Per- and Polyfluoroalkyl Substances (PFAS) in Garden Produce: A Local Case Study from New Hampshire

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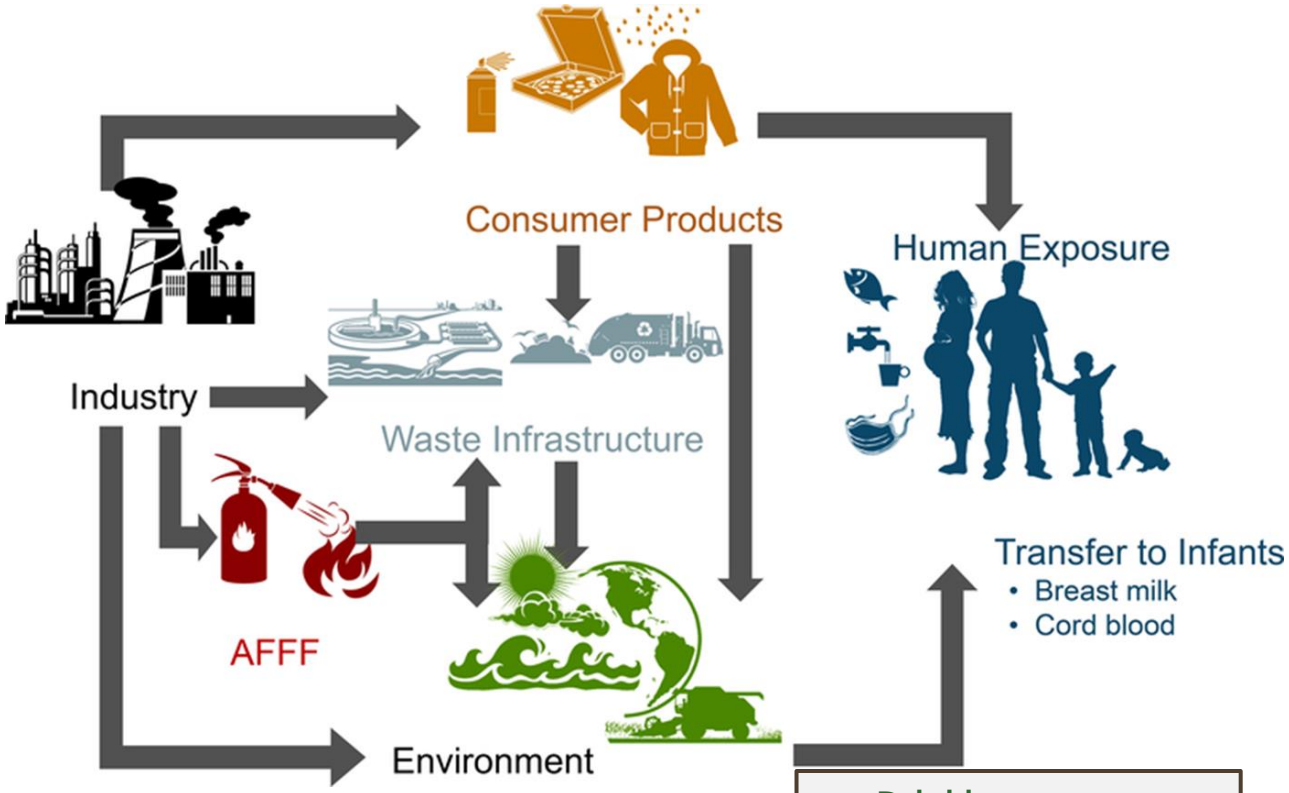
Problematic Lifecycle of Per- and Polyfluoroalkyl Substances (PFAS)

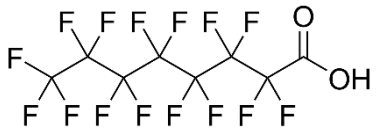
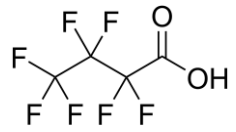
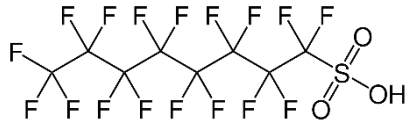
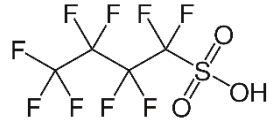
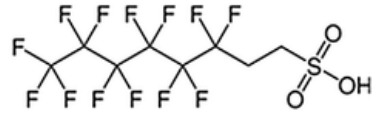
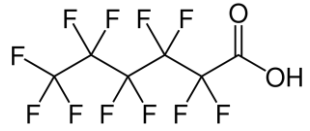
- **Persistent** & **mobile** in the environment.
- **Bioaccumulative** in people and wildlife.
- Importantly, certain PFAS can **accumulate to toxic levels** in people.



Sunderland et al. J Expo Sci Environ Epidemiol. 2019 Mar;29(2):131-147.

