

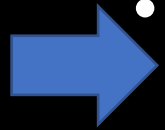
PFAS Contamination and Vegetable Farming



NEVFC, December 14, 2022

Caleb P. Goossen, PhD, Crop & Conservation Specialist

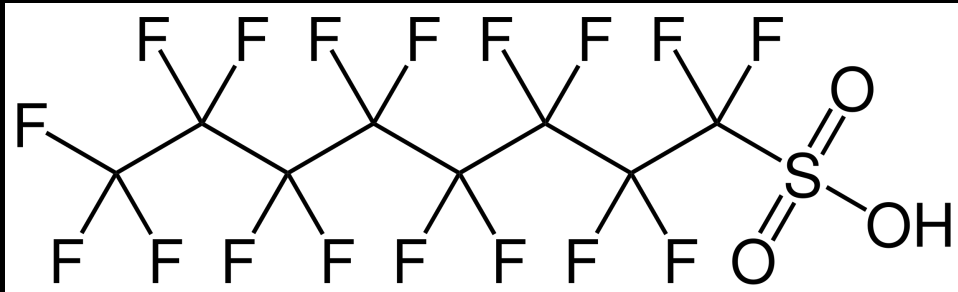
Agenda



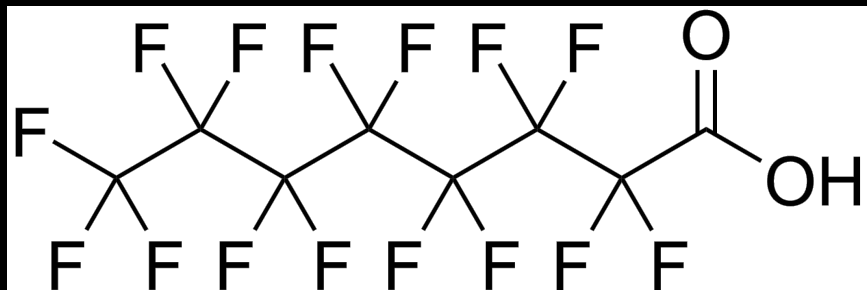
- **What are PFAS, and where are they found?**
- **What happened in Maine**
- **PFAS uptake by plants**
- **PFAS contamination examples**
- **PFAS remediation/mitigation**

What are PFAS?

Per- and Polyfluorolalkyl Substances



PFOS – Perfluorooctanesulfonic acid



PFOA – Perfluorooctanoic acid

- **C-F bond is strongest single chemical bond in organic chemistry**
 - **source of usefulness, and persistence**
- **PFOS and PFOA are among the oldest, and best studied PFAS compounds**
 - **Known health impacts**
- **Many more PFAS in trade now, often smaller molecules**

For simplicity's sake my examples will focus largely on PFOS

Potential health effects of PFAS



Increased cholesterol levels



Changes in liver enzymes



Small decreases in infant birth weights



Decreased vaccine response in children



Increased risk of high blood pressure or pre-eclampsia in pregnant women



Increased risk of kidney or testicular cancer

Common Items with PFAS



FOOD PACKAGING
microwave popcorn
bags, sandwich
wrappers, takeout
containers, fast food
wrappers



HOUSEHOLD ITEMS
makeup, floss, waxes,
paints, stains



STAIN-RESISTANT
carpets, rugs, and
furniture



**NONSTICK
COOKWARE**

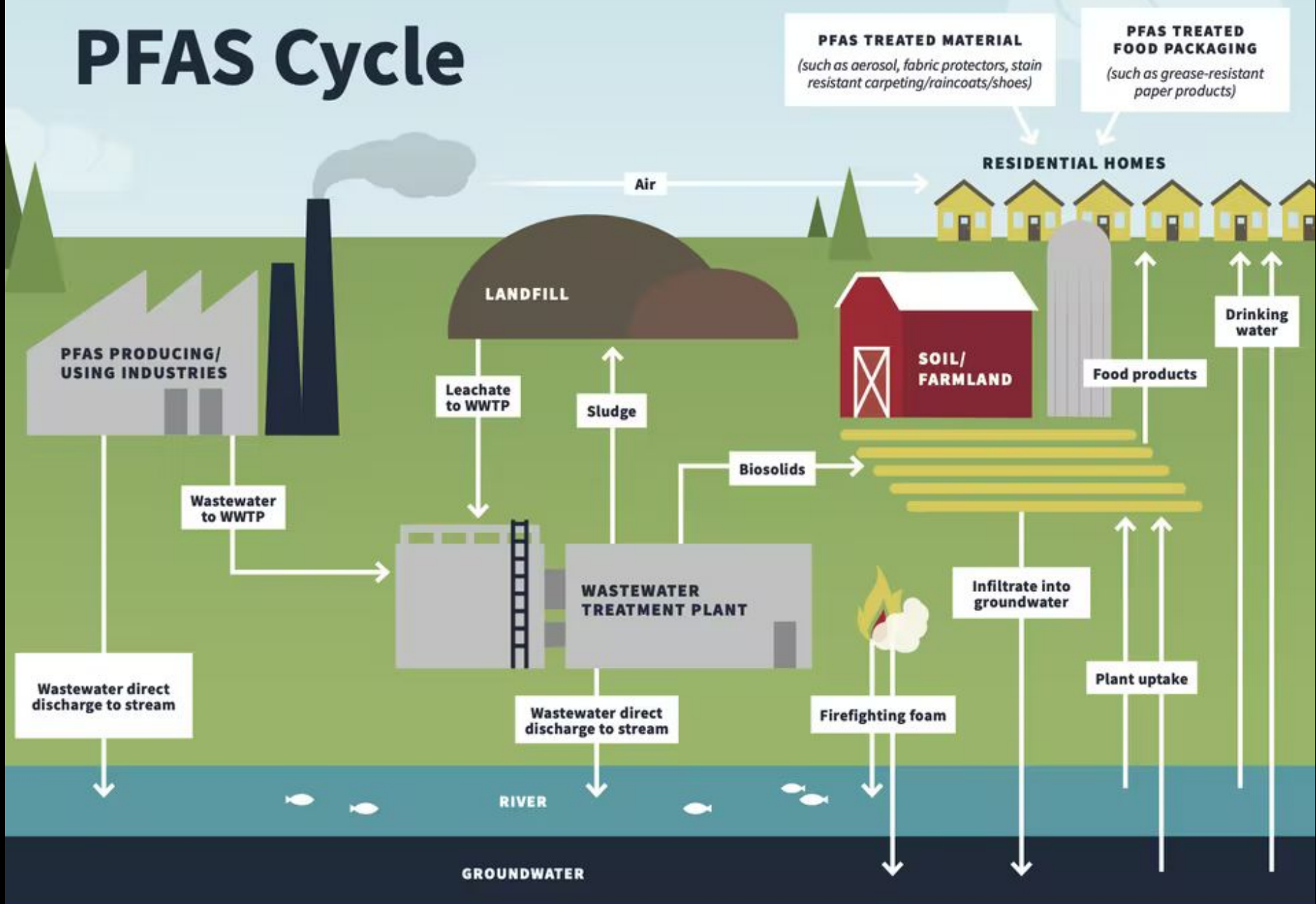


OUTDOOR GEAR
with a "durable water
repellent" coating



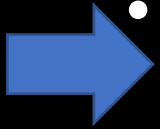
FIREFIGHTING FOAM

PFAS Cycle



Agenda

- What are PFAS, and where are they found?
- What happened in Maine
- PFAS uptake by plants
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Stoneridge Farm



Third-generation dairy farmers in Arundel, Maine

First farm where high levels of PFAS were discovered (2016 - 2017)

Spoke out in 2019

Maine Gov't Response

- ➔ Governor calls forth a PFAS Task Force – 2019

Maine Gov't Response

- Governor calls forth a PFAS Task Force – 2019
- ➔ • Screening levels begin to be calculated, interim drinking water standard set
 - ~95% of sludge is found to be higher than screening level

