

# PFAS Forever Chemicals: Their Health Impact and What You Can Do

RACC Presentation May 18, 2022

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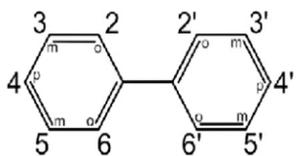
# Presentation Goals

- General information on Per- and polyfluoroalkyl substances (PFAS).
- Health risks associated with PFAS exposure.
- Dangers of PFAS associated with Landfill Leachate, Biosolids, and Effluent.
- Mitigating PFAS risks.

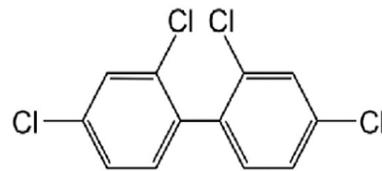
# General Information

- **1938** - Roy J. Plunkett **accidentally invented** polytetrafluorethylene (PTFE) - In **1945**, DuPont commercialized PTFE as **Teflon** the "first compound in the family of Perfluorinated compounds (PFCs) used in consumer products.
- **1942** - Manhattan Project was at an impasse - weapons-grade uranium corroding everything it came into contact. **General Groves commissioned DuPont** to make **PTFE gaskets** which stop the uranium leakage **enabling** the completion of the **Atomic Bomb**.
- **1954** - R. A. Dickison, who was employed at **DuPont**, received an inquiry about C8's (PFOA) "**possible toxicity and in 1961** "A DuPont in-house toxicologist" said C8 was toxic and should be "handled with extreme care.
- **1956** - it was noted that PFAS **binds to** proteins in **human blood**.
- **1960s** - **3M** maker of Aqueous Film Forming Foam (AFFF) for fire fighting notes "experiments on rats and monkeys concluded that PFAS compounds "**should be regarded as toxic**".
- **1970s – 2000**: 3M Lake Elmo's Washington County Landfill (MN) & Oakdale Dump (MN) + DuPont Parkersburg (WV) - are just a few locations where PFAS we dumped causing significant human and environmental damage.

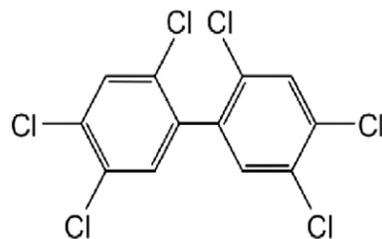
# General Information



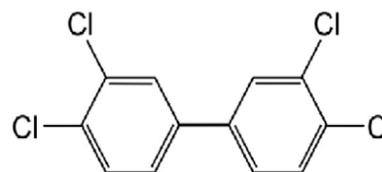
Generalized structure of PCB



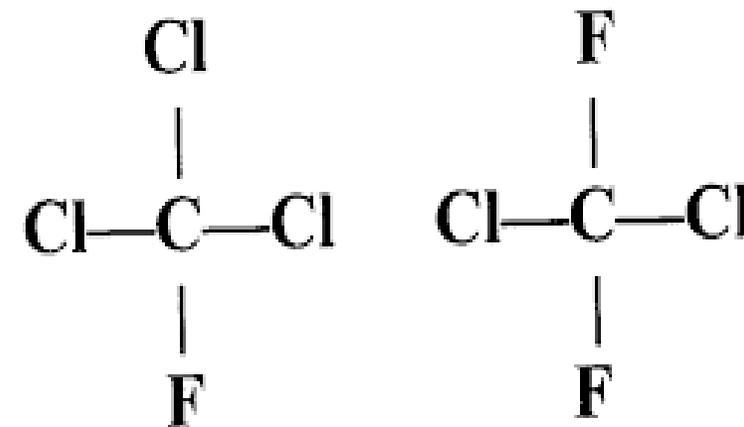
2,2',4,4'-Tetrachlorobiphenyl  
(PCB-47)



2,2',4,4',5,5'-Hexachlorobiphenyl  
(PCB-153)

