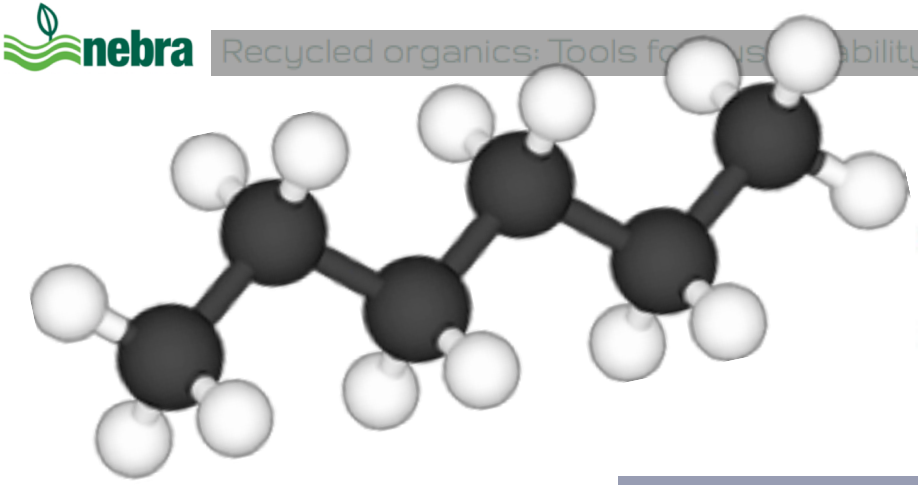
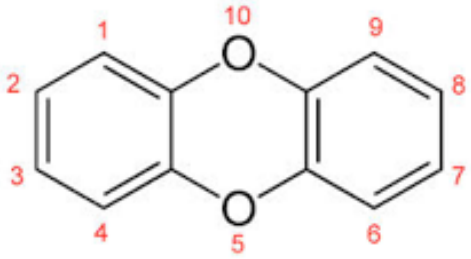
nebra Recycled organics: Tools for sustainability.





Emerging Contaminants (CECs)

Ned Beecher • NEBRA

January 27, 2019

NEWEA/NEWWA Young Professionals Workshop

nebiosolids.org

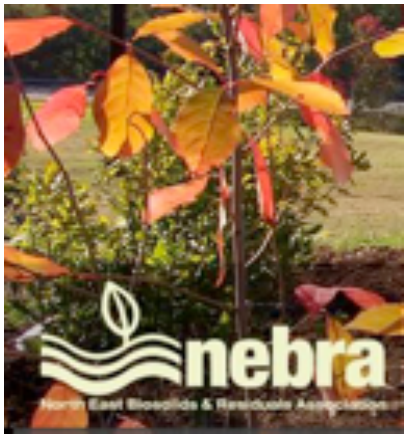
What NEBRA Does For You

Tours, workshops, conferences, outreach to advance best practices & understanding to advance the recycling of biosolids & other organic residuals in New England & eastern Canada.

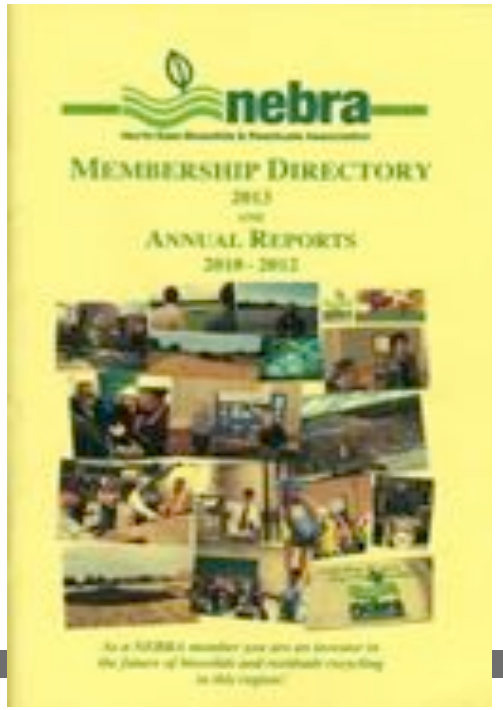
What NEBRA Does For You

- **Tracking & sharing research, news, legislation, & regulation**

NEBRAMail – free email newsletter; sign up at nebiosolids.org
On Twitter: @nebiosolids



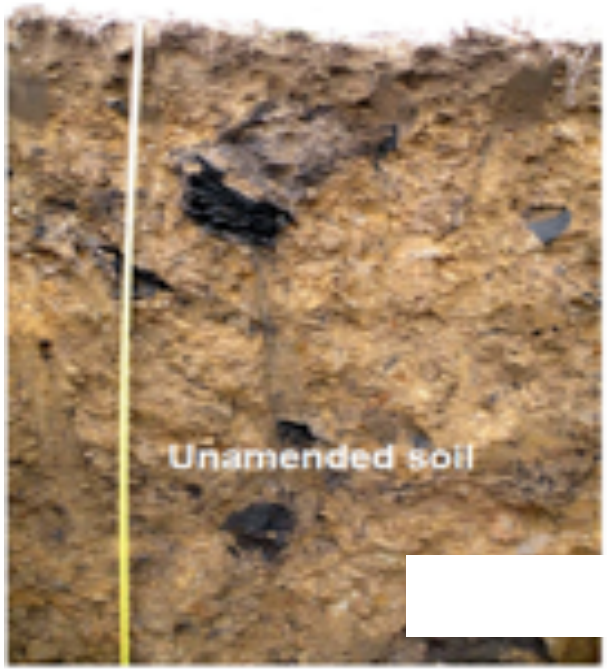
We depend on members!
nebiosolids.org

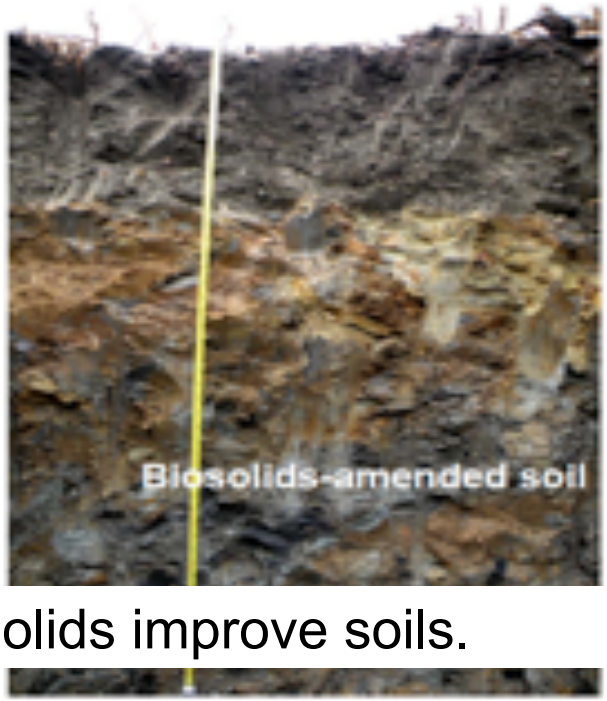


Let me tell you about biosolids!