Per- and Polyfluoroalkyl Substances (PFAS): The Long and Short of It

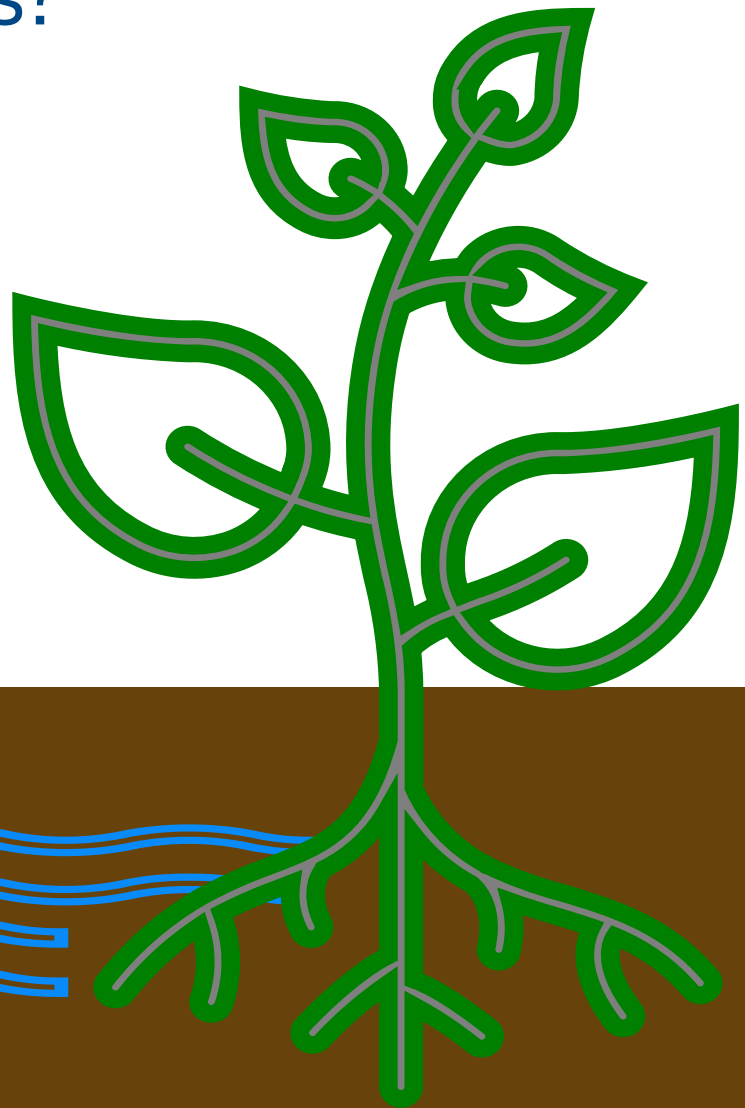
- **Persistent** & **mobile** in the environment.
- **Bioaccumulative** in people and wildlife.
- Importantly, certain PFAS can **accumulate to toxic levels** in people.
- These features are **influenced by the chemistry** of specific PFAS.

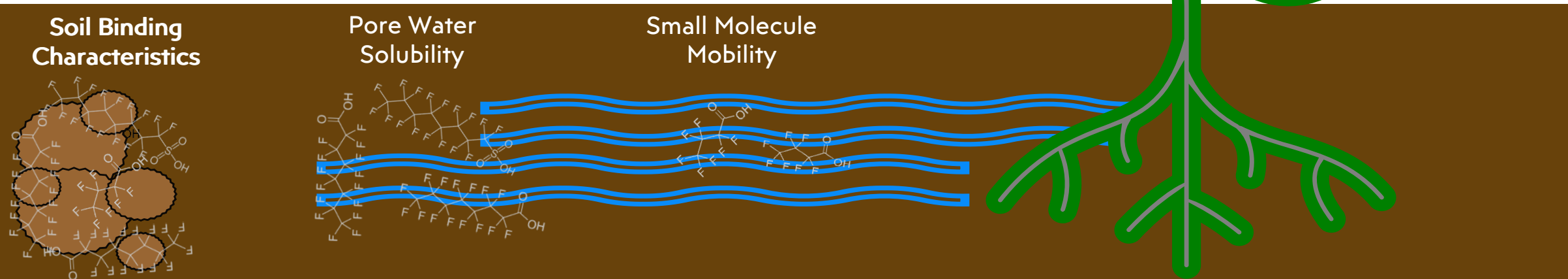
	"Long Chain" > 5-6 carbons	"Short Chain" < 5-6 carbons
Carboxylic Acids	 **PFOA** "octanoic acid"	 **PFBA** "butanoic acid"
Sulfonic Acids	 **PFOS** "octane sulfonic acid"	 **PFBS** "butane sulfonic acid"
Precursors	 **6:2 FTS** "Fluorotelomer sulfonic acid"	 **PFHxA** "hexanoic acid"

What about PFAS Uptake in Plants?

What controls PFAS uptake into plants?

1. Binding to soil matter **reduces root uptake**
2. Solubility in "pore" water **increases root uptake**
3. Shorter "chain length" **increases root uptake**
4. Certain plants may have "**selective uptake**"
5. All of this is likely **concentration dependent**





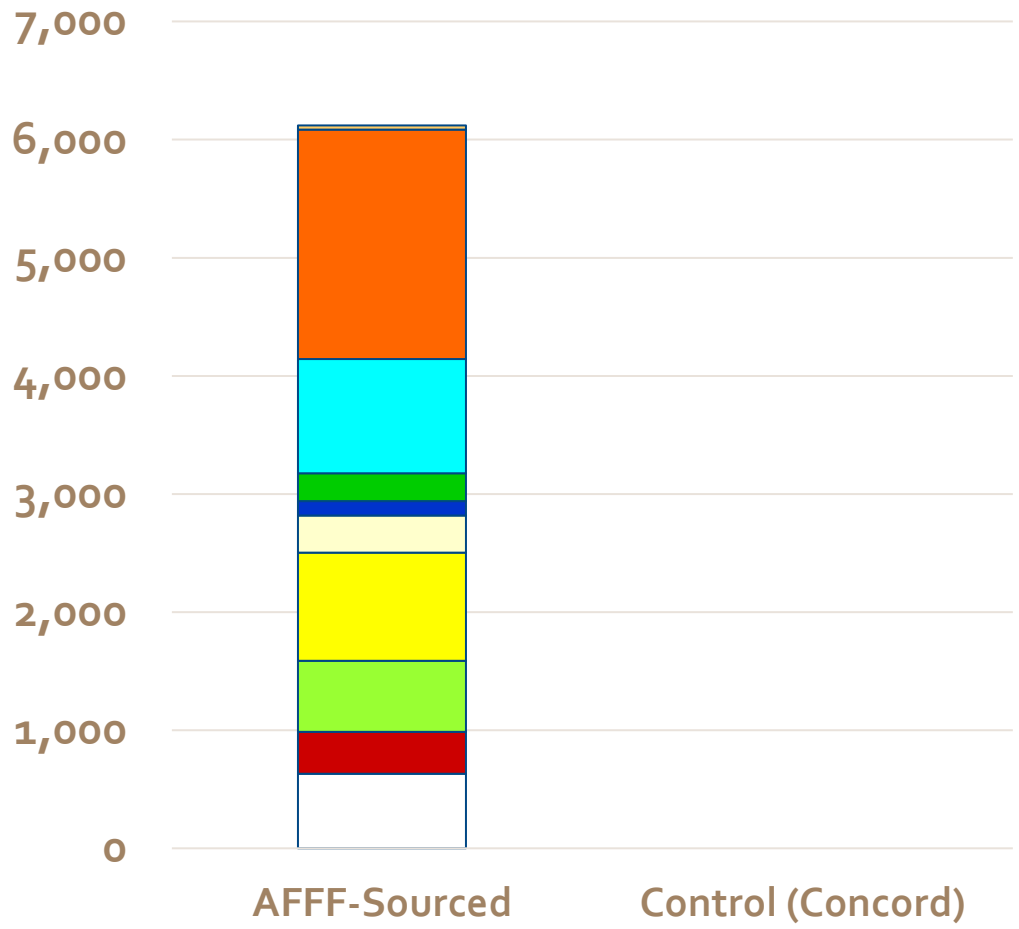
Question: What are the effects of soil, irrigation source and amendments on PFAS uptake in common garden produce?

