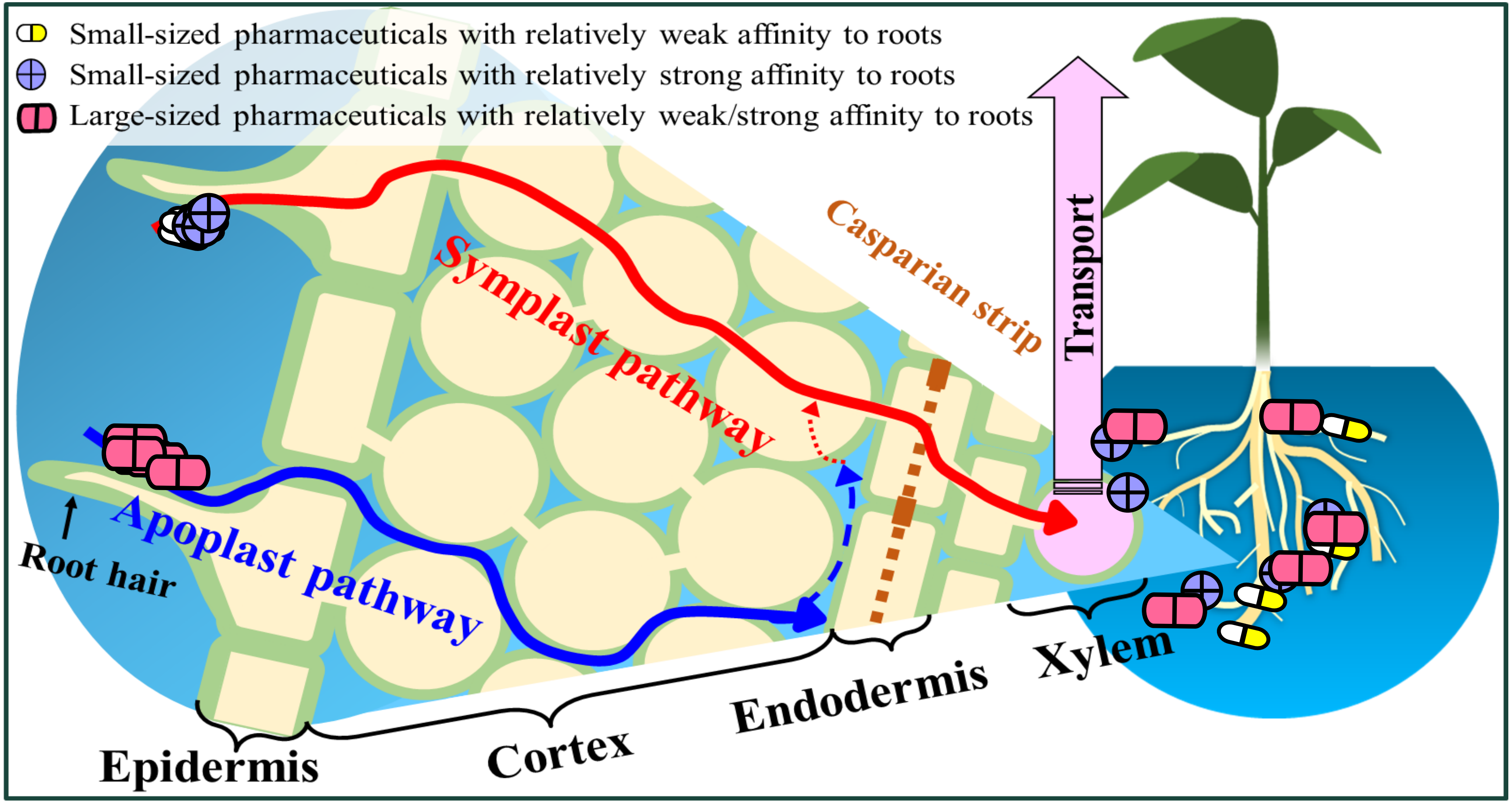
SPE

- Root: solution: 0.025 g: 20 mL
- Pharmaceutical concentration (initial pH of 5.8): 10, 20, 30, 40, and 50 μg/L in nutrient solution
- Equilibration time: 24 hours