40+ Years of Research

…has shown the benefits & manageable risks

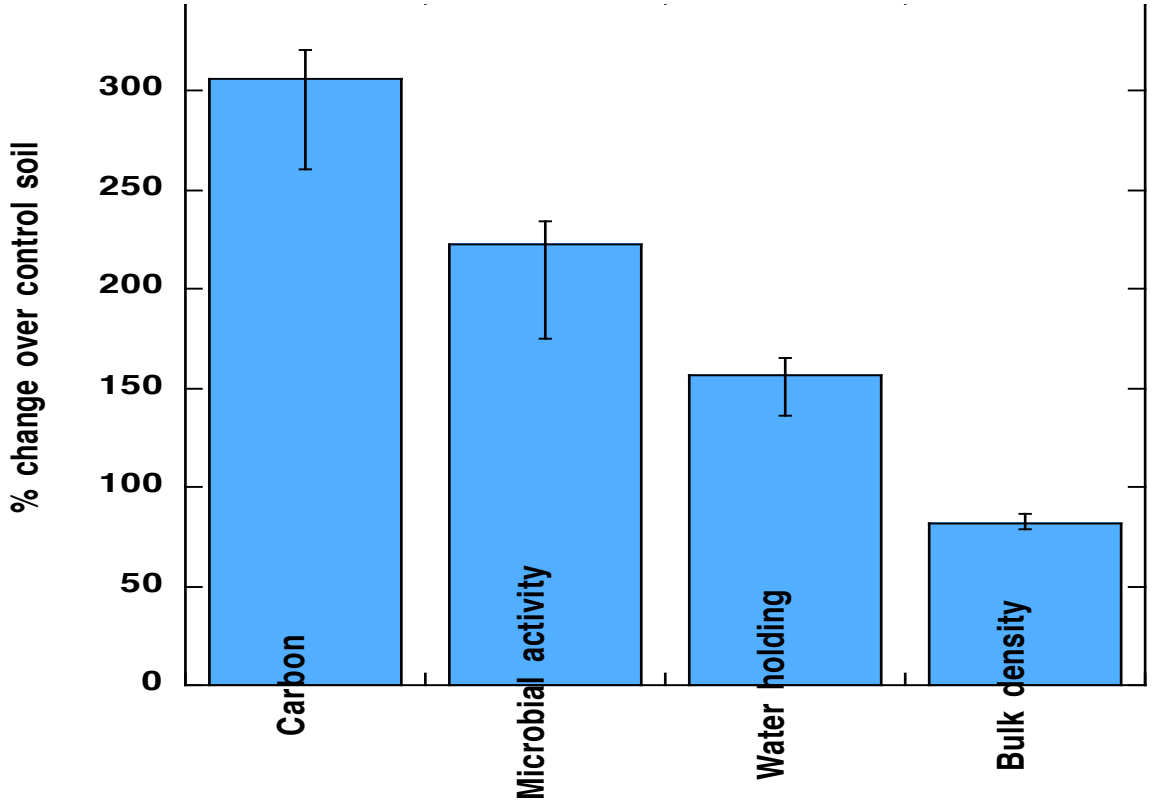




Biosolids improve soils.

Findings: Organic residuals improve soils

Univ. of Washington study, 2011



Numerous studies demonstrate the benefits derived from adding organic matter, such as biosolids, to soils: higher carbon content (carbon sequestration), increased microbial activity, increased water-holding capacity, and lower bulk density (which means easer tillage & handling).

The alternatives?

- Landfill disposal:
  - Fugitive methane (CH4) emissions
  - Loss of nutrients & organic matter & energy
  - Antithetical to zero waste goals
  - Necessary back-up option for WRRFs
- Incineration
  - Loss of nutrients & organic matter
  - Energy balance is marginal at best
  - Currently a critical part of New England's wastewater solids management market

nebra Recycled organics: Tools for sustainability.

Managing BIOSOLIDS & other organic residuals:

What's ideal for sustainability?

MAXIMIZE BENEFICIAL USES OF RESOURCES

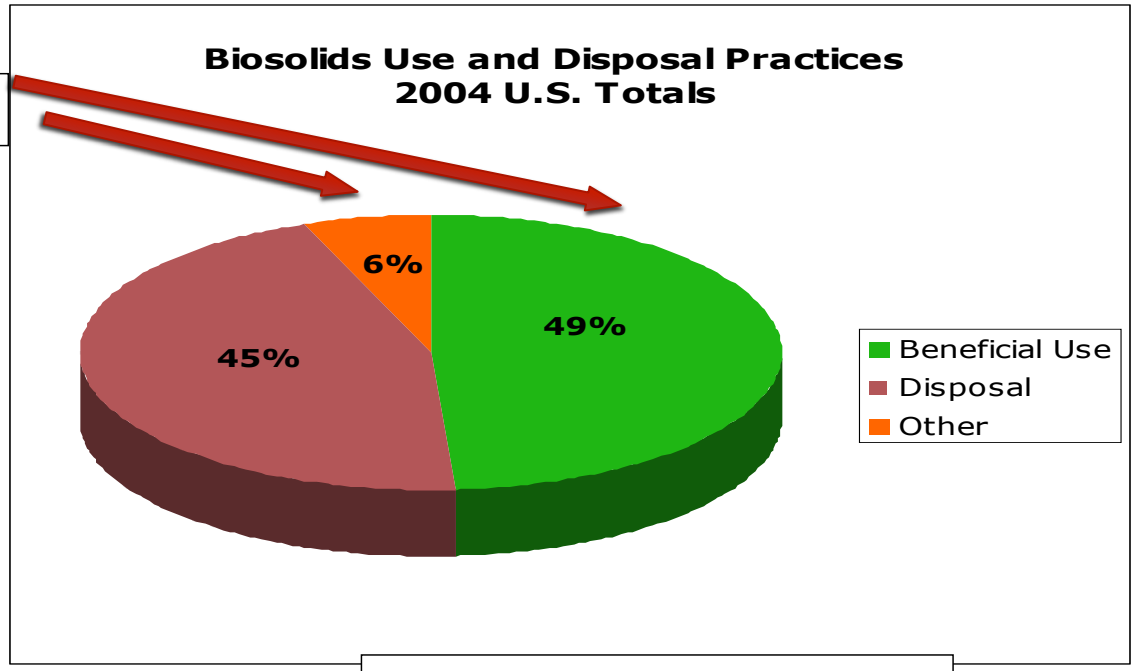
Constituent	Benefits	Concerns
Water	valuable in agriculture in dry times	cost of transport
Organic matter	vital to soils	putrescible, odor
Nutrients	plant & animal food	impacts to water
Energy	renewable, displaces oil/gas	air emissions, no use of nutrients & organic matter if incinerated