Greenhouse Manipulation Study		Merrimack Soil	Community Compost	Commercial Soil
Irrigated with Municipal Water	No Biosolids	Radishes Tomatoes Basil	Radishes Tomatoes Basil	Radishes Tomatoes Basil
	Added Biosolids	Radishes Tomatoes Basil	Radishes Tomatoes Basil	Radishes Tomatoes Basil
Irrigated with AFFF-Sourced Water (NH Fire Academy)	No Biosolids	Radishes Tomatoes Basil	Radishes Tomatoes Basil	Radishes Tomatoes Basil
	Added Biosolids	Radishes Tomatoes Basil	Radishes Tomatoes Basil	Radishes Tomatoes Basil
Amherst Community Garden Sampling				
Irrigated with Community Garden Well	Amherst Soil & Community Compost		Butternut Squash Tomatoes Kale	

Average PFAS Concentrations (ng/L or ppt) Water Treatments for NHTI Study

- Water treatments consisted of two types:
  - **Control water** was City of Concord public water.
  - **Aqueous film forming foam (AFFF)-sourced water** was from a monitoring well at the NH Fire Academy.
- Analyzed by Alpha Analytical for 23 PFAS analytes.

"Short" Chain PFAS	"Long" Chain PFAS	Precursor PFAS
PFBA	PFHpA	6:2 FTS
PFBS	PFHpS	PFEESA
PFPeA	PFOA	N-EtFOSA
PFPeS	PFOS	N-MeFOSA
PFHxA	PFNA	
PFHxS	PFDA	
	PFUnA	
	PFDoA	
	PFTrDA	

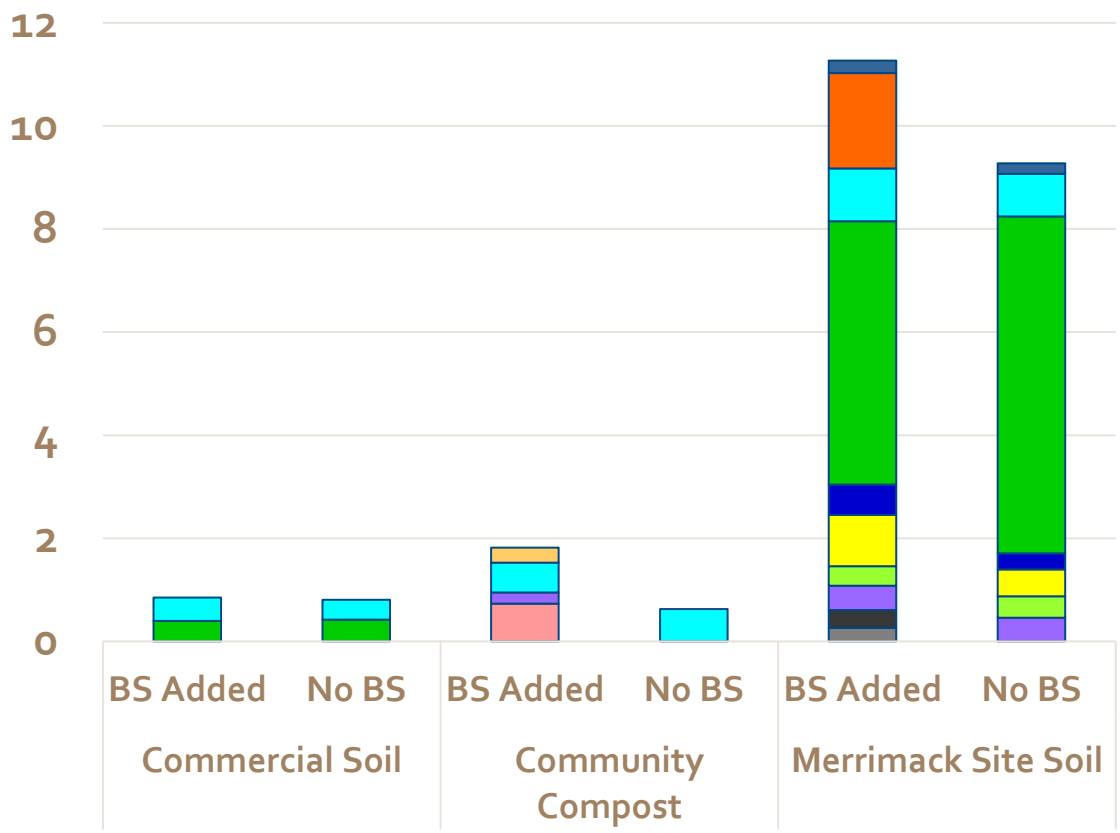


PRELIMINARY DATA ANALYSIS – DO NOT CITE

Average PFAS Concentrations (ng/g or ppb) in Soil Treatments for NHTI Study

- Analyzed by Alpha Analytical for 23 PFAS analytes.
- Only 13 PFAS above detection limits.
- Additional soil parameters collected for this study.
  - % carbon content, soil texture, pH, nutrient content, calcium, etc.

"Short" Chain PFAS	"Long" Chain PFAS	Precursor PFAS
PFBA	PFHpA	6:2 FTS
PFBS	PFHpS	PFEESA
PFPeA	PFOA	N-EtFOSA
PFPeS	PFOS	N-MeFOSA
PFHxA	PFNA	
PFHxS	PFDA	
	PFUnA	
	PFDoA	
	PFTrDA	



PRELIMINARY DATA ANALYSIS – DO NOT CITE

Plant Sampling & Analyses

Greenhouse Manipulation Study		Merrimack Soil	Community Compost	Commercial Soil
Irrigated with Municipal Water	No Biosolids	**Radishes** **Tomatoes** **Basil**	**Radishes** **Tomatoes** **Basil**	Radishes Tomatoes **Basil**
	Added Biosolids	**Radishes** **Tomatoes** Basil	Radishes **Tomatoes** Basil	**Radishes** **Tomatoes** **Basil**
Irrigated with AFFF-Sourced Water	No Biosolids	**Radishes** Tomatoes **Basil**	**Radishes** Tomatoes **Basil**	Radishes Tomatoes **Basil**
	Added Biosolids	**Radishes** **Tomatoes** **Basil**	**Radishes** **Tomatoes** Basil	**Radishes** **Tomatoes** **Basil**
		Grown and sampled		Failed to grow

Sample sizes of 2-11 for each available plant in each treatment combination.