LC/MS/MS

Highlights: Bioaccumulation pf PPCPs is related to molecular size



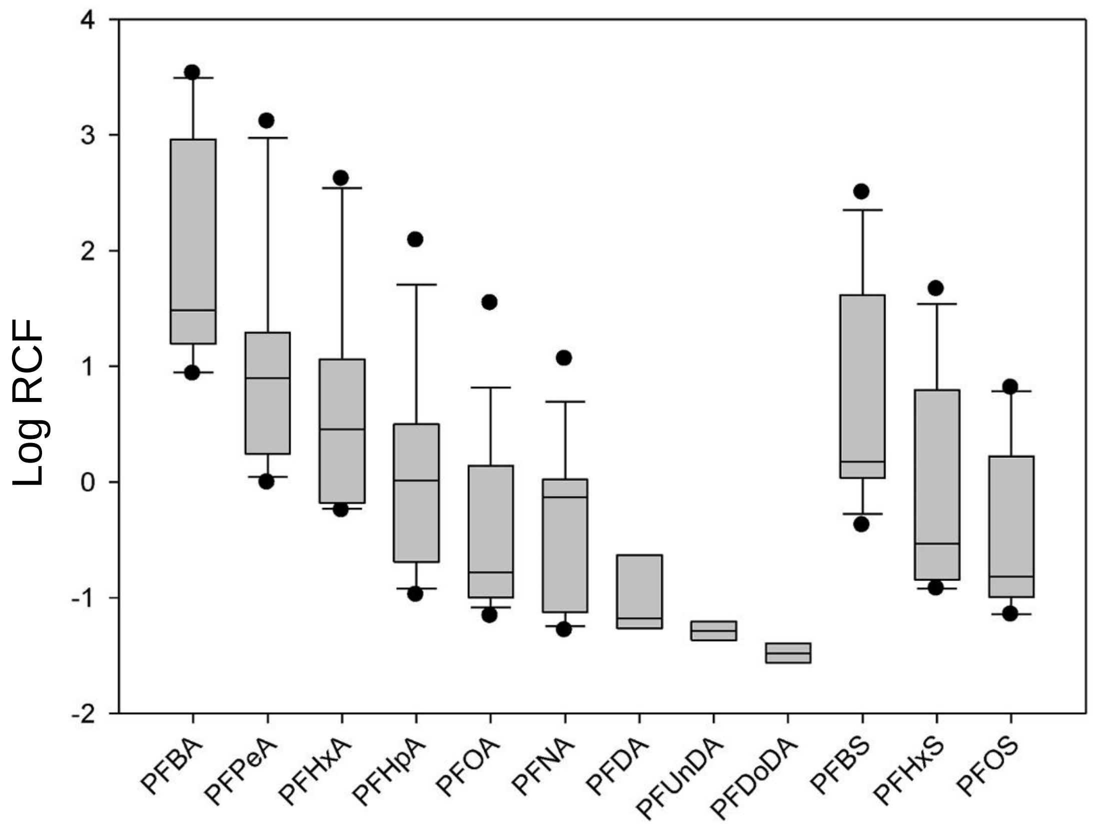
Small-sized pharmaceuticals (MW < 300 Dalton)

Large-sized pharmaceuticals (MW > 400 Dalton)

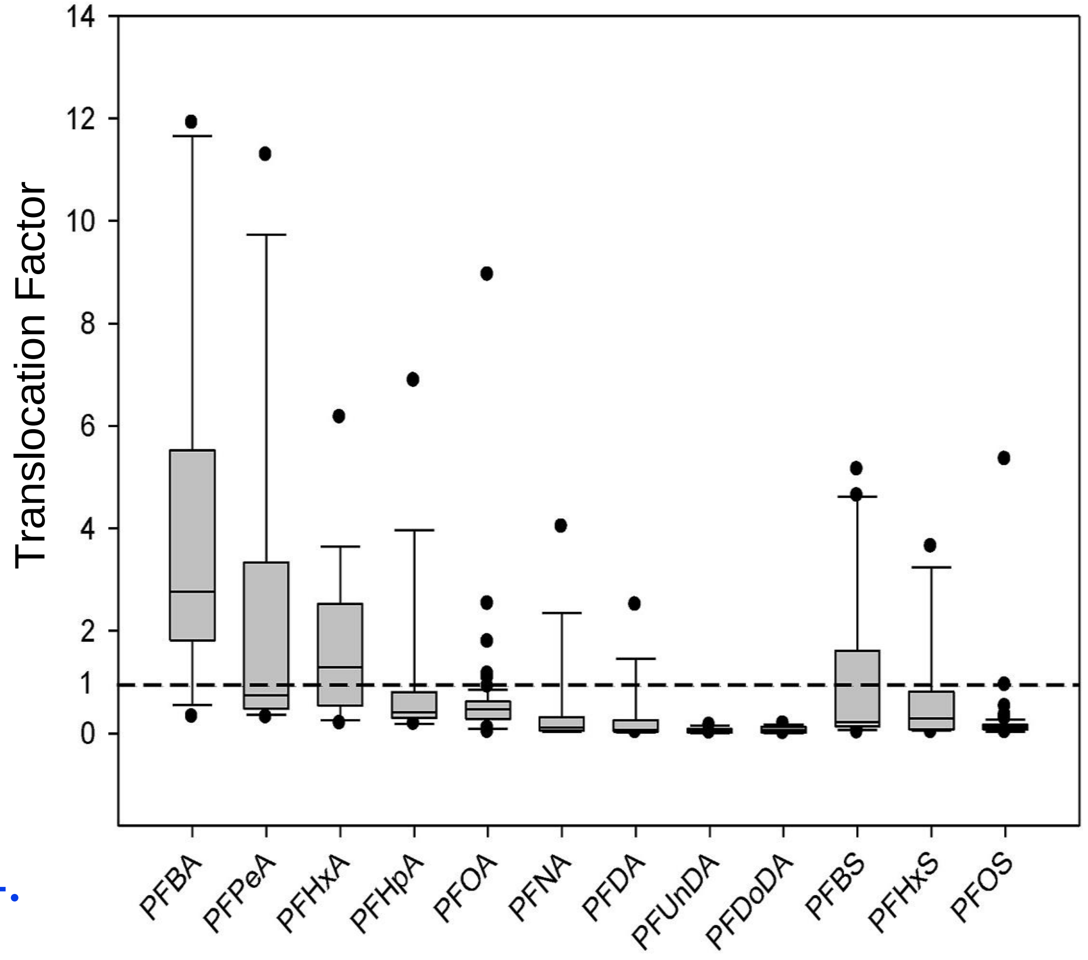
Chuang *et al.*, 2019, *Environ. Int. 131:104976.*