MANAGE TO MINIMIZE POTENTIAL RISKS

Reduce/control/mitigate trace elements (e.g. metals), pathogens, synthetic and natural organic chemical compounds, odors, nuisances

Biosolids management in U. S. (2004 data):
7,180,000 dry U. S. tons/year (~35.9 million wet tons)

55% is used on soils



These data need updating…

Biosolids use: Agriculture

Moorhead, MN: Feed corn grown with liquid injected, Class B, anaerobically-digested biosolids, July 2012

- Bulk material markets: animal feed crops (corn, hay), grains (wheat, hops), soy, other commodity crops
- Prices:
  - Class B - $0 - $30 / wet ton
  - Class A – up to $60 / ton
- Trend: increasing demand; waiting lists in some areas

Biosolids use: Forestry

Photos courtesy of King County, WA
http://dnr.metrokc.gov/WTD/biosolids/

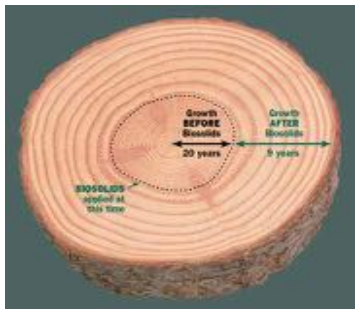
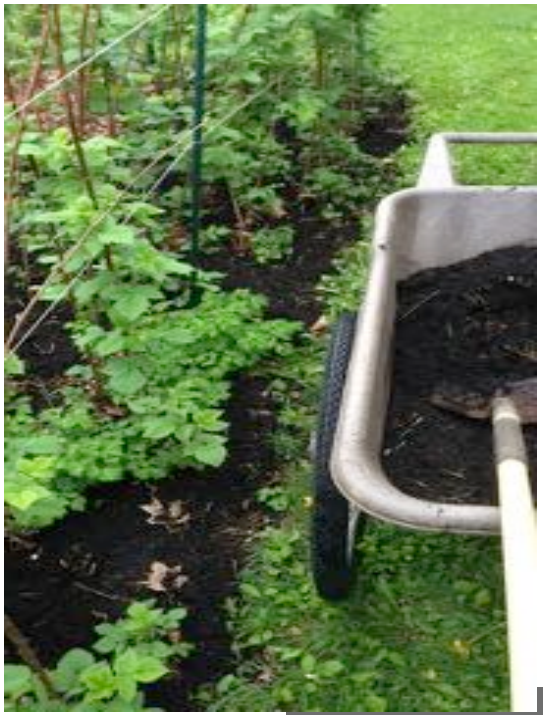


Photo courtesy of Philadelphia Water Dept.

- NW, upper Midwest
- Speeds up harvest cycle in actively managed stands
- Price:
  - Class B $0 - minimal

Biosolids use: Horticulture / Landscaping / Turf

Biosolids compost use on my home garden – raspberries, May 2014



- Class A bulk material markets: potting mixes (e.g. Tagro), golf courses (e.g. Milorganite), parks, lawns, growing turfgrass (e.g. in RI), sports fields (hi-spec turf)
- Prices:
  - Class A bulk – up to $60 / ton
  - Class A bagged/retail – up to $450 / ton
- Trend: increasing demand for quality, consistent products

Horticulture, landscaping: Class A products are 22+% of beneficial use in the U. S.

Bury, Quebec

Maine, 2003

Boston, MA

Columbus, OH

Davenport, IA

nebra Recycled organics: Tools for sustainability.

Making & using biosolids compost

before

after

Biosolids Use: Topsoil Blending

Topsoil blending with paper mill residuals and biosolids, central MA, 2006

- Bulk biosolids given or sold to topsoil blenders
- Prices: vary, often $0
- A way to use less processed material
- Topsoils used for reclamation, landfill cover, highway embankments, construction sites
- Trend: steady use

Reclamation of Disturbed Sites

Spectacle Island in Boston Harbor was reclaimed with biosolids compost and other recycled organics, 2004.

- Bulk material market
- Used to restore healthy soil ecosystem and either native vegetation or cropland
- Prices: vary, often $0
  - Uses a lot of biosolids
- Trend: increasing use, because of huge benefits – biosolids use is best practice for this kind of reclamation

Reclamation of Disturbed Sites

Pennsylvania mine before

Same Pennsylvania mine after

Photos courtesy Bill Toffey, MABA

Biosolids Use:
Landfill Leachate Treatment

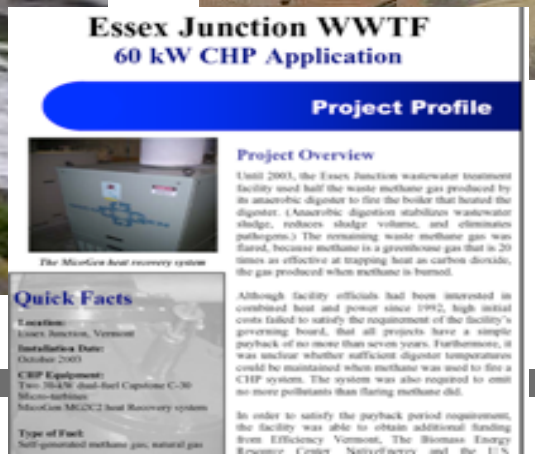
Slide courtesy of Sylvis, Vancouver, BC

Biosolids Use: Energy

Anaerobic digestion (followed by use or disposal)