Average PFAS Concentrations (ng/g) in Tomato Fruit from NHTI Study

- Analyzed by SGS AXYS for 39 types of PFAS analytes.
- Predominantly short chain and precursor PFAS.
- None exceed *current* screening levels.

"Short" Chain PFAS	"Long" Chain PFAS	Precursor PFAS
PFBA	PFHpA	6:2 FTS
PFBS	PFHpS	PFEESA
PFPeA	PFOA	N-EtFOSA
PFPeS	PFOS	N-MeFOSA
PFHxA	PFNA	
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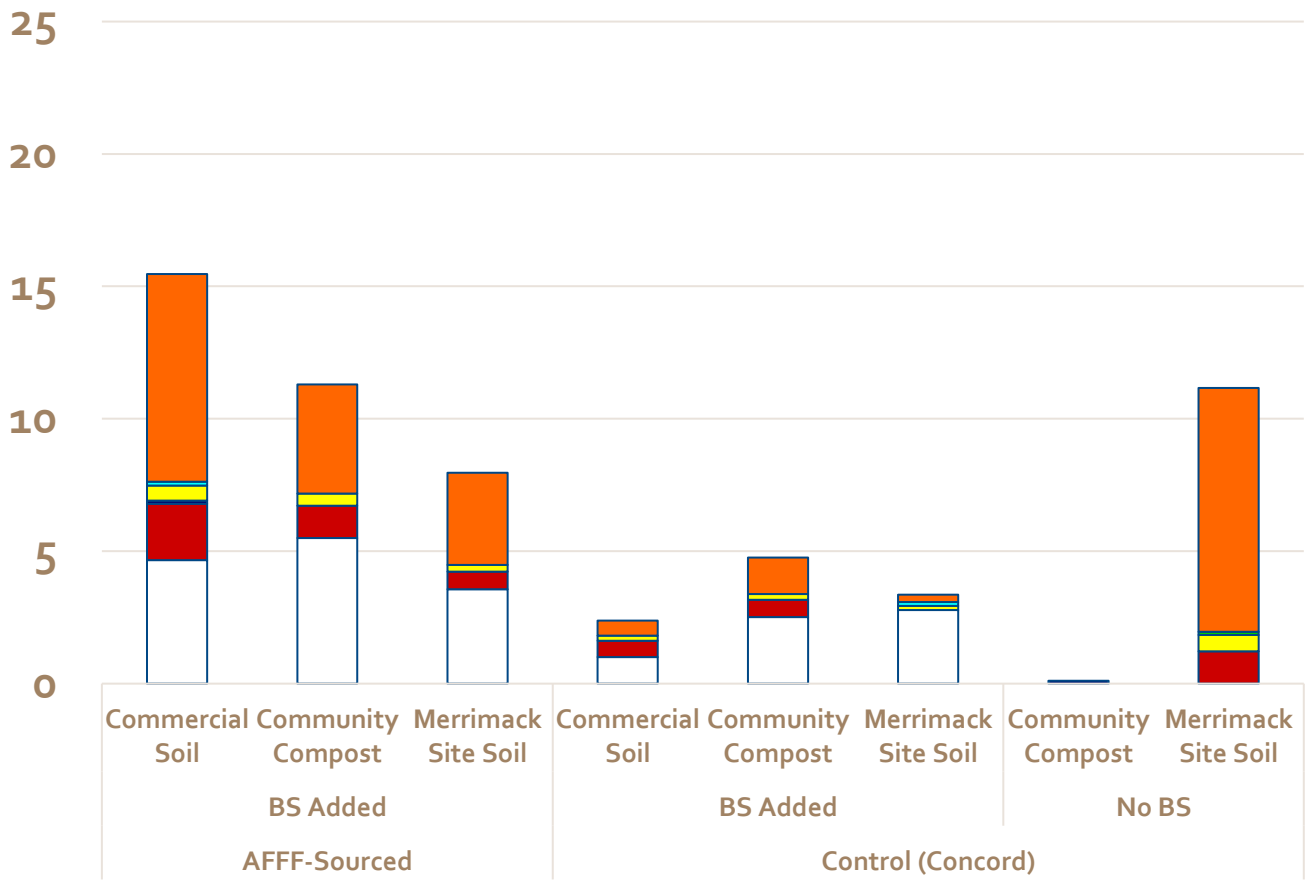
	PFUnA	
	PFDoA	
	PFTrDA	