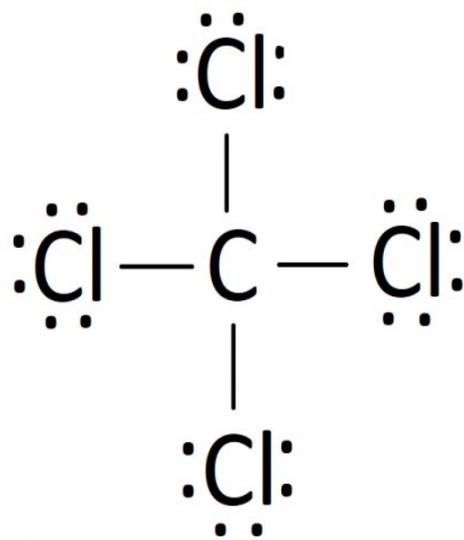


3,3',4,4'-Tetrachlorobiphenyl  
(PCB-77)



Freon-11

Freon-12



Carbon Tetrachloride

group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og
				57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
				La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
				89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
				Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Legend: ■ - halogen

<p>Polybrominated biphenyls (PBBs) 209 congeners</p> <p><math>x + y = 1-10</math></p>	<p>Polybrominated diphenylethers (PBDEs) 209 congeners</p> <p><math>x + y = 1-10</math></p>
<p>Hexabromocyclododecane (HBCD)</p>	<p>Tetrabromobisphenol A (TBBPA)</p> <p>4</p>

# General Information

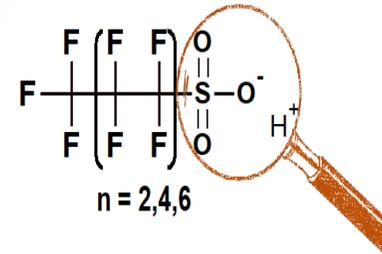
- “Per” = each carbon atom has a Fluorene attached

- “Poly” – more than one Carbon atom has a Fluorene attached



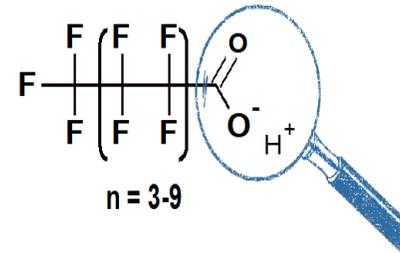
## Common PFAS Chemical Structures

- Perfluorinated



Perfluorosulfonic Acids (PFSAs)

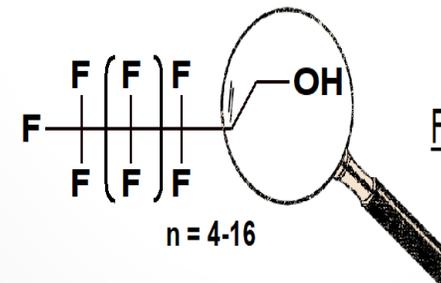
PFBS, PFHS, PFOS



Perfluorocarboxylic Acids (PFCAs)