Greater Lawrence San. Dist., Andover, MA

Nashua, NH



Essex Junction WWTF

60 kW CHP Application

Project Profile

Project Overview

Quick Facts

VT

Recycled organics: Tools for sustainability

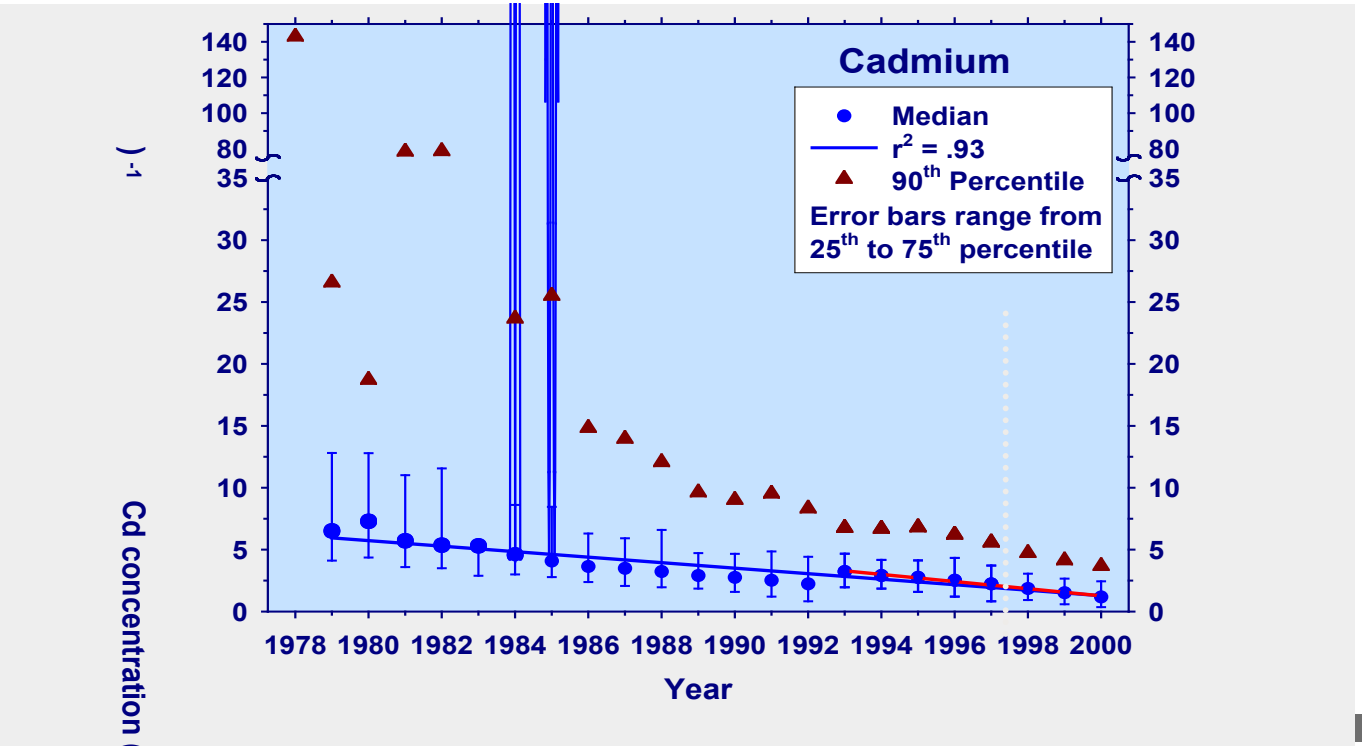
- enhances soil health
- recycles nutrients
- sequesters carbon (mitigating climate change)
- reduces fertilizer & pesticide use (more energy and resources and climate efficient)
- strengthens farm economies (thousands of farmers choose to use biosolids, because they work)
- restores vitality to degraded lands
- puts to productive use residuals that every community has to manage. (Wastewater treatment is a vital public health service, and it creates residual solids that have to be managed!)
- Sustainability & healthy soils require recycling organic residuals.

But what about the heavy metals?
What about the chemicals?

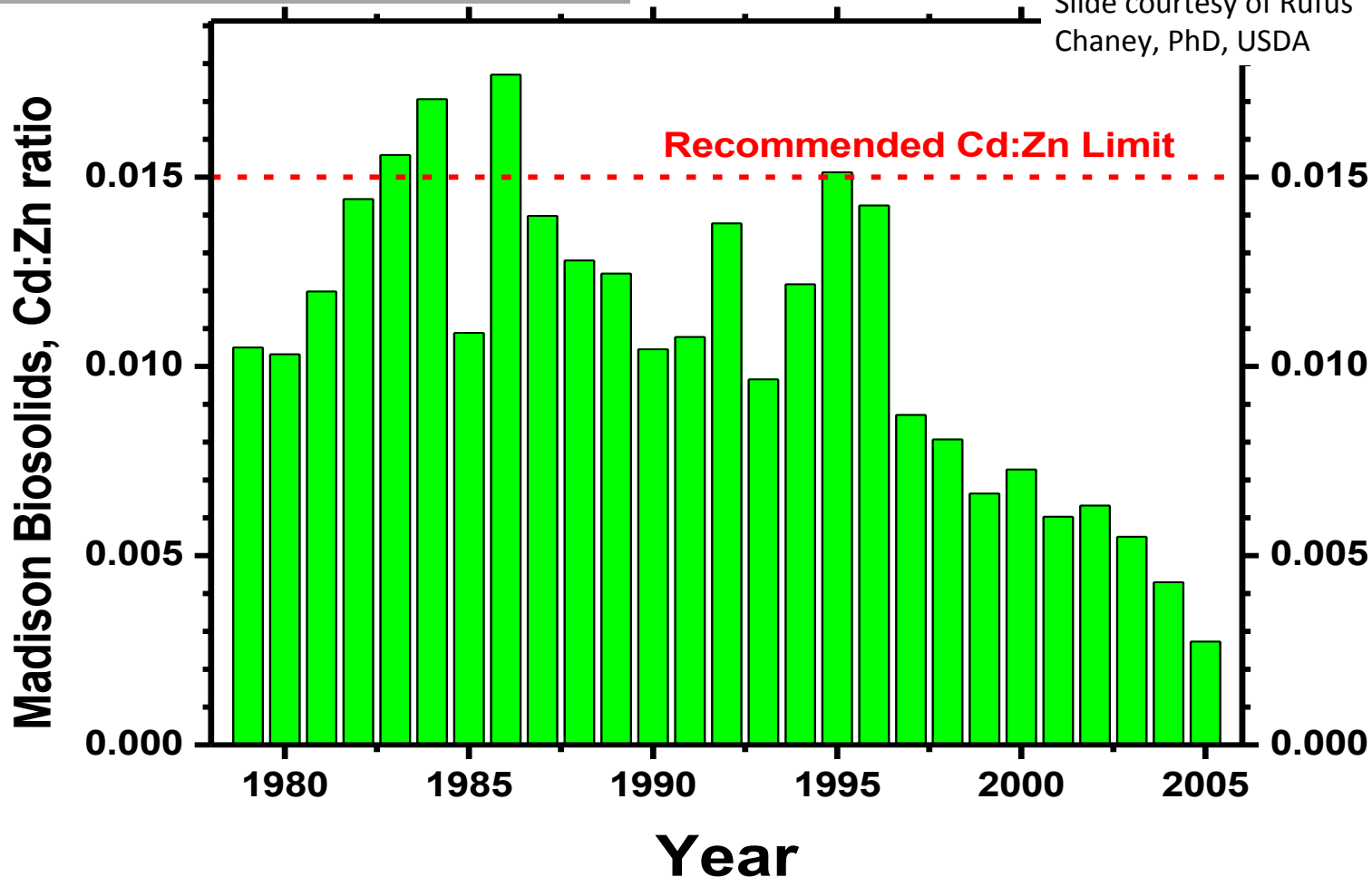
Good questions.