MAINE PFAS SCREENING LEVELS							June 2021
Soil Remedial Action Guidelines ¹ (mg/kg)							
Compound	Leaching to Groundwater	Residential	Commercial Worker	Park User	Recreator Sediment	Construction Worker	
PFBS	7.1	1,700	22,000	4,900	5,700	51,000	
PFOS	0.0036	1.7	22	4.9	5.7	5.1	
PFOA	0.0017	1.7	22	4.9	5.7	5.1	
Soil Beneficial Use ² (ng/g, dry weight)		Recreational Angler RAGs ³ (mg/kg wet weight)					
Compound	Beneficial Use	Compound	Fish Tissue				
PFBS	1,900	PFBS	52				
PFOS	5.2	PFOS	0.052				
PFOA	2.5	PFOA	0.052				
Interim Drinking Water Standard ⁴ (ng/l or ppt)							
Compound			Residential				
PFOS + PFOA + PFHpA + PFNA + PFHxS + PFDA			20				
Milk ⁵ (ng/l or ppt)		Beef ⁶ (ng/g)					
Compound	Action Level	Compound	Action Level				
PFOS	210	PFOS	3.4				

A brief detour to talk about units of measurement

- Ag folks typically think in parts per million (ppm, AKA mg/kg, AKA lb/acre ÷ 2)
 - E.G., An acre furrow slice of your soil may have 100 lb Ca/acre (50 ppm Ca)
 - Formerly a detection limitation for many compounds
- Individual PFAS are typically measured in soil in ppb ($\mu\text{g}/\text{kg}$)
 - ppb also used for most non-liquid substrates
 - This is partially due to analytical constraints

$100 \text{ lb Ca/acre} = 100 \text{ lb Ca} / 2 \text{ million lb of soil per acre furrow slice} = 50 \text{ ppm Ca}$

$50 \text{ ppm Ca} = 50,000 \text{ ppb Ca} (50,000 \mu\text{g Ca/kg soil})$

A brief detour to talk about units of measurement

- **PFAS in water and other liquids are commonly measured in ppt (ng/L or ng/kg)**
 - **New interim guidance from the EPA is pushing towards ppq (pg/L or pg/kg)**

1 ppq = 0.001 ppt = 0.000001 ppb = 0.0000000001 ppm

1 ppm = 1,000 ppb = 1,000,000 ppt = 1,000,000,000 ppq

Maine's screening levels are built off of federal guidance

- 2009 EPA provisional health advisories
 - PFOS – 0.3 mg/kg body weight (bw)/day.
 - Therefore, drinking water should be < 200 ppt
- 2016 EPA Drinking Water Health Advisories
 - PFOS – 0.00002 mg/kg bw/day. (AKA, 20 ng/kg bw/day)
 - Therefore, drinking water should be < 70 ppt

Maine's screening levels are built off of federal guidance

- 2020 CDC Agency for Toxic Substances and Disease Registry (ATSDR)

Table 1-2. Overview of Minimal Risk Levels Derived for Perfluoroalkyls

Compound	Inhalation MRLs			Oral MRLs		
	Acute	Intermediate	Chronic	Acute	Intermediate	Chronic
PFOA	X ^a	X	X	X	3x10 ⁻⁶ mg/kg/day (Table 1-3)	X
PFOS	X	X	X	X	2x10 ⁻⁶ mg/kg/day (Table 1-4)	X
PFHxS	X	X	X	X	2x10 ⁻⁵ mg/kg/day (Table 1-5)	X
PFNA	X	X	X	X	3x10 ⁻⁶ mg/kg/day (Table 1-6)	X

In other words, 4 compounds with daily intake guidance ranging from 2 to 20 ng/kg bw/day

...about ten fold lower for PFOS and PFOA

- EPA released their Interim Health Advisory in 2022
 - PFOS 7.9 ng/kg bw/day, therefore water <0.02 ppt (AKA, <20 ppq)
 - PFOA 1.5 ng/kg bw/day, therefore water <0.004 ppt (AKA, <4 ppq)

Current Maine guidelines and thresholds are based off of prior federal guidance, and are being updated. (I.E., likely to see milk < 50 ppt, beef < 0.5 ppb) More thresholds are to be added with the update: yogurt, eggs, pork, spinach, lettuce and white potatoes. (As well as being calculated for additional PFAS compounds; PFHxS and PFNA)

Soil Remedial Action Guidelines ¹ (mg/kg)						
Compound	Leaching to Groundwater	Residential	Commercial Worker	Park User	Recreator Sediment	Construction Worker
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Compound	Action Level
PFOS	210

Beef ⁶ (ng/g)	
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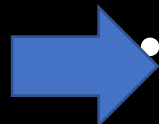
Dairy ⁷ - PFOS Crop-Specific Soil Screening Levels (ng/g dry weight)			
	Soil to Hay to Milk Screening Level	Soil to Corn-Silage to Milk Screening Level	Soil to Hay and Corn-Silage to Milk Screening Level
Grass-Based Farm	6.8	120.0	6.4
Average Maine Farm	13.8	54.8	11.0

Maine Gov't Response

- ➔ • ME Department of Environmental Protection (DEP) tasked with testing at 700+ locations with known sludge or septage application

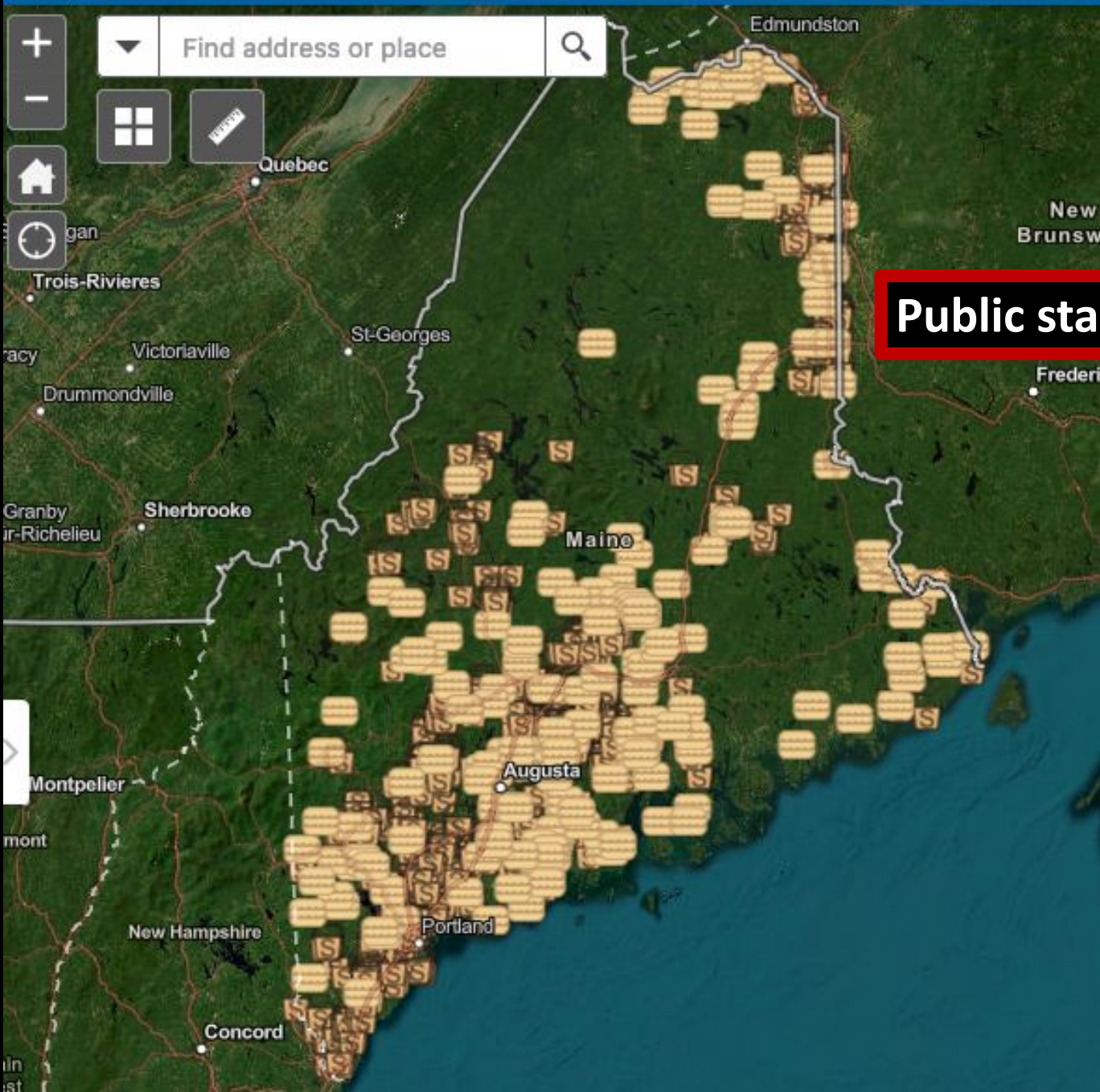
Maine Gov't Response

- ME Department of Environmental Protection (DEP) tasked with testing at 700+ locations with known sludge or septage application

-  Retail milk testing identifies a second dairy farm above threshold. DEP groundwater testing identifies a third dairy

...both in Fairfield Maine area.