C<sub>6</sub> acid – C<sub>12</sub> acid  
PFOA C8 acid

- Polyfluorinated



Fluorotelomer Alcohols

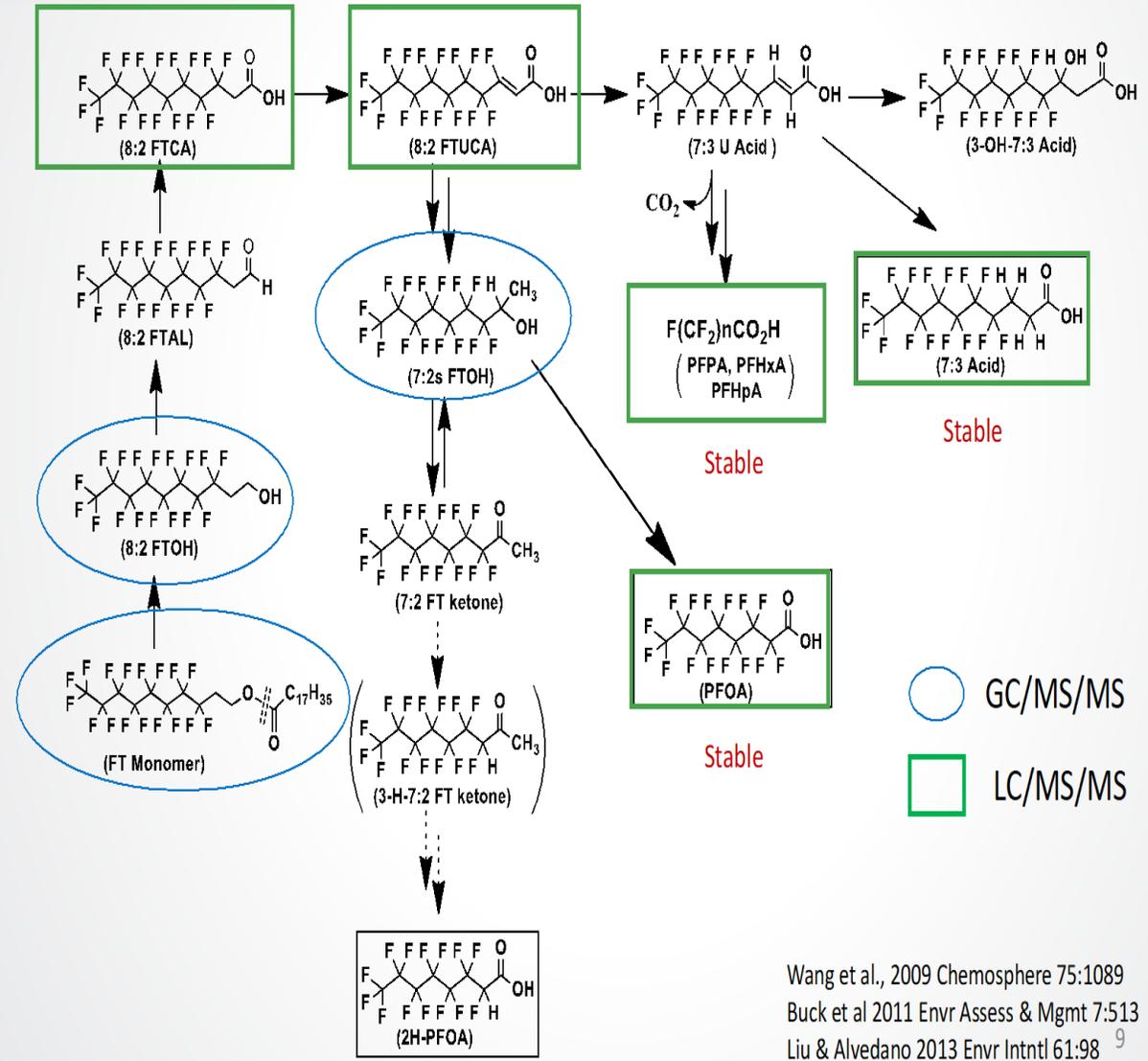
6:2, 8:2 and 10:2

# General Information

Intermediates can form PFOA and Other PFAS chemicals



## Transformation of PFCAs



Wang et al., 2009 Chemosphere 75:1089  
 Buck et al 2011 Envr Assess & Mgmt 7:513  
 Liu & Alvedano 2013 Envr Intntl 61:98 <sup>9</sup>

# Health Risk

One must first understand the basic concept behind toxicology in order to understand the risk(s) associated with exposure.

Toxicology is the study of the adverse effects of chemicals or physical agents on living organisms.

***First rule of toxicology:***

*“The Dose Makes The Poison”*

***When a dose cannot be calculated:***

*Precautionary Principle - “Do No Harm”*

*The precautionary principle enables decision-makers to adopt precautionary measures when scientific evidence about an environmental or human health hazard is uncertain and the stakes are high.*

# Health Risk

- 98% of Americans have one or more PFAS in their blood (CDC)

- Average Level in Blood= 10,000 ppt (2014 CDC)

- Currently EPA Health Advisory Level = 70 ppt



# Health Risk

- Carbon-Fluorene (C-F) bond is one of the strongest single bonds in chemistry.
- 1,000<sup>0</sup>C to 1,400<sup>0</sup>C is required to break the C-F bond

PFAS are a class of thousands of chemicals that are known as “*Forever Chemicals*”

- They can persist in our bodies and in the land/water for periods ranging from several years/decades and several months in the air. The “**half-life**” of PFOA:
  - **8 years** in the human blood
  - **92 years** in land/water
  - **130 days** in the air
- They have spread throughout our world and can be found in soil, water, air and in most living things as well as in untold numbers of consumer and agricultural products.
  - Virtually all products containing PFAS end-up in landfills and wastewater treatment plants (WWTP) via leachate and commode.