Metals? Pretreatment has worked

Slide courtesy of Richard Stehouwer, PhD, Penn State Univ.



Slide courtesy of Rufus Chaney, PhD, USDA



But how much is little enough?

- "Heavy metals," other elements of concern, chemicals – they are inevitably there in measurable concentrations.
- What levels are acceptable in biosolids applied to soils, so as to not cause harm to human health or the environment?

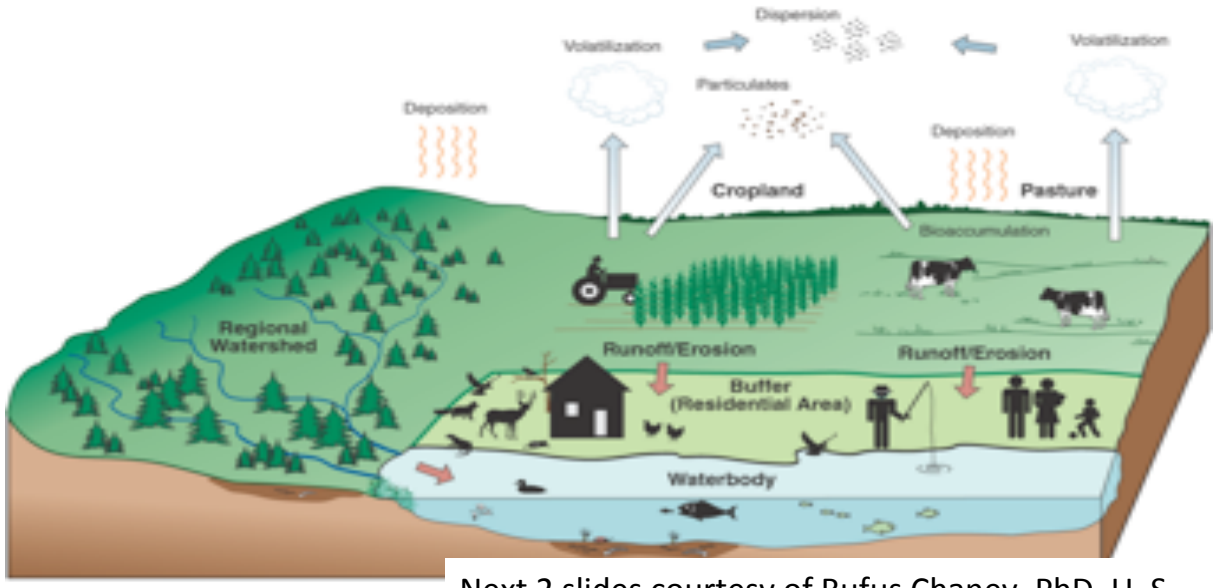
Federal Part 503 Regulations - 1993

- 40 CFR Part 503 defined acceptable levels of 9 (10) metals
- Based on risk assessment
- Require biosolids applications according to agronomic needs, which reduces total mass of contaminants
- Based on the principal of absorptive capacity of the soil.
- Research & review continue under 503, but the basics are sound.

Risk Assessment

EPA Risk Assessment for Part 503:
Exposure Pathways Assessed
Agricultural Land Application Scenario to Assess Human Exposure

The presence of a contaminant in biosolids does not mean there is risk; its fate and impact on humans and the environment must be evaluated.



Next 2 slides courtesy of Rufus Chaney, PhD, U. S. Dept. of Agriculture.

Pathways for Risk Assessment of Elements in Soils, and Highly Exposed Individuals-1.

Pathway	Highly Exposed Individual
1. Soil➔Plant➔Human	Farm markets; 2.5% of food
2. Soil➔Plant➔Human	Home gardens; 60% of garden foods for lifetime; 1000 t/ha
3. Soil➔Human	200 mg/day soil/dust ingestion; 1000 t/ha
4. Sol ➔Plant➔Animal➔Human	Farms; 45% home-grown meat; 1000 t/ha
5. Soil➔Animal➔Human	Grazing ruminants; soil is 2.5% of annual diet; 45% home-grown meat.
6. Soil➔Plant➔Livestock	100% of livestock feeds grown on soils; 1000 t/ha
7. Soil➔Livestock	Grazing ruminants; 2.5% soil in diet.

Pathways for Risk Assessment of Elements in Soils and Highly Exposed Individuals-2.

Pathway	Highly Exposed Individual
8. Soil➔Plant	Sensitive crops; strongly acidic; 1000 t/ha
9. Soil➔Soil Biota	Earthworms; microbes; metabolic function of soil; 1000 t/ha
10. Soil Biota➔Soil Biota Predator	Shrews; 1/3 of diet presumed to be earthworms full of soil; 1000 t/ha
11. Soil➔Airborne Dust➔Human	Tractor operator; 1000 t/ha
12. Soil➔Surface water➔Human	Subsistence fishers.
13. Soil➔Air➔Human	Farm households
14. Soil➔groundwater➔Human	Well water on farms.

Perspective on metals land applied

Moss et al., 2002, WERF

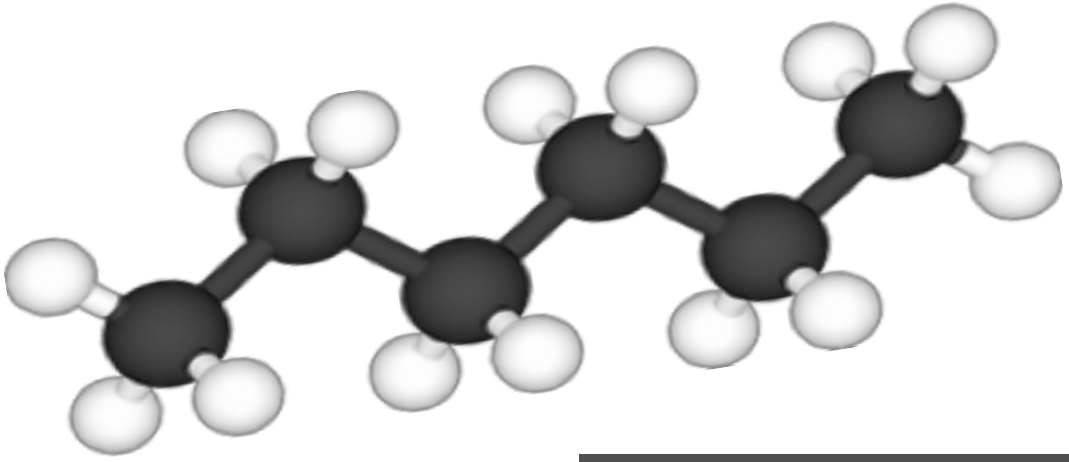
Table 5
Estimated Total Metals Applied to Land From Various Products
Apparent Metals (tons/year)[1]