EGAD Septage and Sludge Sites with Sample Locations



Public starts to look at the map in 2021

Unity organic farm pulls products after tests reveal high levels of 'forever chemicals'

Songbird Farm is the first apparent recorded case in the state of a produce farm being tainted by 'forever chemicals,' also known as PFAS.

BY [KAITLYN BUDION](#) MORNING SENTINEL



In Maine, 'forever chemicals' are upending this family farm

February 08, 2022

By Kevin Miller, Maine Public



Many other farms began testing...

As of October 2022, at least 32 Maine farms of all sorts have at least one contaminated field.

Maine DEP's of former spreading sites is on-going, though moving on to "tier 2" sites.

Compound Injustice: PFAS may concentrate over time in landfills near the Penobscot Indian Reservation

Potential risks from PFAS and other contaminants threaten the traditional foods and tribal traditions of the Penobscot Indian Nation.

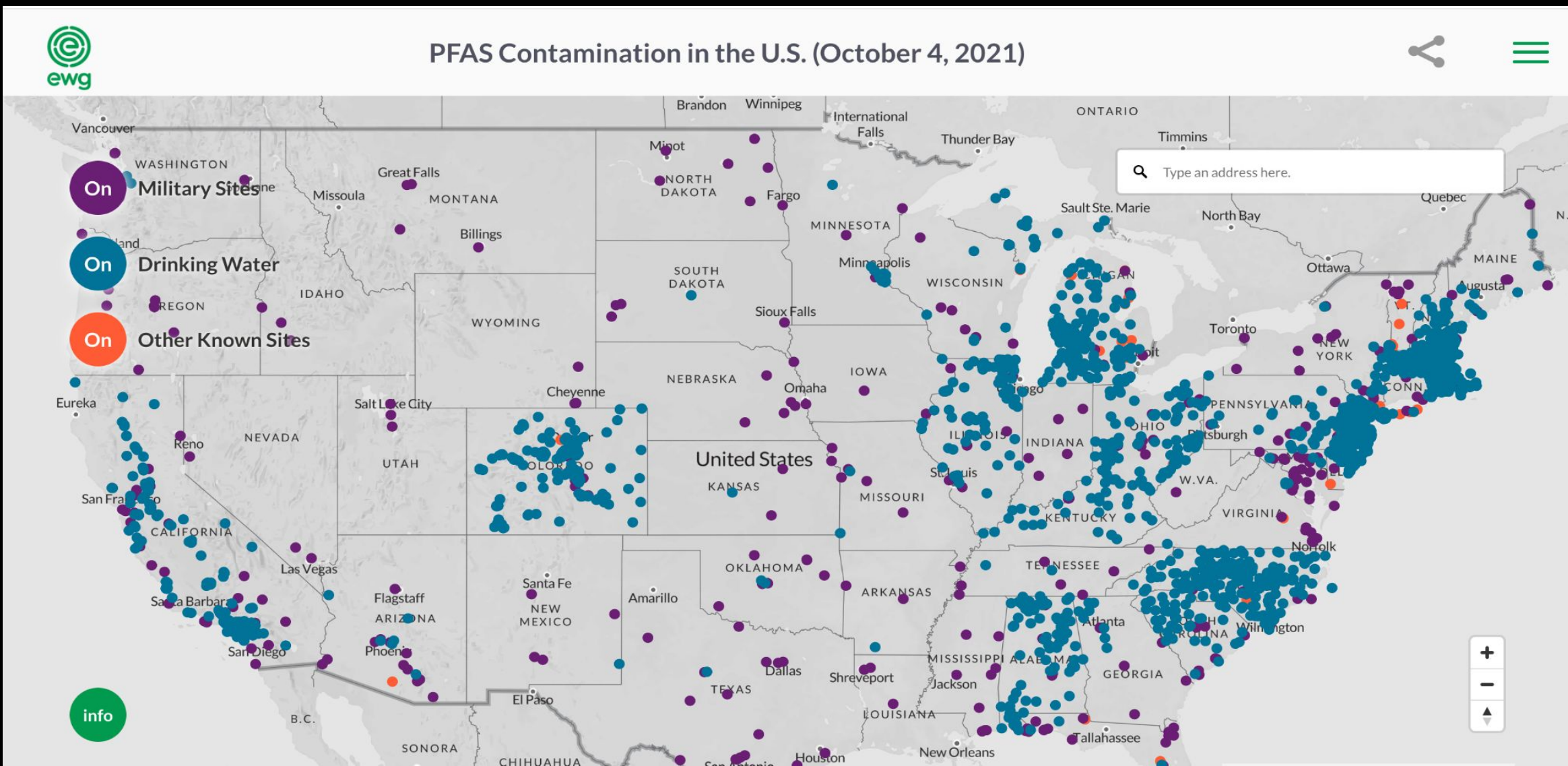
BY **MARINA SCHAUFFLER** | SEPTEMBER 10, 2022

MOFGA's response

- **Farmer support**
 - **Technical assistance**
 - **Testing support**
 - **Farmer PFAS Emergency Fund with Maine Farmland Trust**
 - **Mental Health Support**
- **Coalition work**
 - **Statewide agencies and ag service providers working together**
 - **FRSAN Network**
 - **Federal coalition work**



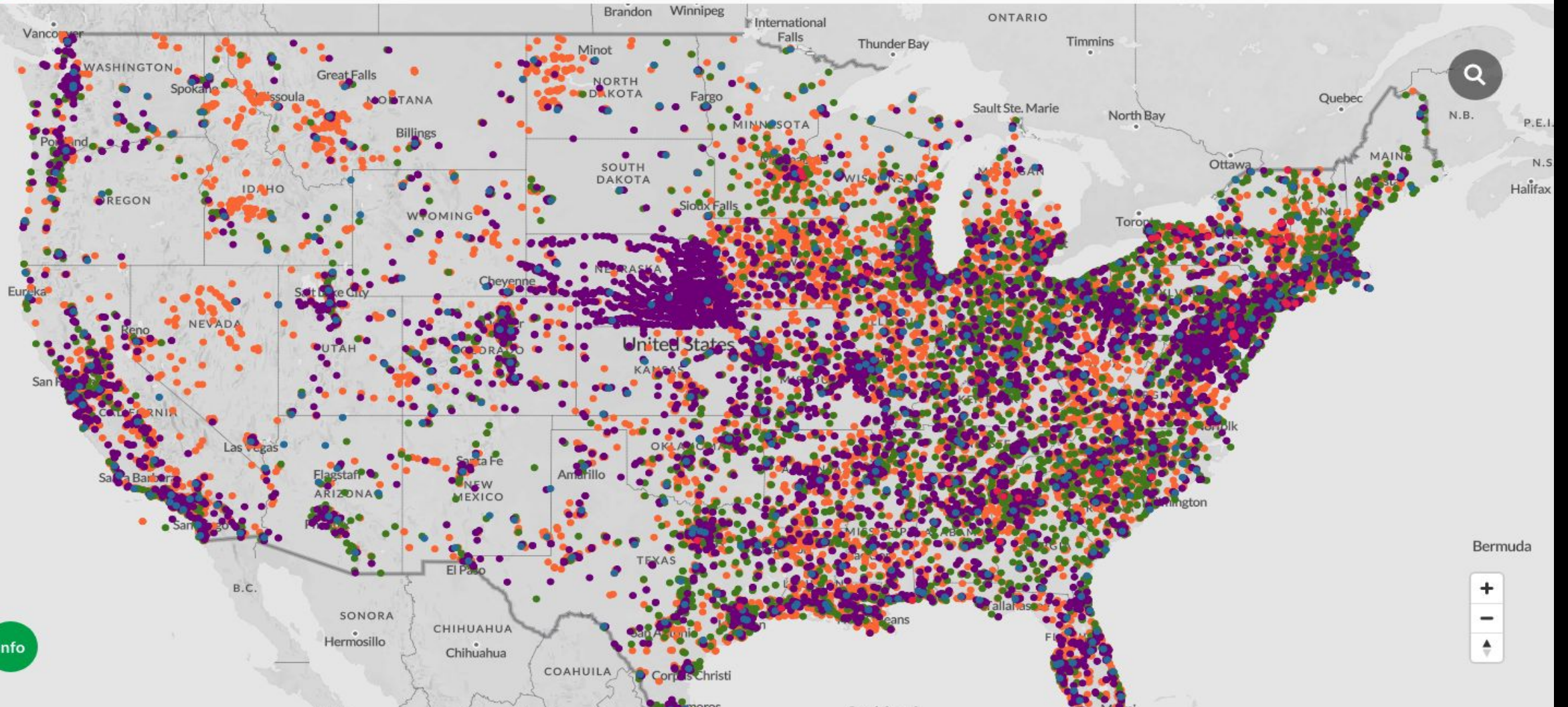
Is it worse in Maine ...or did we just start looking first?