# Health Risk

- Impact of Carcinogenic Data

- Numerous other health concerns exists including developmental and reproductive effects to multiple generations

For chemical contaminants in DRINKING WATER that are carcinogens, **EPA** sets the maximum contaminant level goal (MCLG) at **ZERO** if both of these are the case:

**1) “There is evidence that a chemical may cause cancer”**

The National Toxicology Program (Health & Human Services) has determined that PFOA demonstrated “**some to clear evidence of carcinogenicity**” involving the **liver and pancreas** of male rats and the **liver, kidney, forestomach, and thyroid gland** of female rats. The International Agency for Research on Cancer (World Health Organization) has observed cancers of the **liver and pancreas** and some **kidney, bladder, liver, testes, prostate, thyroid, and breast cancers** based on 2 rodent studies, 1 trout study and 3 human epidemiological studies.

**2) “There is no dose below which the chemical is considered safe”**

*Individual exposure levels (**dose**) of PFOA/PFOS cannot be determined because there are so many sources of exposure.*

For chemical contaminants in FOODS/FOOD WRAPS that are carcinogens, **FDA**, via the Delaney Amendment, is not allowed “regardless of the dose” or animal/human model tested” via the Food, Drug and Cosmetic Act <sup>10</sup>

In 2019, more than 180 countries agreed to ban production and use of the most notorious PFAS chemical, PFOA, as well as its salts and other PFOA-related compounds.

# Health Risk

## Moving Forward

**As Europe Moves to Ban PFAS, Why Can't the U.S.? May 26, 2020 —**  
*Officials in Sweden, the Netherlands, Germany, and Denmark have taken steps to restrict all PFAS compounds under Europe's chemical regulations ...*



From the collection of Stanford Research Into the Impact of Tobacco Advertising (tobacco.stanford.edu)

**Nike comes clean with chemicals elimination pledge**  
**Giant sports apparel make responds to Greenpeace campaign by reiterating a goal to achieve zero discharge of hazardous chemicals across its supply chain by 2020.**  
**By Heather Clancy | August 22, 2011**

**Nike to replace ten priority chemistries with 'cleaner' alternatives by 2025**  
**PFASs, bisphenols, VOCs among substance groups retail giant reveals to Chemical Watch**  
**By Chemical Watch | 08 April 2021**

**Chemours – maker of GenX - If PFAS are banned it could cause an increase in global climate change.**  
**Industry Lawyer – If PFAS are banned we could be missing the next cure for cancer.**

# Landfill Leachate, Biosolids and Effluent



- Seneca Meadows = 2.19 million tons/yr
- Ontario County = 1.20 million tons/yr
- Hyland = 0.47 million tons/yr
- Hakes = 0.47 million tons/yr
- Lexington Landfill = 0.05 million tons/yr
- PFAS Levels Unknown

**The highest PFAS readings at Finger Lakes region landfills (ppt)**  
(NYS limit for PFOA and PFOS in drinking water: 10 ppt)

	<b>Seneca Meadows</b>	<b>Ontario County</b>	<b>Hyland</b>	<b>Hakes</b>
PFBS:	15,200	PFOA: 3,270	PFBA: 3,170	PFHxA: 3,900
PFHxA:	5,370	PFHxA: 3,040	PFHxA: 3,050	PFPeA: 3,500
PFBA:	4,520	PFBS: 2,750	PFOA: 2,510	PFBA: 1,700
PFBA:	4,520.	PFBA: 2,560	PFBS: 2,150	PFOA: 1,200
PFOA:	4,160	PFPeA: 2,130	PFPeA: 1,310	PFHpA: 820