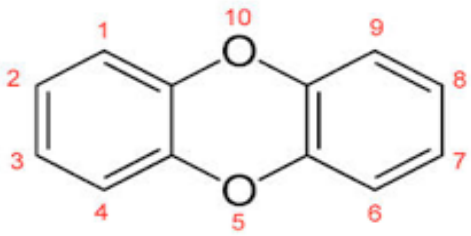
Metal	Biosolids [2]	Swine Manure [3]	Poultry Manure [4]	Phosphate Fertilizer [5]
Arsenic	14.2	33.3	189	49.7
Cadmium	12.59	22.5	33	286
Chromium	168	NA	NA	751
Copper	1,352	2,145	6,143	249
Lead	215	68.4	867	53.7
Mercury	5.07	NA	NA	0.3
Molybdenum	34.2	NA	NA	NA
Nickel	94.1	264	NA	121
Selenium	10.89	NA	NA	NA
Zinc	2,081	4,995	6,729	1,057

Notes

Pretreatment helps POTWs meet 503.

- Part 503 includes 2 tiers of metals standards.
- Almost all current biosolids in the U. S. meet the higher quality “EQ” standard (lower metals)
- New England states have even lower numerical standards for metals.
- Today’s biosolids are clean enough for widespread use – thanks to pretreatment & source control.





And the chemicals?

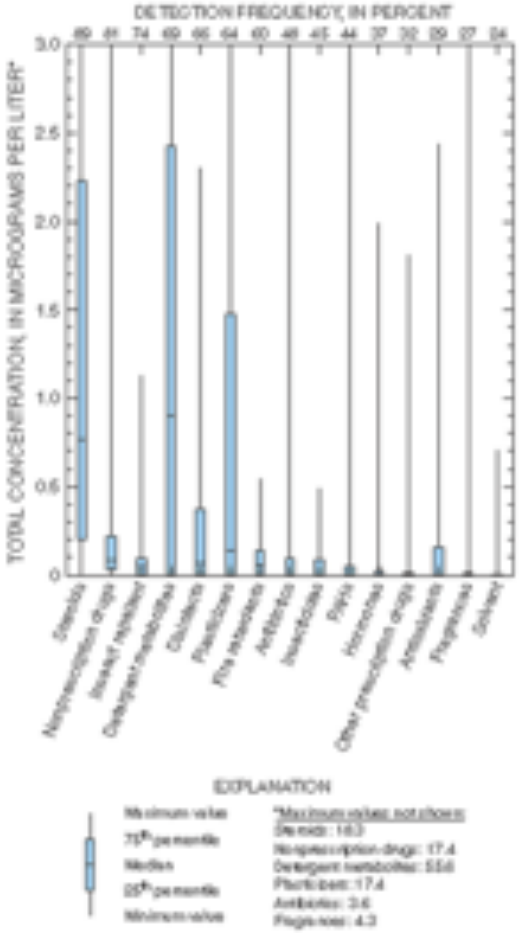
…antibiotics to pharmaceuticals to dibenzo-p-dioxins (CECs, TOrCs,PPCPs, Eds)

USGS stream work

Household chemicals can enter streams through wastewater discharges. A wastewater treatment facility near Atlanta, Georgia, is shown above. (Photograph by Daniel J. Hippe, U.S. Geological Survey)

Buxton & Kolpin, 2002, https://toxics.usgs.gov/pubs/FS-027-02/

Veterinary pharmaceuticals used in animal agriculture can enter streams through runoff or infiltration. A swine facility near the South Fork Iowa River, Iowa, is shown above. (Photograph by Doug Schnoebelen, U.S. Geological Survey)



Steroids, nonprescription drugs, and an insect repellent were the three chemical groups most commonly detected in susceptible streams. Detergent metabolites, steroids, and plasticizers generally were found at the highest concentrations.

Aquatic vs. terrestrial: different fate, transport, & impacts

"Assessment and minimization of the risks of exposure to complex chemical mixtures in the environment are priorities for human and environmental health organizations. The current lack of information on the composition and variability of environmental mixtures and a limited understanding of the potential combined effects of exposure to chemical mixtures are fundamental obstacles to timely identification the real versus perceived risks to humans and other organisms exposed to chemical mixtures."

–USGS Toxic Substances Hydrology Program (https://toxics.usgs.gov/investigations/chem_mix/index.php)