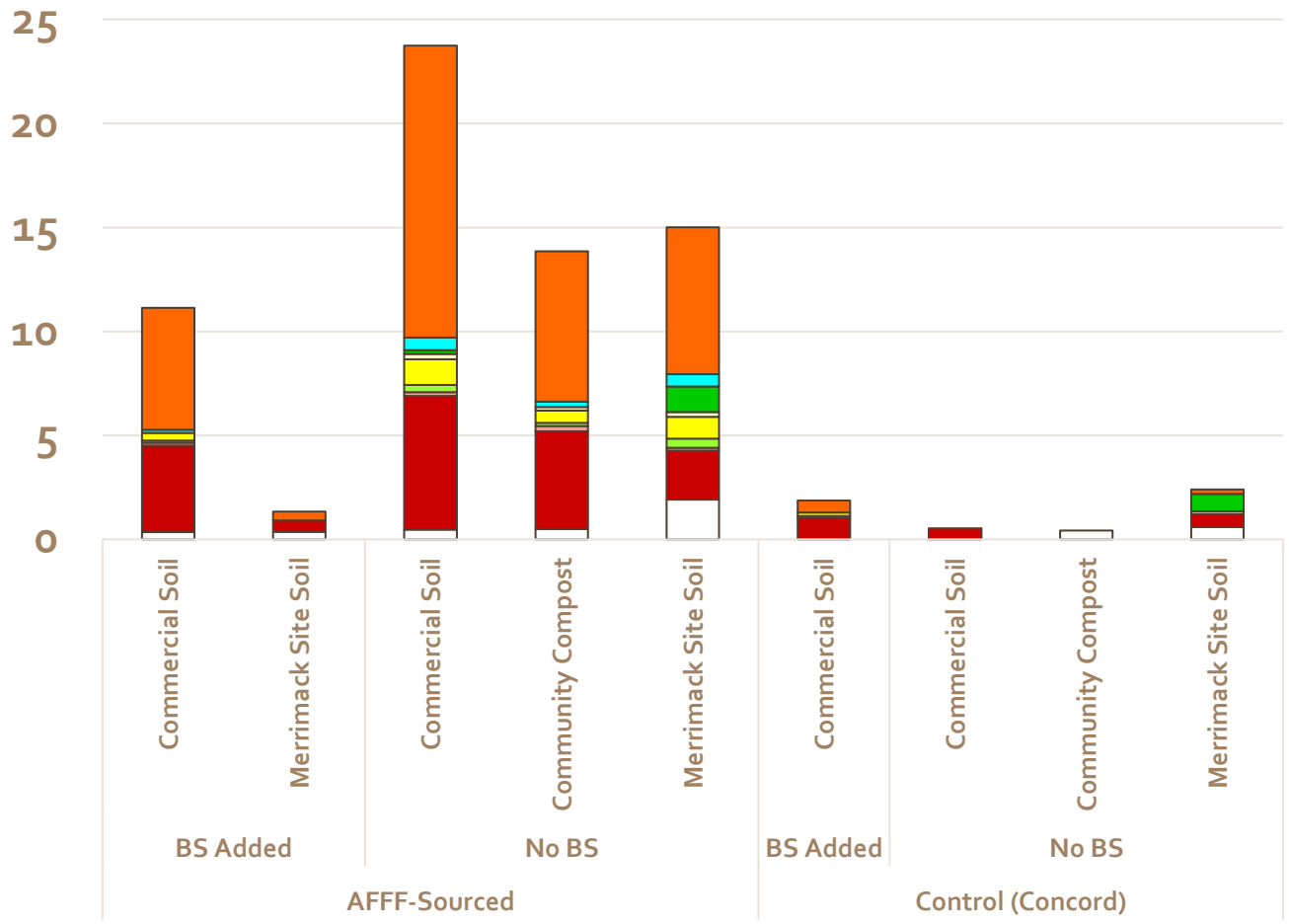


PRELIMINARY DATA ANALYSIS – DO NOT CITE

Average PFAS Concentrations (ng/g) in Basil Leaves from NHTI Study

- Analyzed by SGS AXYS for 39 types of PFAS analytes.
- Predominantly short chain and precursor PFAS.
- None exceed *current* screening levels.

"Short" Chain PFAS	"Long" Chain PFAS	Precursor PFAS
PFBA	PFHpA	6:2 FTS
PFBS	PFHpS	PFEESA
PFPeA	PFOA	N-EtFOSA
PFPeS	PFOS	N-MeFOSA
PFHxA	PFNA	
PFHxS	PFDA	
	PFUnA	
	PFDoA	
	PFTrDA	