Sources: TestAmerica data from 2018 and Hakes C&D Landfill annual reports from 2019, 2020. Photo of Seneca Meadows Landfill in Seneca Falls from the Finger Lakes Times. 12

# Landfill Leachate, Biosolids and Effluent

Class A – No Detectable Pathogens

Class B Biosolids – Prohibited from public access areas

Products	Purchased	Biosolids Source	Percent Biosolids	PFOA (PPB)	PFOS (PPB)
<b>Cured Bloom</b>	W.S Jenks & Sons Washington DC	Washington DC Water-Blue Plains Advanced WWTP	100	<b>23.8*</b>	<b>22.1*</b>
<b>Earthlife Natural Fertilizer</b>	York Woods Tree & Products, Eliot, ME	Quincy, MA – New England Fertilizer Co. (NEFCO)	100	<b>2.75*</b>	<b>17.3*</b>
<b>EcoScraps Slow Release Fertilizer</b>	The Home Depot	Unknown – company based in Nevada	100	1.2	<b>16.9*</b>
<b>GreenEdge Slow Release Fertilizer</b>	The Home Depot	Jacksonville, FL – JEA sewer collection system	100	1.39 – 1.66	<b>12.9 - 13.5*</b>
<b>Menards Premium Natural Fertilizer</b>	Menards	Unknown – company based in Wisconsin	100	1.01	<b>9.05*</b>
<b>Milorganite 6-4-0 Fertilizer</b>	The Home Depot	Milwaukee, WI – Metro-politan Sewerage District	100	0.67	<b>8.66*</b>
<b>Pro Care Natural Fertilizer</b>	Lowe's	Georgia (Multiple locations)	85.5 – 91.5	0.94	<b>14.9*</b>
<b>Synagro Granulite Fertilizer Pellets</b>	Sacramento, CA Pelletizer	Elk Grove, CA – Sacramento Regional WWTP	100	0.95	3.71
<b>TAGRO Mix</b>	Ace Hardware	Tacoma, WA – Central WWTP	50	<b>7.51*</b>	<b>7.92*</b>

\*Maine State Biosolid limits: PFOA: 2.5 ppb, PFOS: 5.2 ppb;

# PFAS Contamination from Wastewater to Farm & Garden

Landfill Leachate, Biosolids and Effluent



Application of biosolids to farmland “as it exists now” contaminates the land, air and water leading to contamination of crops, dairy, livestock, wildlife, and humans.