Concentrations of TOrCs in biosolids

Clark and Smith, 2010

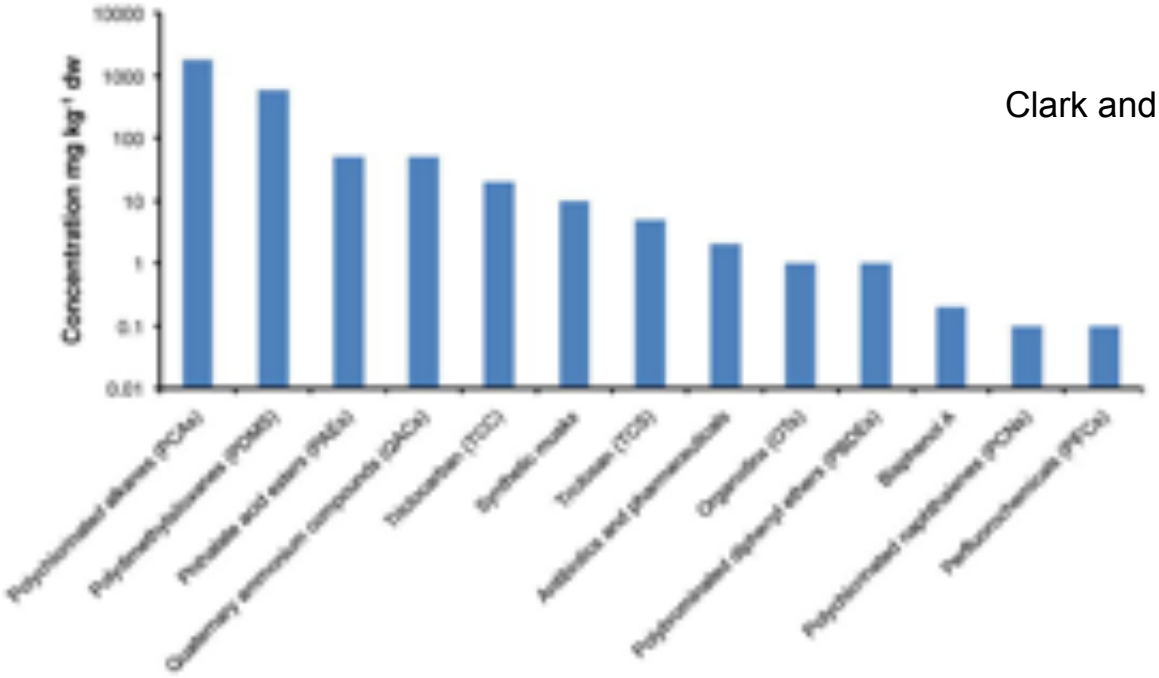


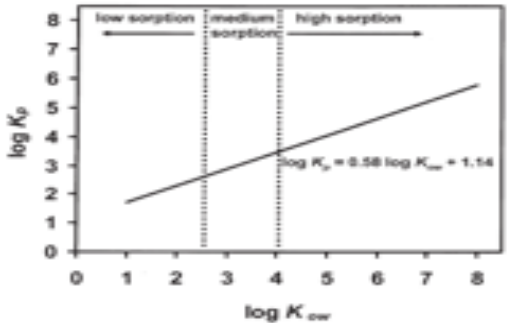
Fig. 1. Typical concentrations of selected 'emerging' organic contaminants in sewage sludge (mg kg⁻¹ dw).

What does it mean?

Chemicals of greatest concern in biosolids have…

- High log K_{ow} - octanol-water partition coefficient
- High toxicity (to some species)
- Long half-lives (persistent)
- Bioaccumulative
- Dioxins/furans are excellent example: thoroughly studied and not found to require regulation (EPA, 2003) PFAS? That's another question…

Xia et al. 2005



Far greater concerns and impacts are in the WRRF effluent and receiving aquatic environment.

Think carefully of exposure pathways & risk.

Remember:

1 ppm = 1 second in 11.6 days

1 ppb = 1 second in 31.7 years

1 ppt = 1 second in 31,700 years

Healthy, microbially-active soils are the best medium for treatment of traces of organic chemicals.

Significant impacts to biota have been measured in aquatic environments, but not in biosolids-amended soils.

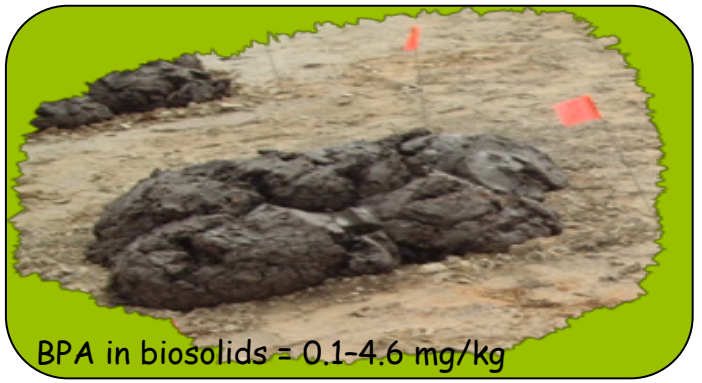
Risk to human health through biosolids-application-to-soil pathways appear to be negligible. Far greater human exposure to most are through daily use of products.

Source reduction should focus on persistent compounds with known or potential toxicity.

BPA – Bisphenol A

Save your credit card receipts?