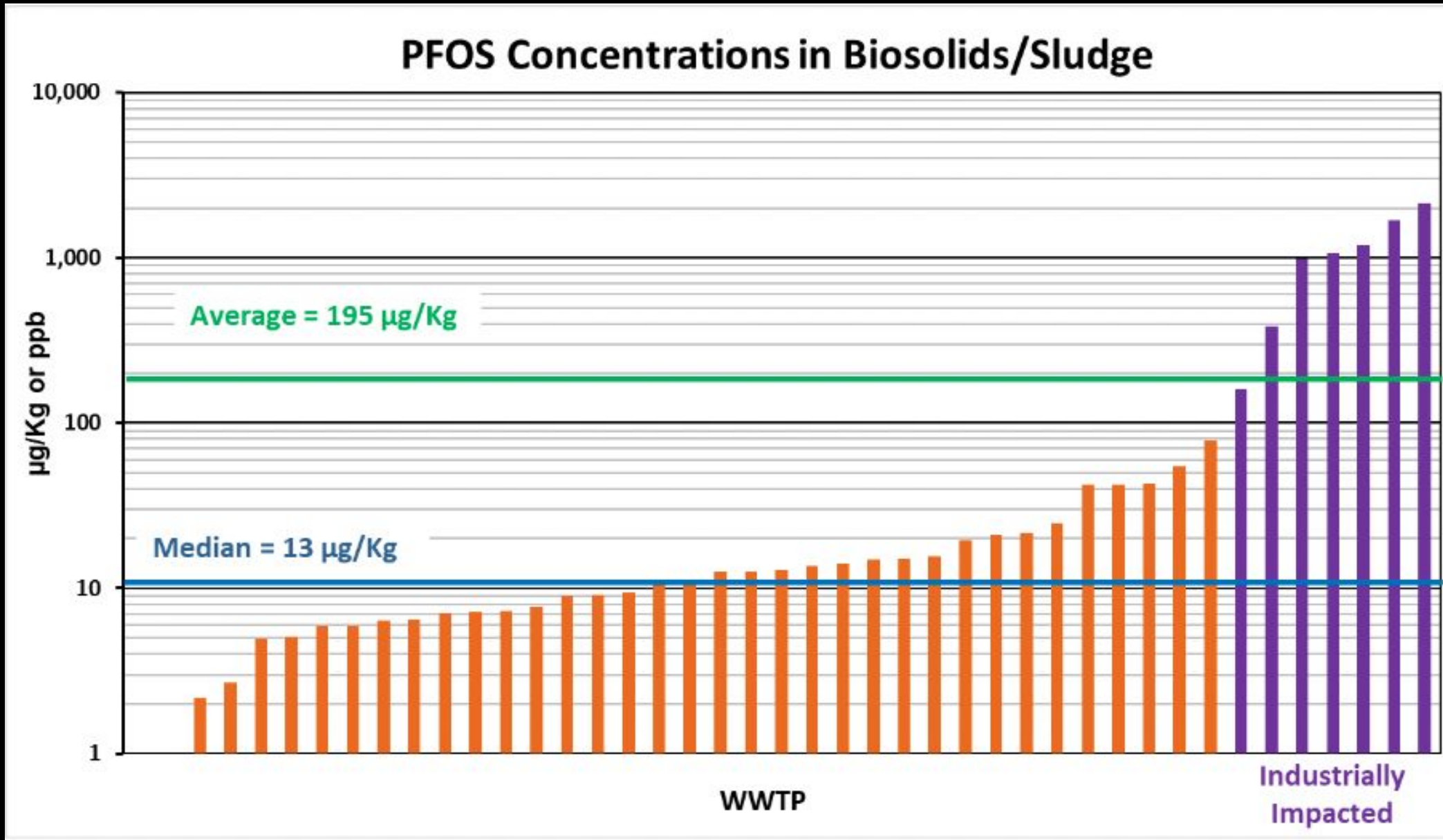
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Suspected industrial discharges of PFAS

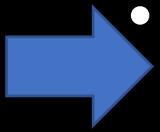


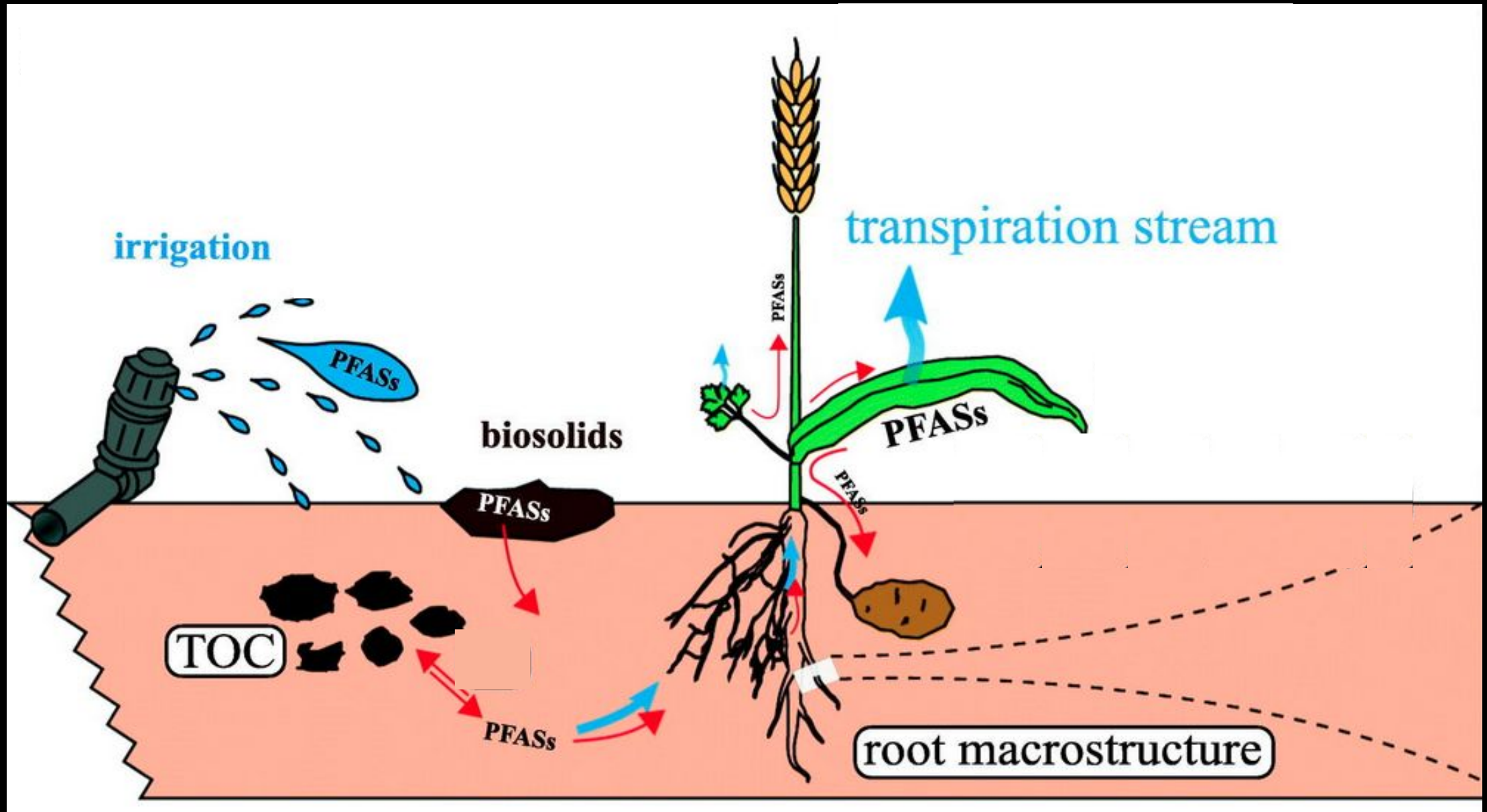
Sludge PFAS levels in Michigan



Agenda

- **What are PFAS, and where are they found?**
- **What happened in Maine**
- **PFAS uptake by plants**
- **PFAS contamination examples**
- **PFAS remediation/mitigation**