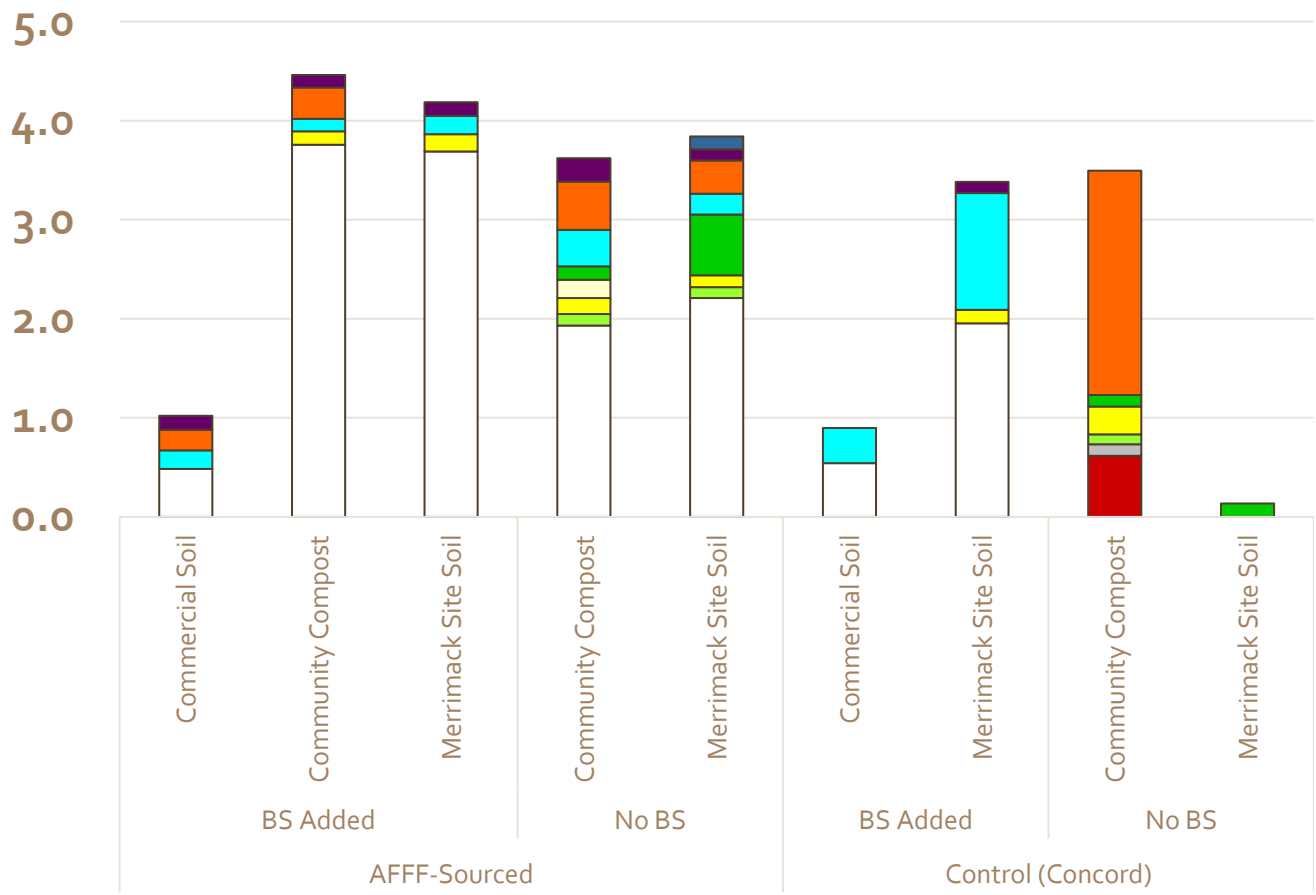


PRELIMINARY DATA ANALYSIS – DO NOT CITE

Average PFAS Concentrations (ng/g) in Radish Roots from NHTI Study

- ***NOTE Y-AXIS SCALE CHANGE***
- Analyzed by SGS AXYS for 39 types of PFAS analytes.
- More long chain PFAS present than basil or tomato samples.
- None exceed *current* screening levels.

"Short" Chain PFAS	"Long" Chain PFAS	Precursor PFAS
PFBA	PFHpA	6:2 FTS
PFBS	PFHpS	PFEESA
PFPeA	PFOA	N-EtFOSA
PFPeS	PFOS	N-MeFOSA
PFHxA	PFNA	
PFHxS	PFDA	
	PFUnA	
	PFDoA	
	PFTrDA	



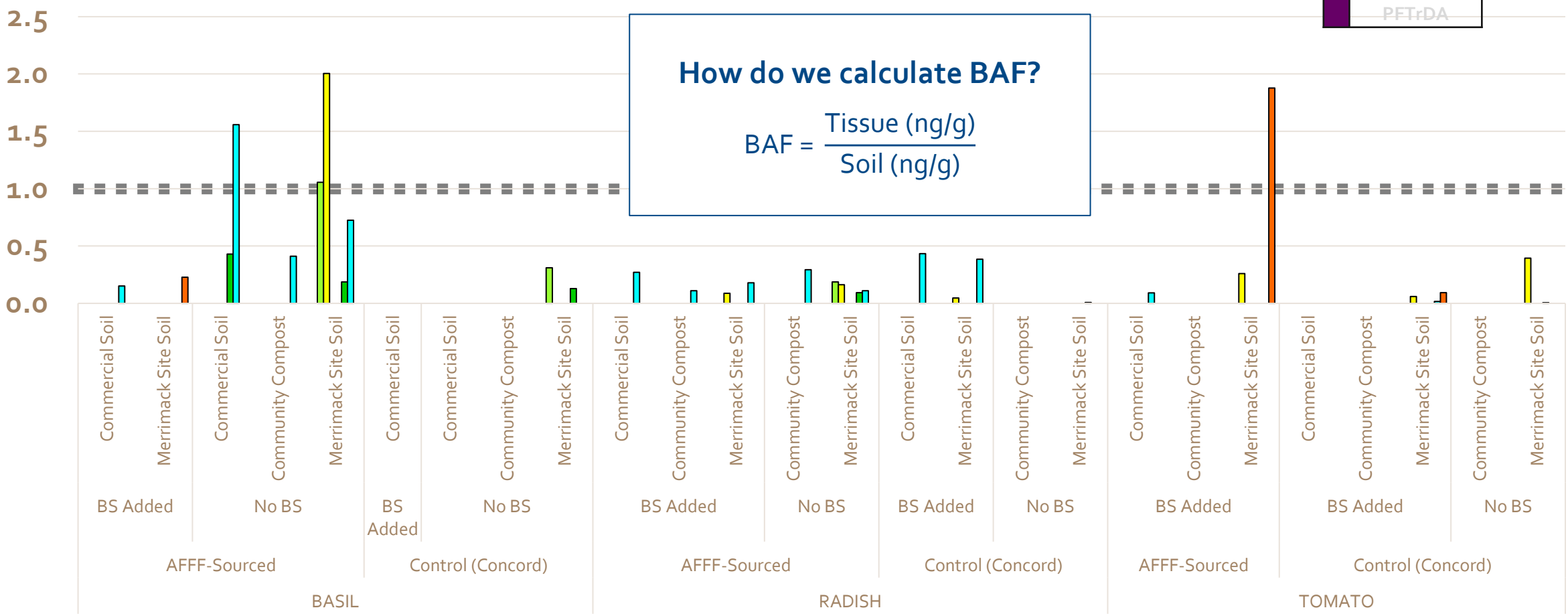
PRELIMINARY DATA ANALYSIS – DO NOT CITE

Average PFAS **Bioaccumulation Factors** (**BAFs**) Across All Plant Types

"Short" Chain PFAS	"Long" Chain PFAS	Precursor PFAS
PFBA	PFHpA	6:2 FTS
PFBS	PFHpS	PFEESA
PFPeA	PFOA	N-EtFOSA
PFPeS	PFOS	N-MeFOSA
PFHxA	PFNA	
PFHxS	PFDA	
	PFUnA	
	PFDoA	
	PFTrDA	

How do we calculate BAF?

$$BAF = \frac{\text{Tissue (ng/g)}}{\text{Soil (ng/g)}}$$



PRELIMINARY DATA ANALYSIS – DO NOT CITE

Considering PFAS BAFs from other studies in similar garden produce

Current Study			
PFAS	Basil	Tomato	Radish
6:2 FTS	*	*	*
PFBS	*	*	*
PFBA	*	*	*
PFPeA*	n.d.-0.23	0.09-1.88	*
PFHxA*	n.d-2.00	0.06-0.39	0.06-0.16
PFHpA	0.31-1.06	*	n.d.-0.19
PFOA	0.13-0.43	*	0.01-0.09
PFNA	*	*	*
PFOS	0.09-1.56	0.005-0.092	0.01-0.43