Plant Uptake of PFAS from Soils

Plant root uptake PFAS from soils



Transport of PFAS from roots to shoots

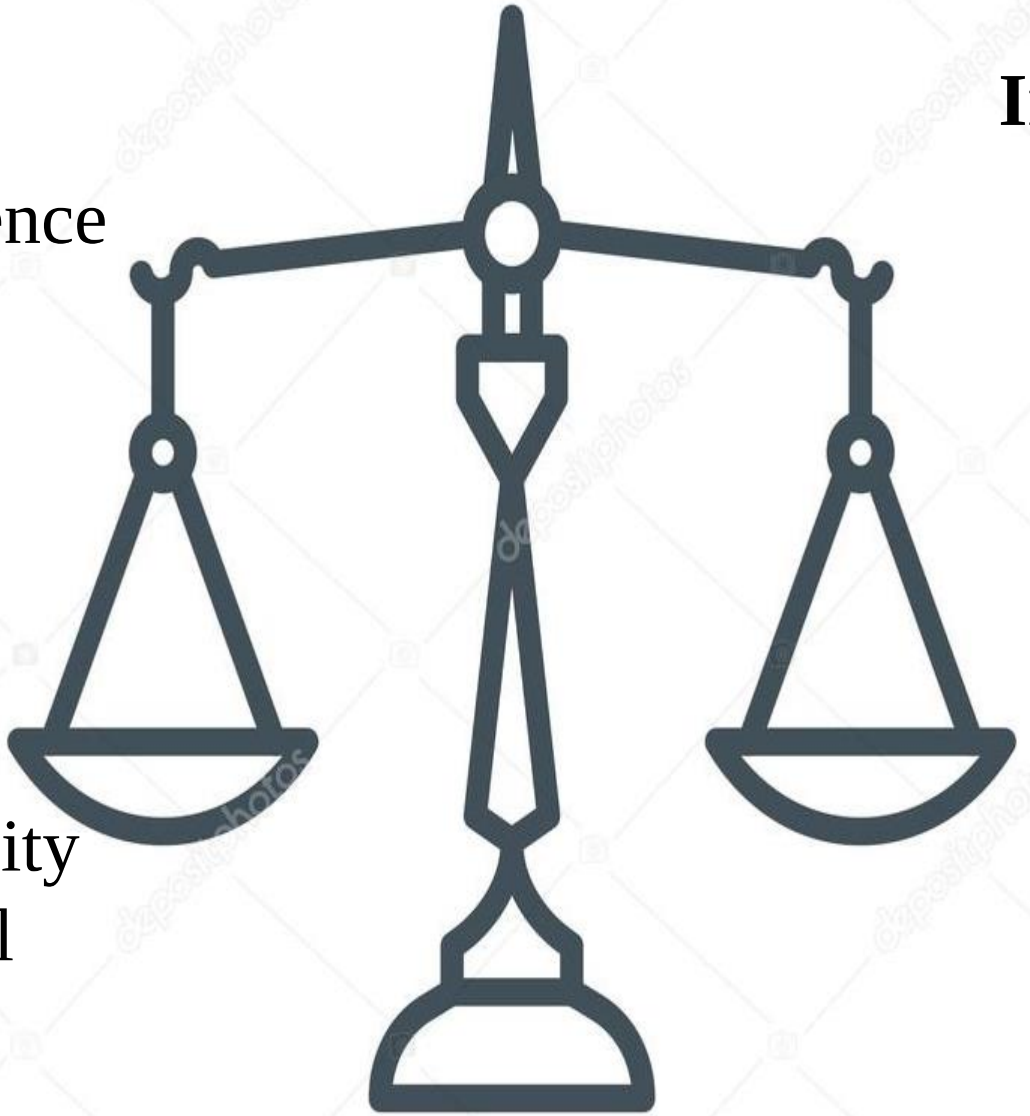


Wang *et al.*, 2020, *Chemosphere* 261: 127584.

Land Application of Biosolids: Benefits versus Impact?

Benefit

- Sustainability/resilience
- Carbon storage
- Climate change
- Ecosystem health
- Biodiversity
- Soil health
- Fertility values
- Water holding capacity
- Inexpensive disposal
- Soil structures
- And many others



Balance and Solution

Impact

- Odor
- Pathogens
- Metals
- PPCPs
- ARGs
- Microplastics
- Nanoparticles
- PFAS
- Water quality
- Food safety
- Human exposure
- And many others

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