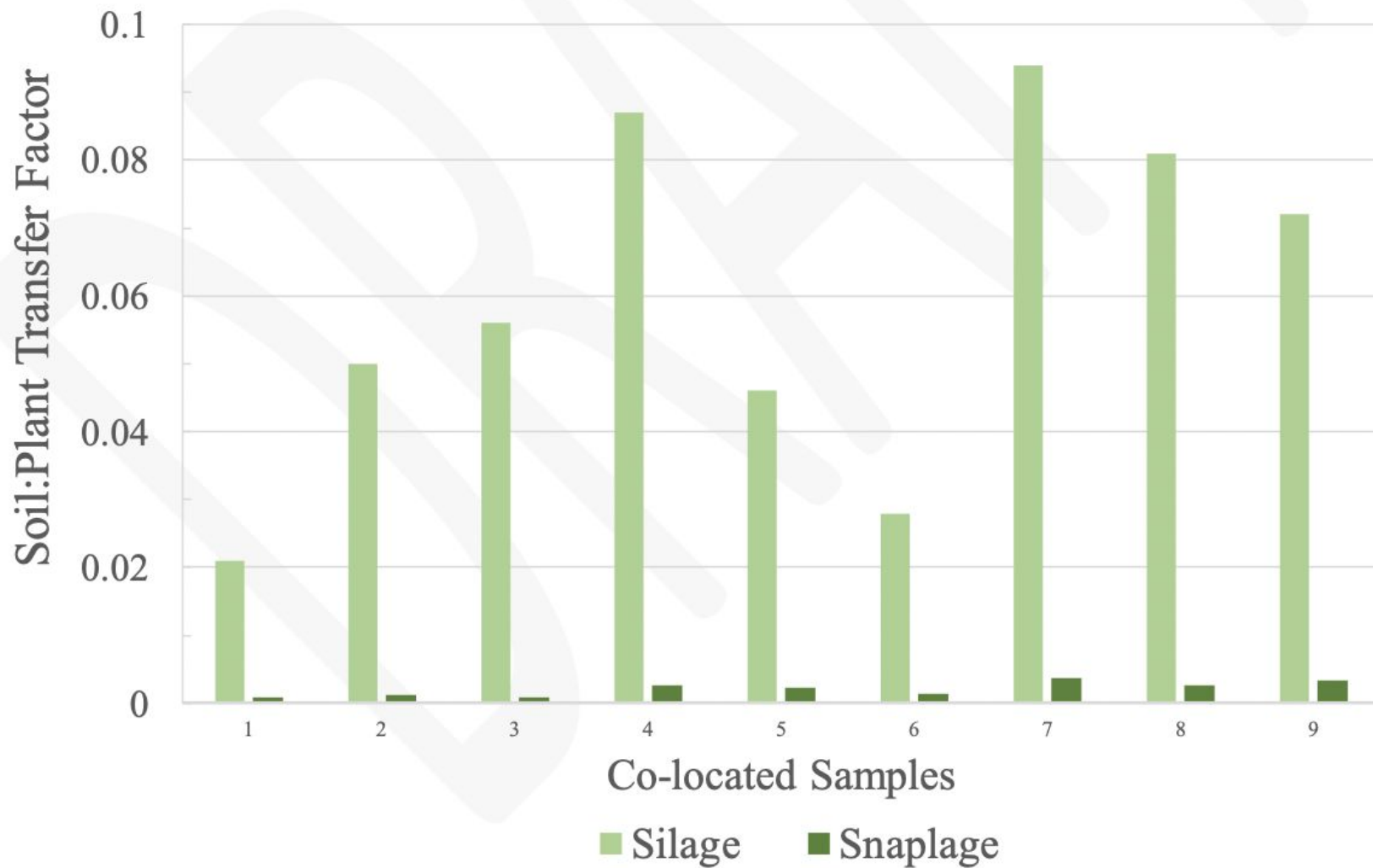
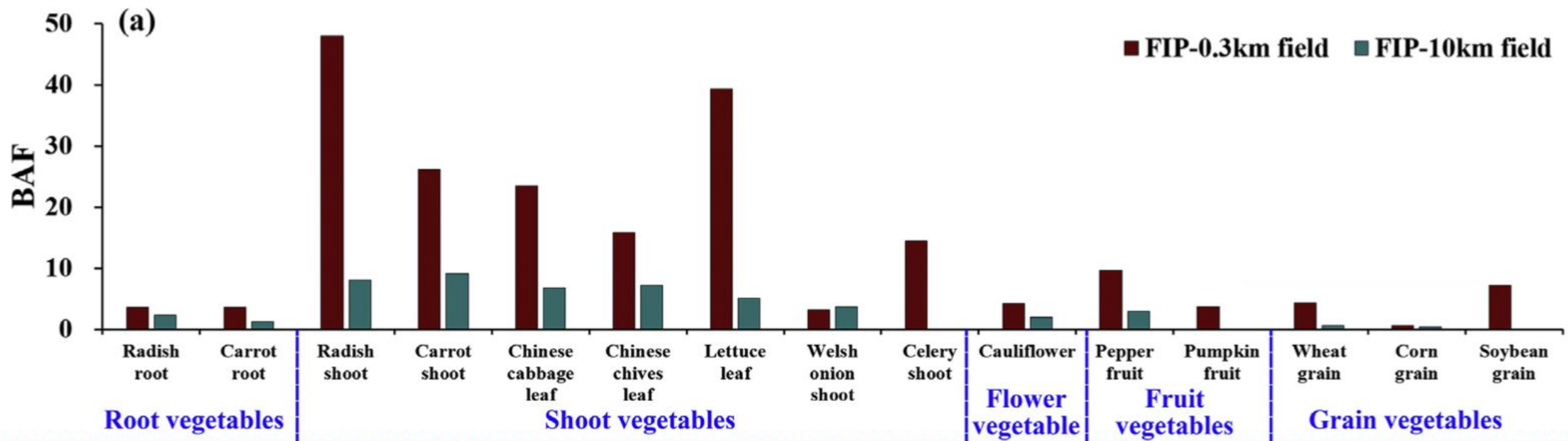
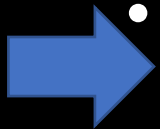