# Landfill Leachate, Biosolids and Effluent

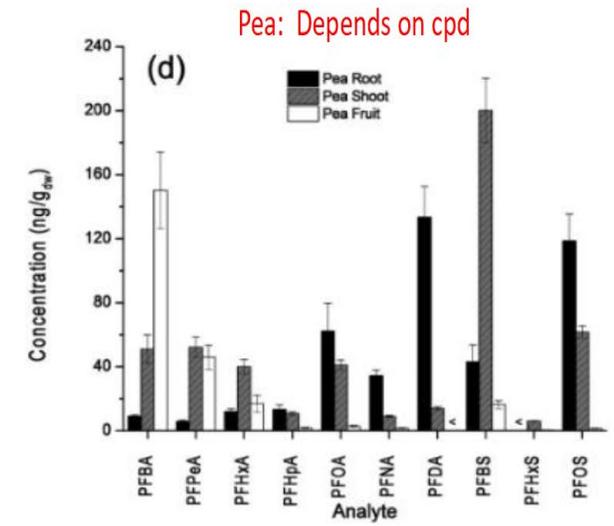
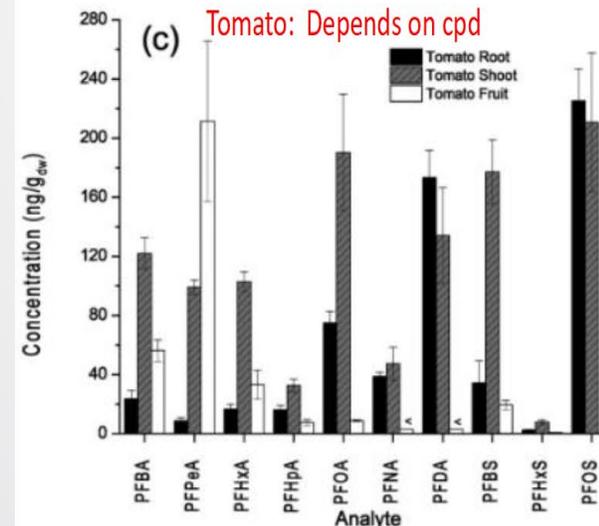
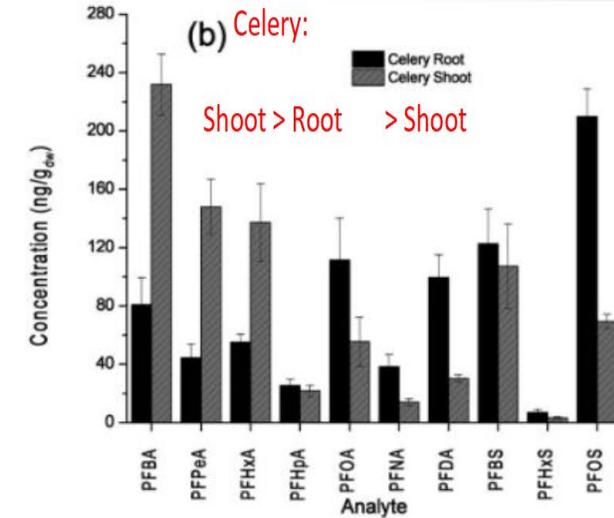
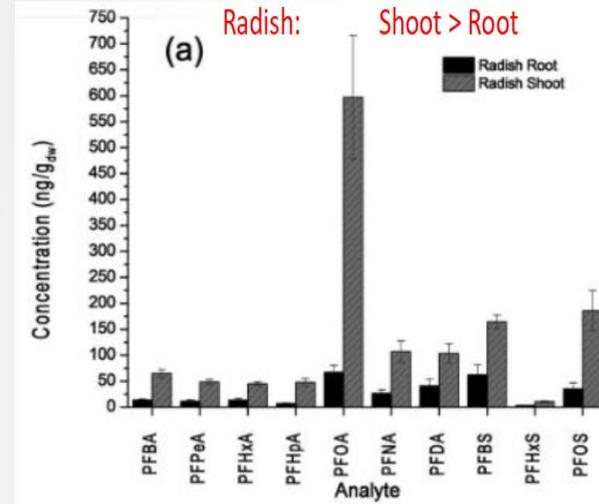


In 4 plants:

Accumulation in produce from soil amended with biosolids



Differential uptake to various compartments within the plant



- Most PFAS appear to remain in the vegetation, however, some can enter into the fruit
- PFAS also wicks into Hay and Corn
- Maine found hay on one farm that had 9,669 ng/kg wet weight (ppt) PFOS.

# Landfill Leachate, Biosolids and Effluent

- Arundel Township Population = 4,264
- Fairfield Township Population = 6,484
- 21 States have some 260 policies in process to regulate PFAS activities and 8 States have Advisories on fish and/or deer meat.

## Maine

- Arundel Township – York County: Sludge containing PFAS was spread on a farm as fertilizer.
  - The milk tested at **690 ppt for PFAS**.
  - More than two years on, the owners still cannot sell the milk from these cows.
  - They estimate spending \$10,000 on testing and are losing over \$400 daily (~\$150,000/yr).
- Fairfield Township - Somerset County: The meat/livers of 8 deer were collected in close proximity to several farms that spread **municipal/industrial sludge for fertilizer or manure from contaminated animals**.
  - PFOS **soil levels** ranged between **300 to 1,000 ng/g** (ppb) range, and surface **water levels** in the **6,000 to 7,000 ng/L** (ppt) range.
  - **Liver samples** were **4- to 51-fold higher than muscle tissue**.
  - As a result, restrictions were placed on the consumption of **deer liver to 1 meal per year for children and adults and 2 meals a year for children and 4 meals for adults of deer meat**. (based on The **Agency for Toxic Substances and Disease Registry [ATSDR] safe levels of 2 ng/Kg/day = ppt/day**).