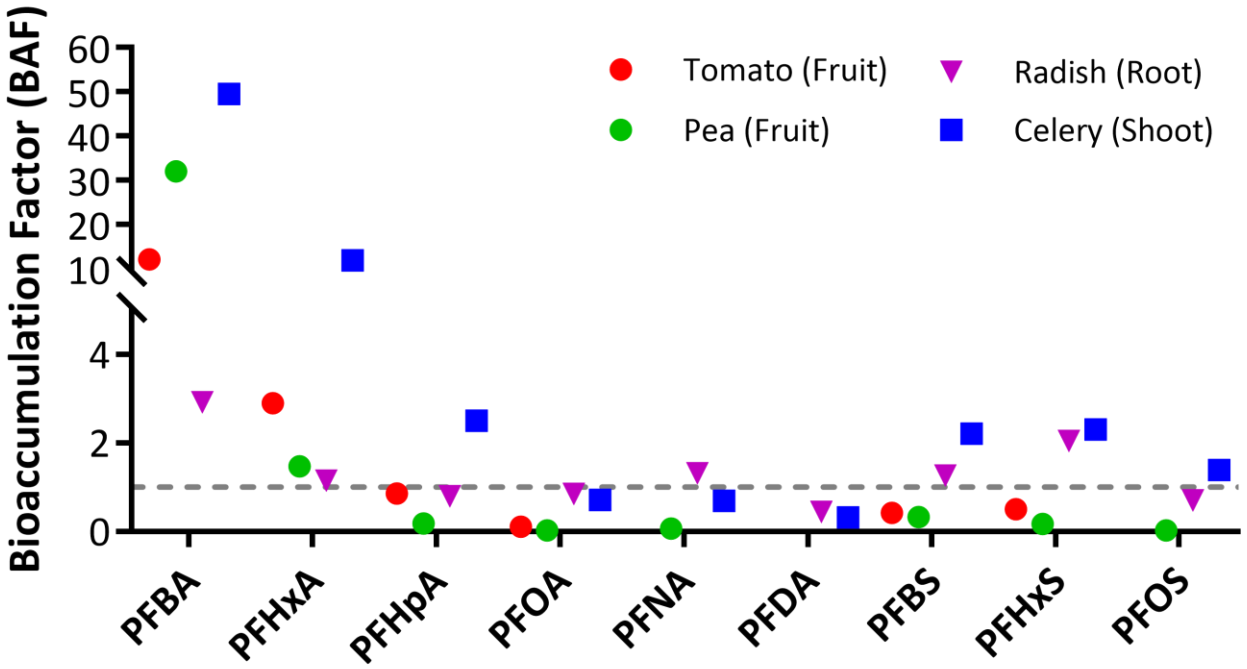


Figure of PFAS BAFs Identified by ITRC

Data for this Figure are from the Interstate Technology & Regulatory Council's (ITRC) PFAS Guidance Document (Table 5-2; https://pfas-1.itrcweb.org/) and Blaine, et al. 2014. Perfluoroalkyl Acid Distribution in Various Plant Compartments of Edible Crops Grown in Biosolids-Amended Soils. Environ. Sci. Technol. 48: 7858-7865.

What about the findings from sampling the Amherst Community Garden?

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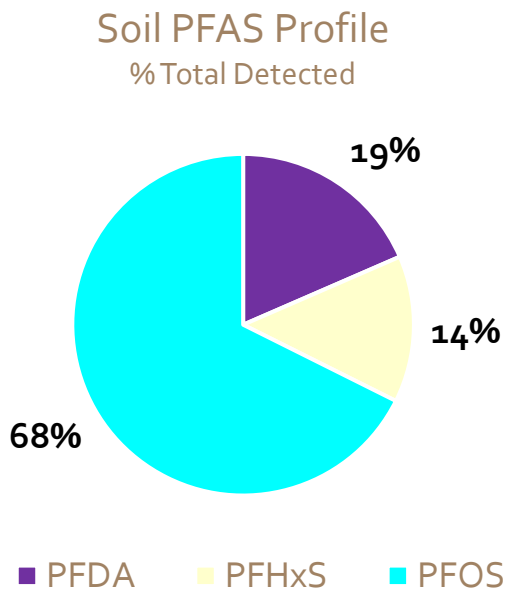
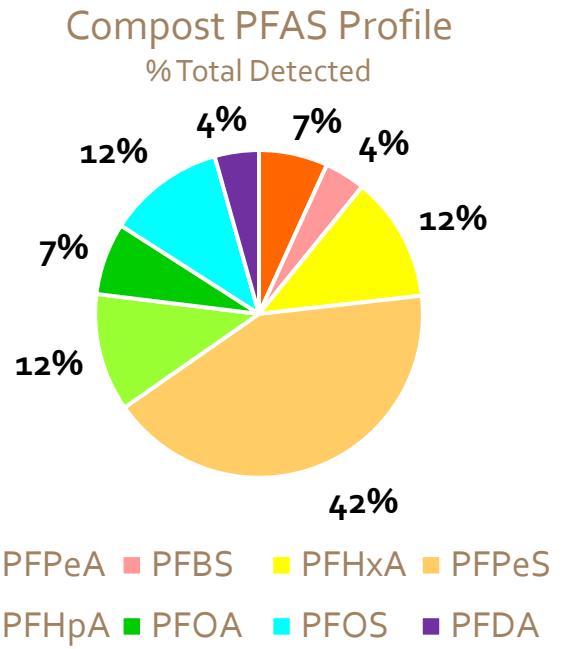
SOIL

Sum of Measurable Concentrations =
3.95 ng/g or parts-per-billion (ppb)



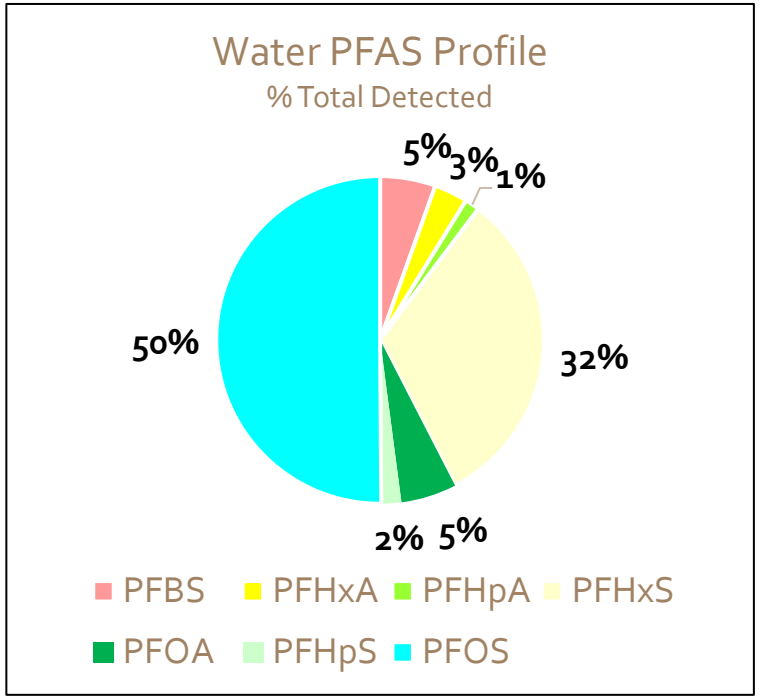
PURCHASED COMPOST

Sum of Measurable Concentrations =
6.27 ng/g or parts-per-billion (ppb)