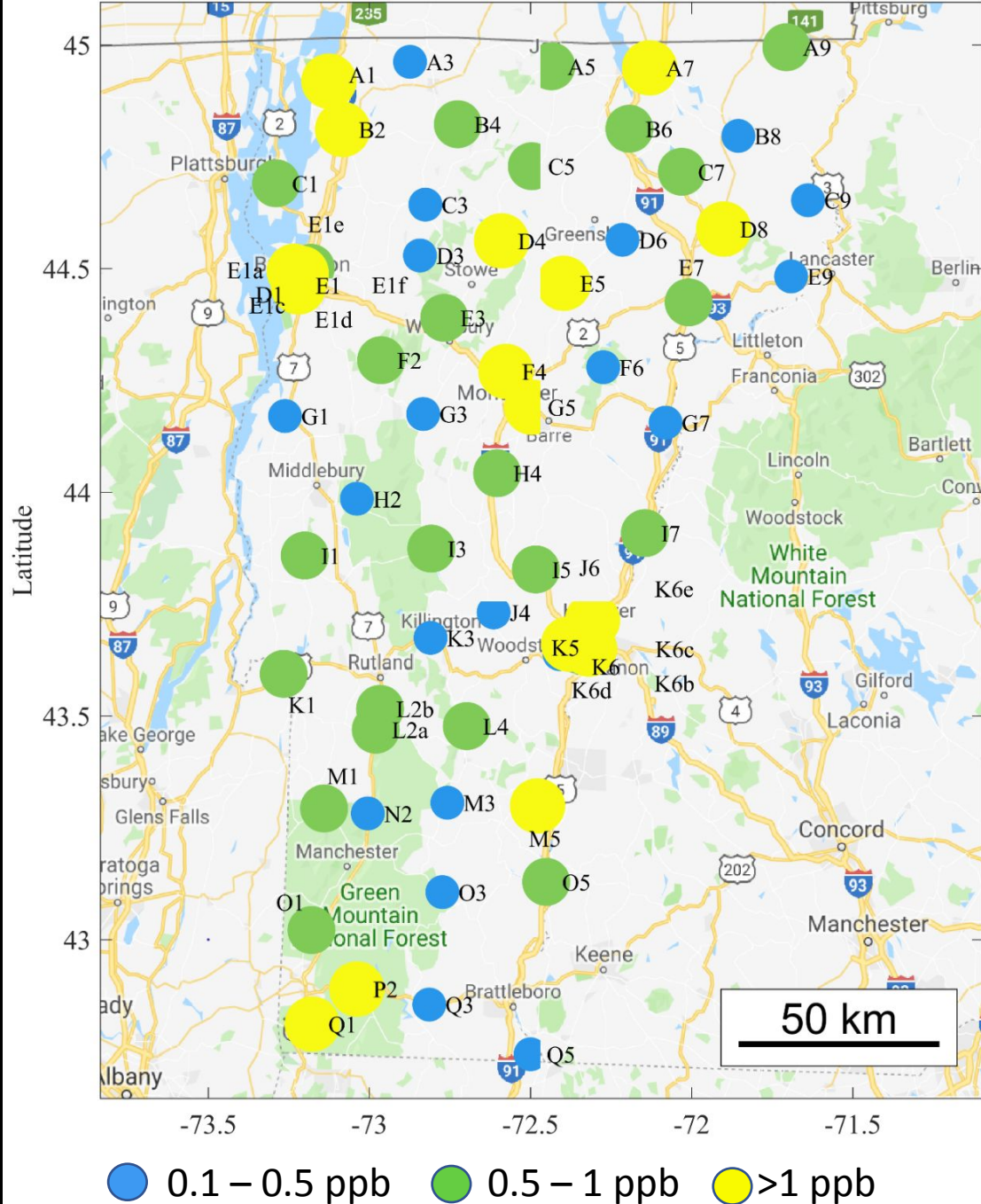
FIGURE 2. Soil-to-plant transfer factors (ratio of plant PFOS to soil PFOS concentration on a dry weight basis) for an entire corn plant (stalks, leaves, ears; light green 'Silage' bars) versus corn ears including husk, shank and tassel; dark green 'Snaplage' bars). Co-located samples 1-3, 4-6, and 7-9 are triplicates obtained from three different fields on one farm. Soil concentrations range from 200 to 500 ng/g on a dry weight basis.



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Modified from, PFAS background in Vermont shallow soils. Zhu et al., 2019

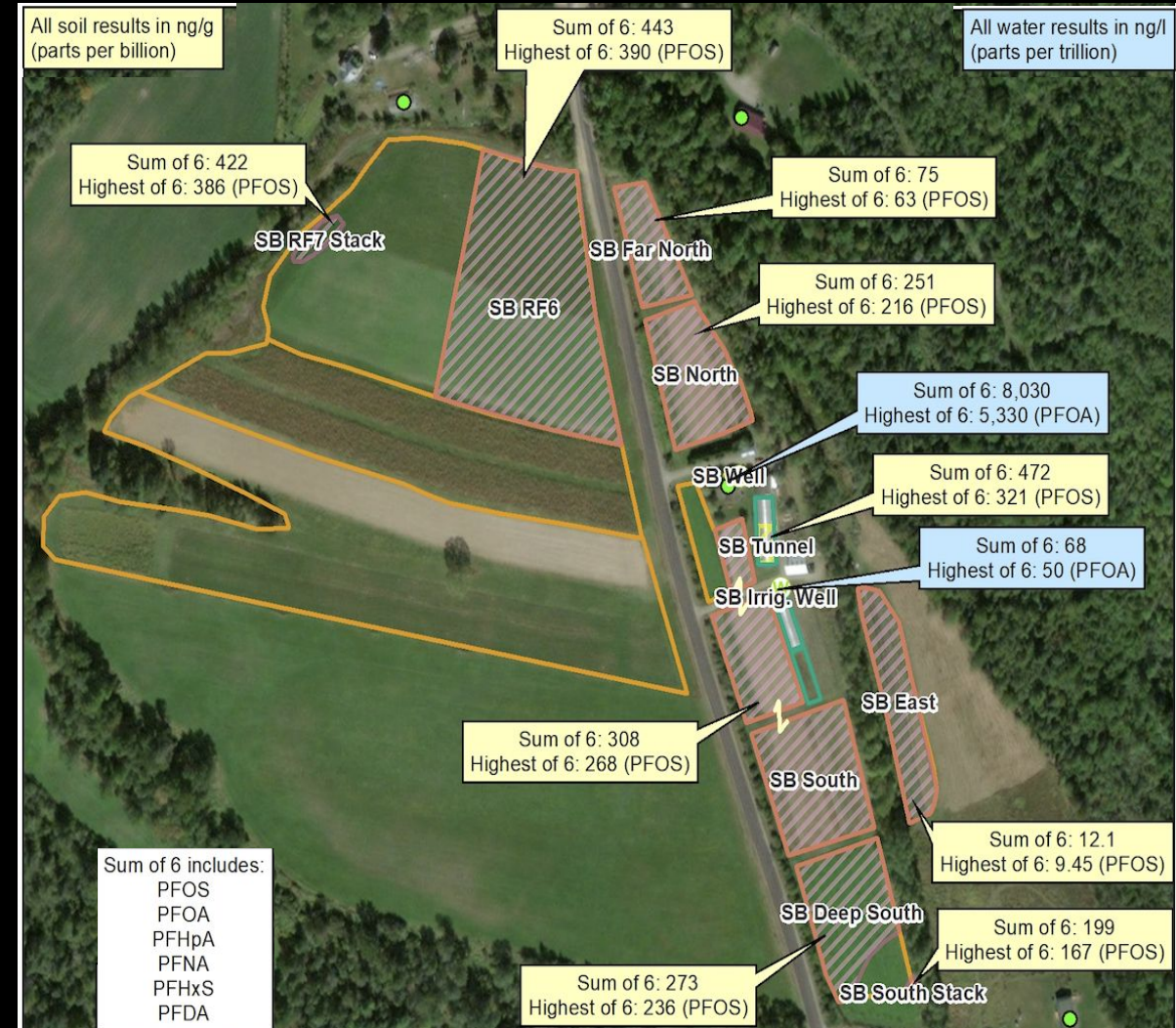
Similar results from a study in Maine.

Background contamination is likely present in most soil in the Northeast, often below 1 ppb, but not always.

Figure 6.10. Spatial distribution of PFOS.

The first Maine veg farm

- Soil levels ranging from 63 – 390 ppb PFOS
- Primary well at 5,330 ppt PFOA
- Non-Detect: corn, rye, oats, onion, garlic
- Low 'other' PFAS, or PFOS/PFOA <LOQ:
wheat, cantaloupe, winter squash, sweet pepper
- Home tomato sauce: ND PFOS, 1.1 PFOA
- Sweet potato: 1.9 ppb PFOS, 1.1 ppb PFOA
- Winter spinach: 4.4-6.3 ppb PFOS, 5.3-6.7 ppb PFOA