# Landfill Leachate, Biosolids and Effluent

- 15 ng/g = 12 meals/year
- 30 ng/g = 6 meals/year
- 60 ng/g = 3 meals/year
- Above 60 ng/g = DO NOT EAT

## New freshwater fish consumption advisory

The Maine CDC is warning residents to limit or forgo consumption of some or all fish species in seven bodies of water based on new, stricter health standards for PFAS chemicals.

Area	Waterbody	Consumption advisory
<b>Fairfield</b>	Police Athletic League (PAL) Ponds	Do not eat any species of fish
<b>Fairfield</b>	Fish Brook, including any tributaries, from the headwaters to the confluence with Messalonskee Stream	Do not eat any species of fish
<b>Waterville /Oakland</b>	Messalonskee Stream from the Rice Rips Dam in Oakland to the Automatic Dam in Waterville	Consume no more than three meals per year of any fish species
<b>Limestone</b>	All of Durepo Pond and Limestone Stream from Durepo to the dam near Route 229 in Limestone	Consume no more than three meals per year of brook trout and do not eat smallmouth bass
<b>Sanford</b>	The Mousam River from below the Number One Pond Dam to Outlet Dam on Estes Lake, including all of Estes Lake	Consume no more than three meals per year of any fish species
<b>Westbrook</b>	The Presumpscot River from Saccarappa Falls in Westbrook to Presumpscot Falls in Falmouth	Consume no more than four meals per year of any fish species
<b>Unity</b>	Unity Pond	Consume no more than six meals per year of black crappie and no more than 12 meals per year for all other fish species

SOURCE: Maine Center for Disease Control and Prevention

STAFF GRAPHIC | JAKE LAWS

# Landfill Leachate, Biosolids and Effluent

- 700 farms maybe contaminated with PFAS.
- Testing revealed their soil, drinking water, irrigation water, crops, and animals were contaminated with high levels of PFAS.

## 'I don't know how we'll survive': the farmers facing ruin in Maine's 'forever chemicals' crisis



# Landfill Leachate, Biosolids and Effluent

- Michigan temporarily banned biosolid applications.

- Alabama, “the best use of biosolids is as a fertilizer.”

## Maine bans use of sewage sludge on farms to reduce risk of PFAS poisoning



# PFAS Mitigation

Powdered or Granular Activated Carbon Adsorption (PAC)	Ion Exchange	Reverse Osmosis / Nanofiltration
Effective for removal of long chain PFAS (PFOA, PFOS)	Effective for removal of long chain PFAS (PFOA, PFOS)	Effective barrier to PFAS and almost all additional CECs
Less effective for short chain PFAS	More effective for short chain PFAS	High energy use

## Comparison of PFAS Removal Technologies for Drinking Water



# PFAS Mitigation

- Getting manufacturers to identify what products contain PFAS is paramount.
- Minimizing or not using PFAS containing products will drastically reduce landfill waste reducing human/environmental exposure.
- Commercially available methods to capture and remove PFAS from biosolids are under development.
- Storing/disposing of contaminated biosolids is not a permanent solution
- Avenues being pursued “collectively” with other scientists:
  - Biological separation (organisms)
  - Chemical separation (binding)
  - Physical separation (molecular weight)
  - Partition to water (filter)
  - Incineration (above 1000°C)

# Summary of What We Know About PFAS Exposure

- So ubiquitous in our world that a dose/exposure can not be accurately calculated.
- 98% of American's have an average PFAS blood level of 10,000 ppt.
- 100% of breast milk tested was found to contain PFAS.
- PFAS chemicals do have (PFOA) and can have (PFOS, PFBS, Gen-X ...) carcinogenic potential.
- Can cause developmental & reproductive birth defects.
- PFAS can stay in water/land for almost 200 years, 16+ years in blood and 9 months in air.
- Farmlands applied with biosolids containing PFAS (since 1990's) are contaminated beyond use.
- The commercial application of biosolids to farmland "**as it exists now**" contaminates the land, air and water leading to contamination of crops, dairy, livestock, wildlife, and humans.
- Stopping PFAS source pollution by banning these chemicals in "ALL" products is a necessity.