WATER

Sum of Measurable Concentrations =
129.51 ng/L or parts-per-trillion (ppt)



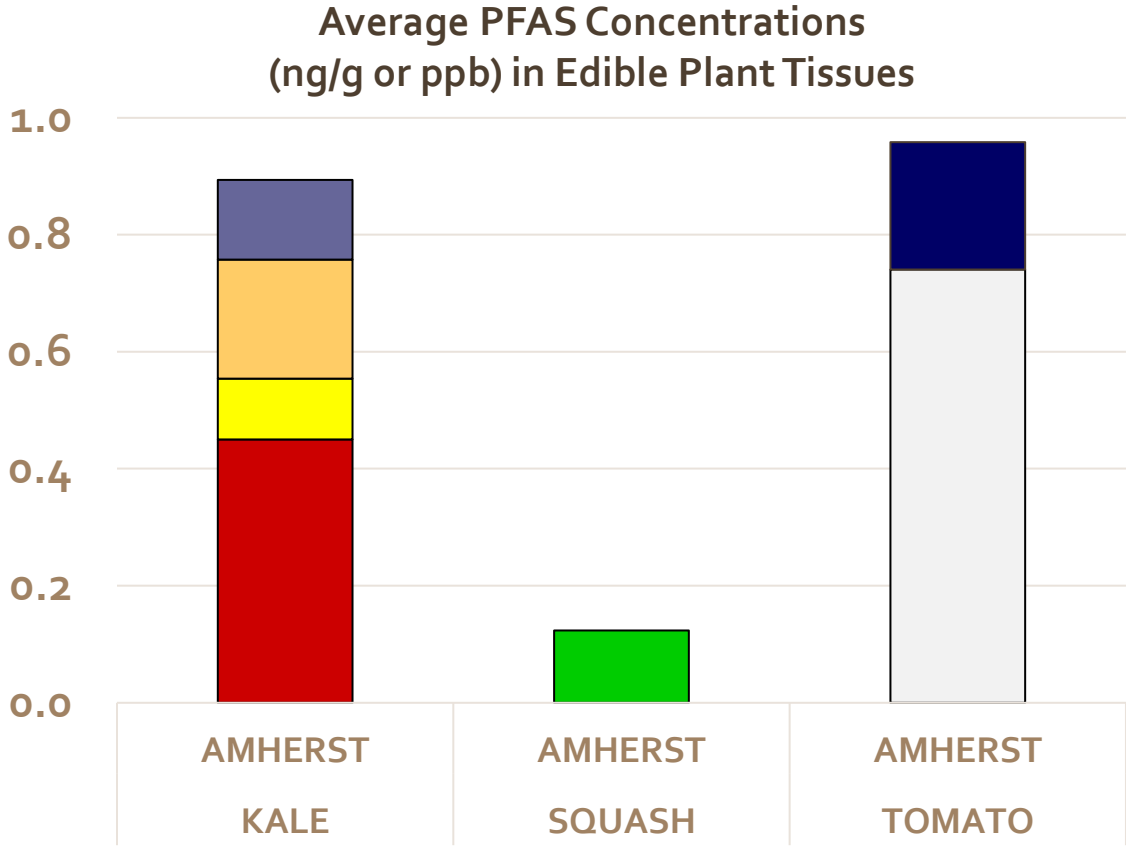
PFAS that were NOT DETECTED in any samples: PFBA, PFNA, PFUnA, PFDoA, NMeFOSE, NEtFOSAA, PFOSA, NMeFOSAA, 4:2 FTS, 6: FTS, 8:2 FTS, 5:3 FTCA, 7:3 FTCA

PRELIMINARY DATA ANALYSIS – DO NOT CITE

What about the findings from the Amherst Community Garden?

- ***NOTE Y-AXIS SCALE***
- Analyzed by SGS AXYS for 39 types of PFAS analytes.
- Fewer PFAS and lower concentrations than simulated scenarios.
- None exceed *current* screening levels.

"Short" Chain PFAS	"Long" Chain PFAS	Precursor PFAS
PFBA	PFHpA	6:2 FTS
PFBS	PFHpS	PFEESA
PFPeA	PFOA	N-EtFOSA
PFPeS	PFOS	N-MeFOSA
PFHxA	PFNA	
PFHxS	PFDA	
	PFUnA	
	PFDoA	
	PFTrDA	



Study Limitations & Uncertainties

1. **Statistical significance of treatment groups and their effects on PFAS uptake**.
   - There is an obvious effect of irrigation water, but analysis is needed to determine if other factors (e.g., soil types) were significant.
   - Additional soil parameters were collected (composition, organic carbon content, nutrient, etc.), and are likely co-variates for plant uptake.
2. **Addressing non-detect results for assessing BAFs.**
   - Assuming "zero" underestimates bioaccumulation, ½ the DL may overestimate bioaccumulation, and there is uncertainty about the role and presence of precursors.
3. **Relevance to farm-scale agriculture**.
   - The study prepared soil mixtures recommended for home gardeners or community gardens, following common guidance from UNH Extension and local garden centers.

What are the next steps?

- Analyze the effect(s) of soil features on PFAS bioconcentration, including organic carbon content.
- Continue the risk assessment of various PFAS in produce items.
  - ***Current toxicity factors*** indicate minimal risk except for heavy consumption of certain plants grown in heavily contaminated soil, with impacted amendments and AFFF-containing water.
  - Evaluate using localized consumption data where available.
- Look for opportunities to improve the limited available scientific literature.
  - e.g., grant applications, academic partnerships, extension specialists, affected communities

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Questions?

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