*All human facing produce measured on a wet weight basis

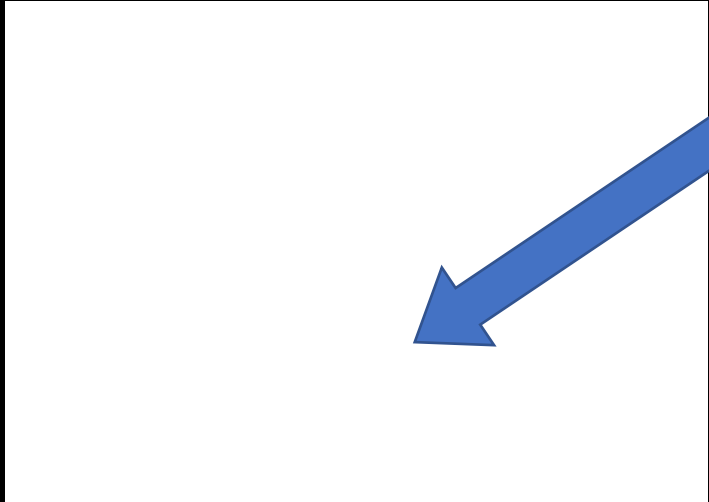
The second Maine crop farm

- **No known sludge spreading on their land**
 - **Neighboring field was former dairy that spread, contaminating groundwater**
- **Around 2018 they put in a high yielding fracked irrigation well, and used it heavily.**
- **Soils relatively low contamination in most uncovered fields, higher in tunnels**
- **Commercially available compost based potting mix was non-detect**



d w

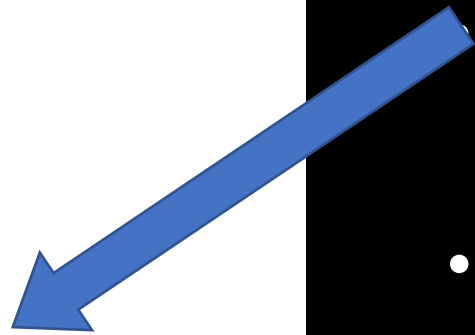
occurred



Highest contaminated outdoor field, but ND PFOS, only 1.7 ppb PFOA and similarly low levels of a few other PFAS in the soil

- Irrigation well was contaminated by many different compounds

CHEMICAL	IRR ppt
TOTAL	12771.1
PFHpA	4840
PFOA	2970
PFHxA	2000
PFPeA	1340
PFBA	535
PFNA	1070
PFOS	16.1



Highest contaminated outdoor field, but ND PFOS, only 1.7 ppb PFOA and similarly low levels of a few other PFAS in the soil

- Irrigation well was contaminated by many different compounds

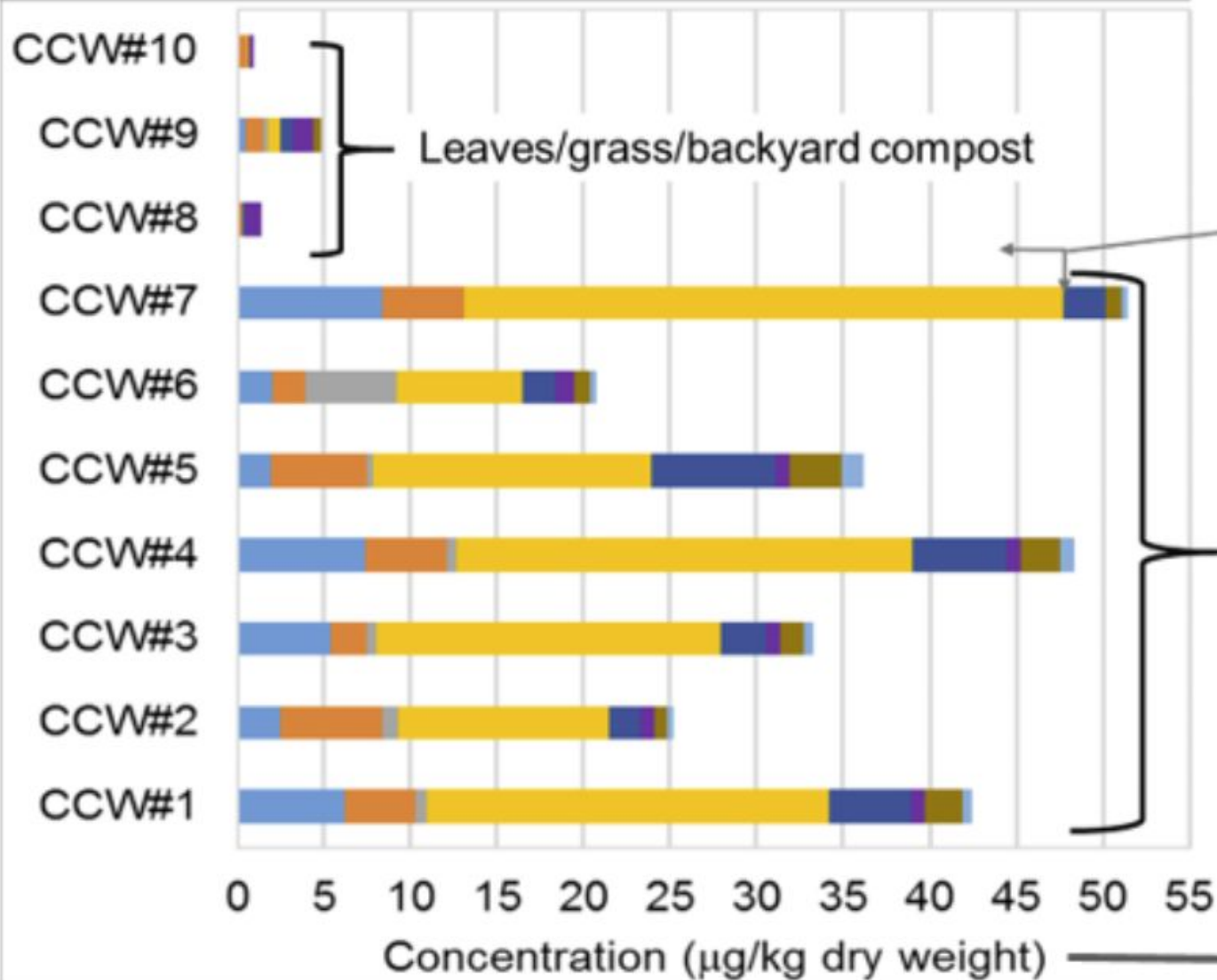
CHEMICAL	IRR ppt	KALE (1C) ppb
TOTAL	12771.1	19.22
PFHpA	4840	1.37
PFOA	2970	U
PFHxA	2000	5.34
PFPeA	1340	6.89
PFBA	535	5.62
PFNA	1070	U
PFOS	16.1	U

Expected state action thresholds are only going to be set for PFOA, PFOS, PFHxS and PFNA until further federal guidance is made available – so a greens crop like this would not be subject

...but it is still quite high in some PFAS compounds (!)

Some other potential PFAS sources on veg farms

PFAS in Composts made with Compostable Food Serviceware



PFAS levels in biosolids composts previously studied by same lab group were generally 2 to 10 times higher.

Includes residential and commercial food waste and compostable products/serviceware

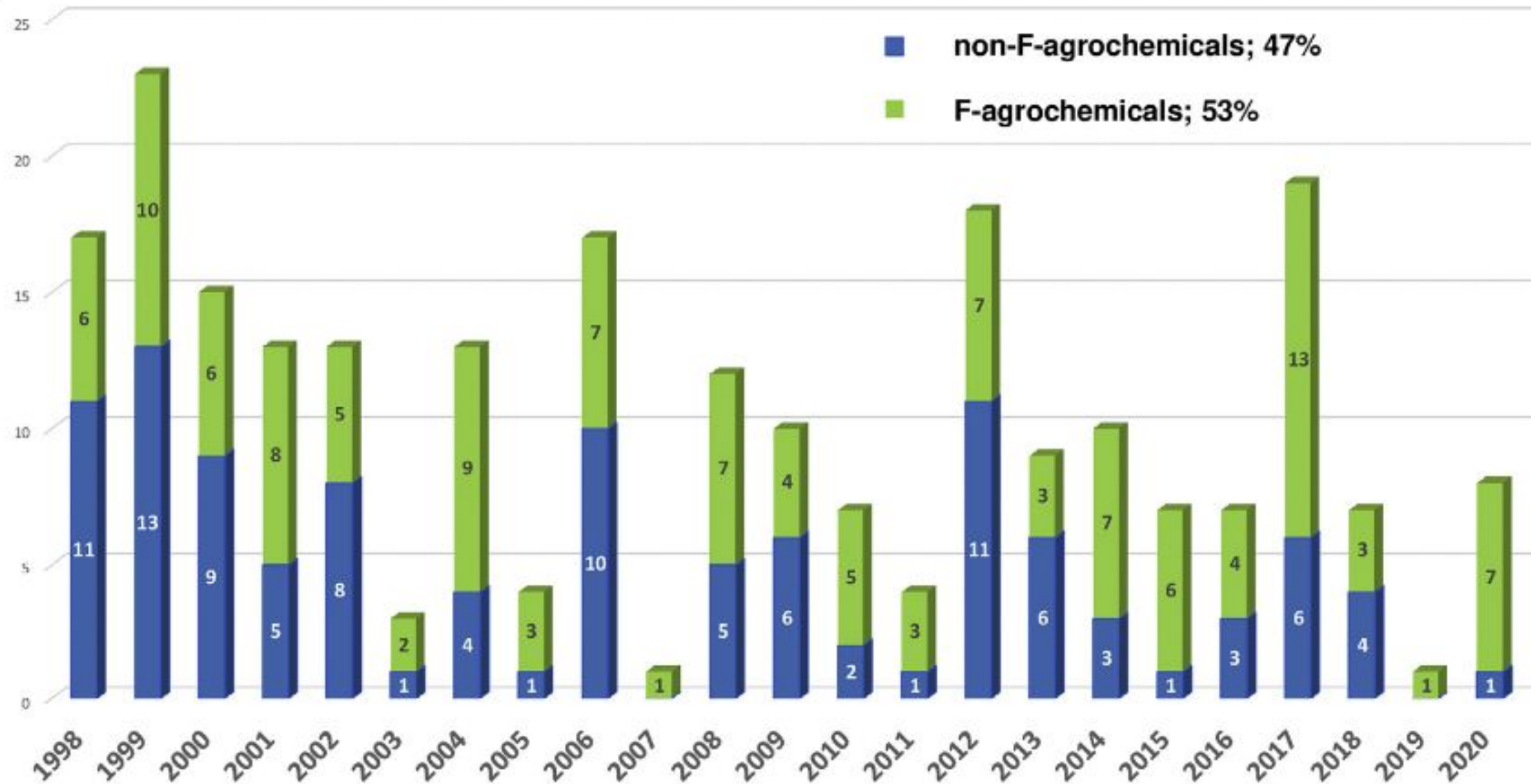
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Figure 3. Prevalence of Fluoro/Non-fluoro-Agrochemicals Assigned New ISO Common Names (1998–2020 (June))

- **Some shockingly high levels of PFAS found, likely intentionally added as “inert” ingredients**
 - **Including PFOS & many other unknown PFAS**

- **Crops tested higher than would be expected based on soil and water levels**

**Study by Lasee et al., 2022.
doi.org/10.1016/j.hazl.2022.100067**

**The
Guardian**

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About this content

Tom Perkins

Fri 7 Oct 2022 06.00 EDT

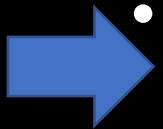
Toxic ‘forever chemicals’ detected in commonly used insecticides in US, study finds

‘Screamingly high’ levels of PFOS, one of the most dangerous PFAS compounds, found in six out of 10 insecticides tested



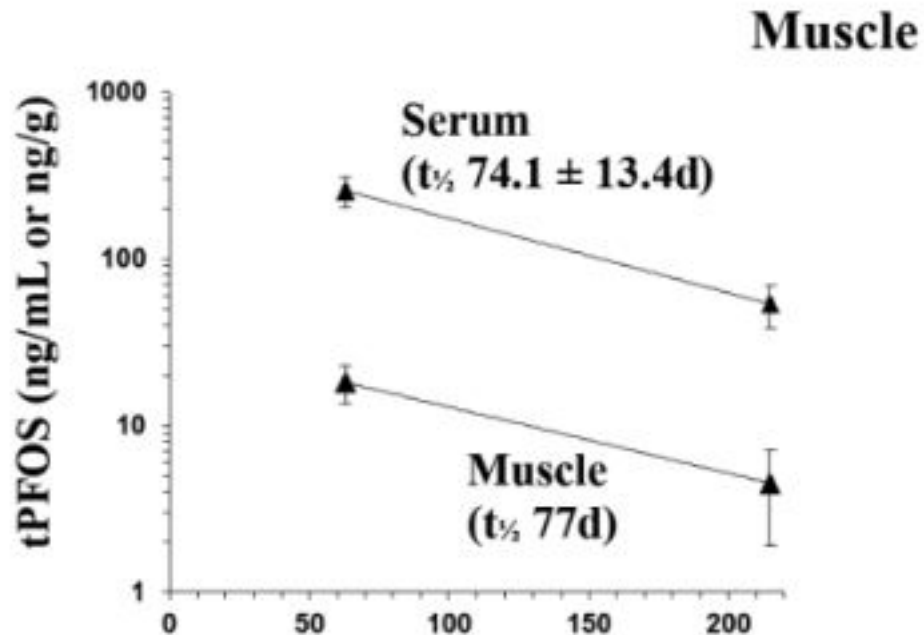
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PFAS are not forever in livestock

Panel A: tPFOS



With a half-life < 3 months, PFAS levels in beef would be expected to be 1/16 of the original concentration after 12 months (4 half-lives) of “clean” feed and water.

Milk and egg production similarly have half-lives. Milk may take a little more time and eggs likely take much less time, but research is ongoing.

Remediation Potential

- **WATER** - Current best practice is to filter with a carbon filter.
 - Other PFAS separation exists (e.g., reverse osmosis, bubble concentration) but not currently economical for most farms
 - Some high tech “PFAS destruction” technologies are being investigated.
- **SOIL** - No proven remediation strategies yet.
 - Phytoremediation (plant uptake) has potential, but will take decades, and what to do with contaminated plants?
 - Research beginning on bacterial/fungal remediation - very early days, most are skeptical.

Mitigation Potential

- **SOIL**
 - **Crop selection**
 - **Avoid leafy vegetables**
 - **Livestock feeding must be done very carefully and contaminated land should only be used for grain or snaplage**
 - **“Deep compost no-till” approach may work if compost is “clean”, particularly in smaller (short season, shallow-rooted) greens crops, and sites with lower contamination**
 - **Biochar may mitigate availability to plants, or reduce leaching**
 - **still many more questions than answers**
 - **could present other issues**

- **2021**

Maine Legislative Actions re:PFAS

- **LD 1600 mandates investigation of all sludge spreading sites**
- **LD 1503 requires phase-out of all non-essential uses of PFAS by 2030**

- **2022**

- **LD 1911 prohibits all land application of sludge/biosolids**
- **Allocated \$60 million to support impacted farmers and PFAS research**
- **LD 2019 requires phase-out pesticide products containing PFAS by 2030**

Resources

- mofga.org/pfas
 - [“Roadmap for Addressing PFAS Contamination”](#)
 - mofga.org/pfas/pfas-emergency-relief-fund/
- extension.umaine.edu/agriculture/guide-to-investigating-pfas-risk-on-your-farm/
- maine.gov/dacf/ag/pfas/index.shtml
- maine.gov/pfastaskforce/materials/report/PFAS-Task-Force-Report-FINAL-Jan2020.pdf
- notillmarketgardenpodcast.libsyn.com/caleb-goossen-organic-crop-specialist-at-mofga-pfas

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Maine Organic Farmers & Gardeners Association

cgoossen@mofga.org



[@organiccropsspecialist](https://www.instagram.com/organiccropsspecialist)

www.mofga.org/pfas

www.mofga.org/farmer-resources/pest-reports-alerts/



“Concentrations of PFAS in food items from non-contaminated areas are generally in the 0.1 to 10 µg/kg [ppb] range, with higher levels seen in food items collected from areas with known sources of PFAS.”

U.S. EPA. 2021 *Persistent Chemical Contaminants*.

<https://www.epa.gov/system/files/documents/2021-08/emerging-issues-in-food-waste-management-persistent-chemical-contaminants.pdf>

Milk ⁵ (ng/l or ppt)		Beef ⁶ (ng/g)	
Compound	Action Level	Compound	Action Level
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Current Maine guidelines and thresholds are based off of prior federal guidance, and are expected to be further reduced. (I.E., milk < 50 ppt, beef < 0.5 ppb)

More thresholds are to be added with the update: yogurt, eggs, pork, spinach, lettuce and white potatoes. (As well as being calculated for additional PFAS compounds, up to 4)

“Concentrations of PFAS in food items from non-contaminated areas are generally in the 0.1 to 10 µg/kg range, with higher levels seen in food items collected from areas with known sources of PFAS. Seafood, followed by meat, may be important contributors to PFAS in food items, possibly due to bioaccumulation”