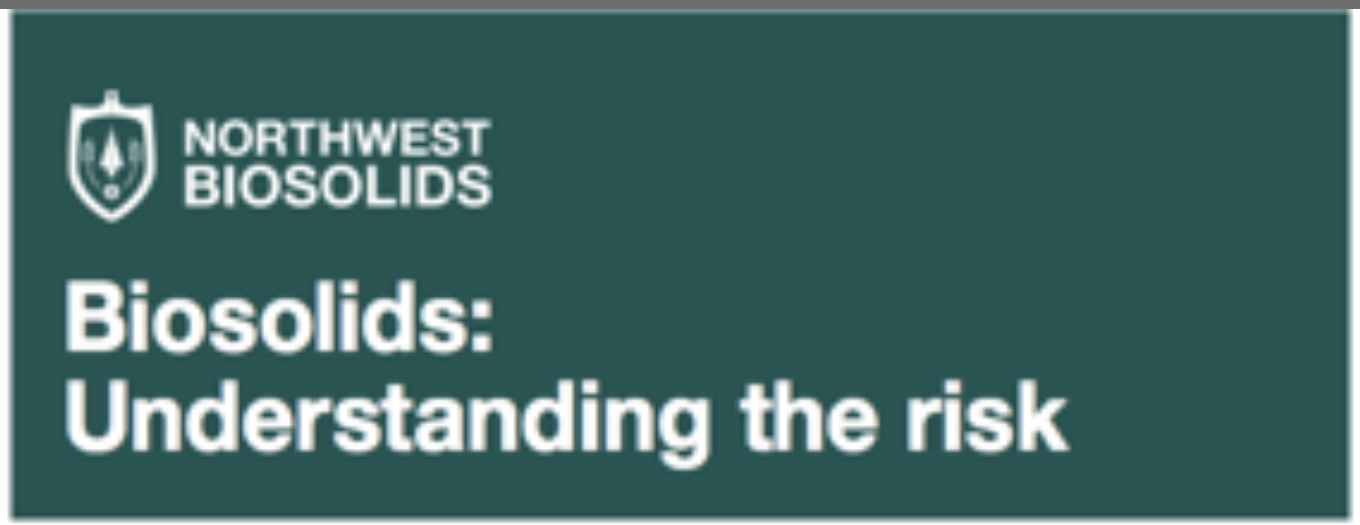
BPA in credit card receipts = 8-17 g/kg



- **How much more concentrated is BPA in these receipts than in biosolids?**

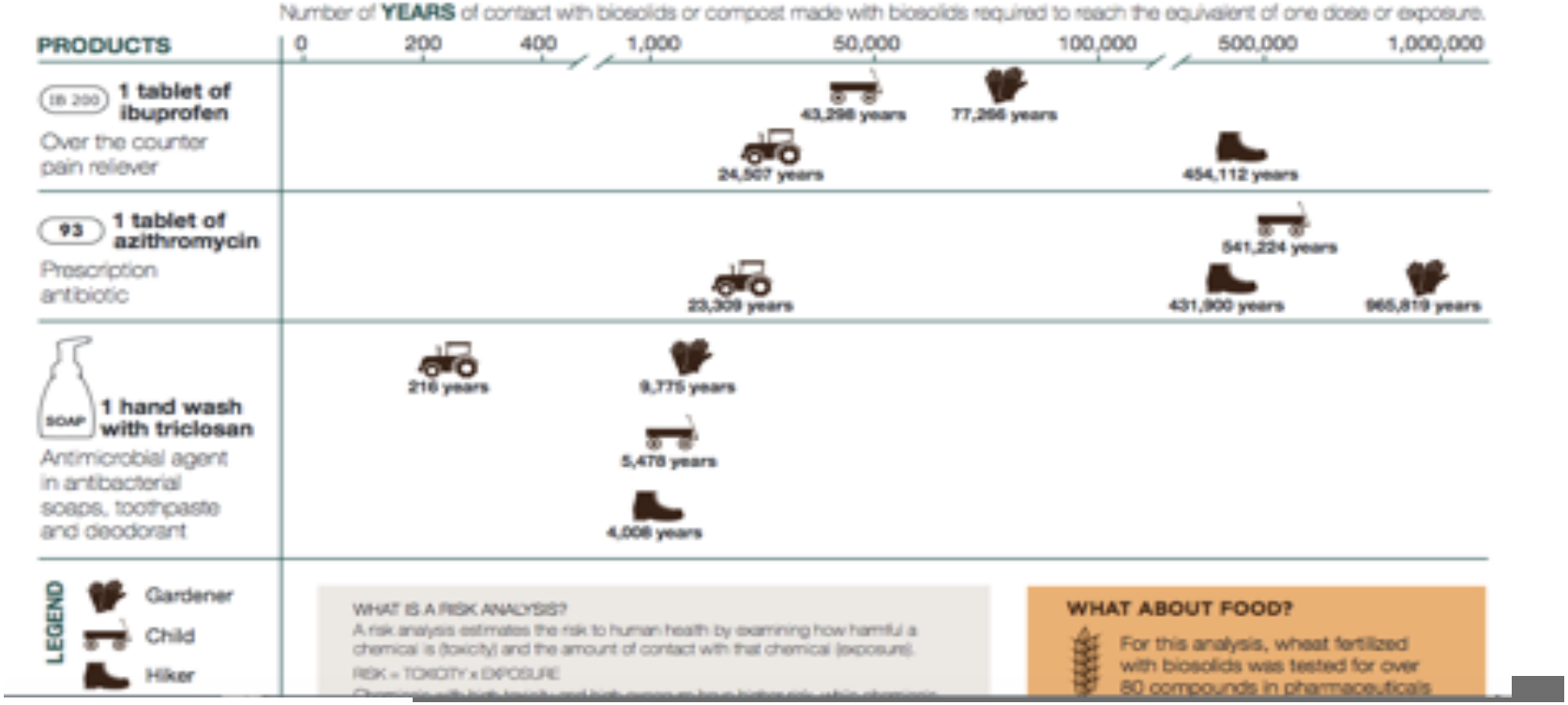
a) Equal b) 400x c) **4000x**

Modified from Sally Brown, PhD, Univ. of WA



http://www.nwbiosolids.org/EventPubs/NWbiosolids_RISKbrochure.pdf

Number of years of contact = 1 dose



nebiosolids.org

From NW Biosolids fact sheet

Biosolids & soils: Remarkable media for managing CECs!

Q: Where do we want to put CECs?
(We can't remove every bit from wastewater.)

A: Get them into the solids…and into soils…

…because healthy soils (e.g. enriched with biosolids and/or other organic amendments) are the best media for degrading most TOrCs.

"These terrestrial systems have orders of magnitude greater microbial capability and residence time to achieve decomposition and assimilation compared with aquatic systems."

– Overcash, Sims, Sims, and Neiman, 2005

Best management to address TOrCs

Focus on biosolids quality.

Source reduction works. Enforce industrial pretreatment. Support phase-outs of persistent CECs.

Year	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
1973	33	712	700	1,261	148	2,031
1983	12.5	360	361	421	79	1,701
1993	7.3	209	764	225	51	1,444
2000	4.2	115	566	178	53	1,619

Philadelphia Water District biosolids quality over time, courtesy of Bill Toffey.

Today's CEC of concern: PFAS

Introduce yourself to one person you are sitting next to.

Everyone now have an identified neighbor?

You two live on the same street in Hyannis, Mass (on Cape Cod). You both are reading the news at the same time… As we go, track *your own* reaction?

Friday news…

Your reactions?

Flint, Michigan is no longer the only American city synonymous with contaminated drinking water. Recent reports show there are Flints in nearly every state. The cities and contaminants change, but the unease remains.

Cape Cod, with its quaint harbors and salty breezes, is more closely associated with Camelot than contaminants. But the sickness escape has been gripped for decades by instances of seemingly unexplainable illnesses.

Within a span of three months, the U.S. government released two reports that called into question the safety of America's drinking water.

In March 2018, the Department of Defense (DoD) provided a full list of military installations that have water near or around them that contain harmful levels of per- and polyfluoroalkyl substances or PFAS.

Dubbed "forever chemicals," these man-made substances like plastic do not break down. They accumulate over time in the environment and some can linger in the human body for years.

PFAS can be found in the most mundane household products from nonstick cookware to microwave popcorn bags to dental floss. The chemicals are also one of the main

How are you *feeling* about this topic?

What associations are you seeing?

The PFAS chemicals seep into soil and groundwater, contaminating them. A Centers for Disease Control and Prevention (CDC) sanctioned study found PFAS in 98 percent of the American population.

In June 2018, the Agency for Toxic Substances and Disease Registry (ATSDR) released a report the White House deemed a "public relations nightmare." That report linked PFAS to various cancers, thyroid defects and pregnancy complications at levels lower than the EPA's drinking water health advisory.

An internal White House email is quoted as saying, "The public, media, and Congressional reaction to these numbers is going to be huge. The impact to EPA and [the Defense Department] is going to be extremely painful. We (DoD and EPA) cannot seem to get ATSDR to realize the potential public relations nightmare this is going to be."

However, long before Washington's so-called "nightmare," the specter of bad water brewed doubt in a popular coastal retreat.

"Higher Rates of Disease Trouble West Cape Cod" is a [illegible]azing headline from a 1986 edition of the New York Times. According to the article, a Massachusetts Department of Public Health study revealed that from 1979 to 1983, residents living in towns surrounding Otis Air National Guard Base and Camp Edwards Military Reservation—both considered parts of the current Joint Base Cape Cod—died of cancer at higher rates than other parts of the Cape or Massachusetts.

Families in two of those towns, Falmouth and Mashpee, were advised not to drink water from private wells as government evidence proved those wells contained carcinogenic

How are you *feeling* about this topic?

Are you relating the information to your own experiences or other events you've heard about?

THE CAPE'S PFAS PROBLEM

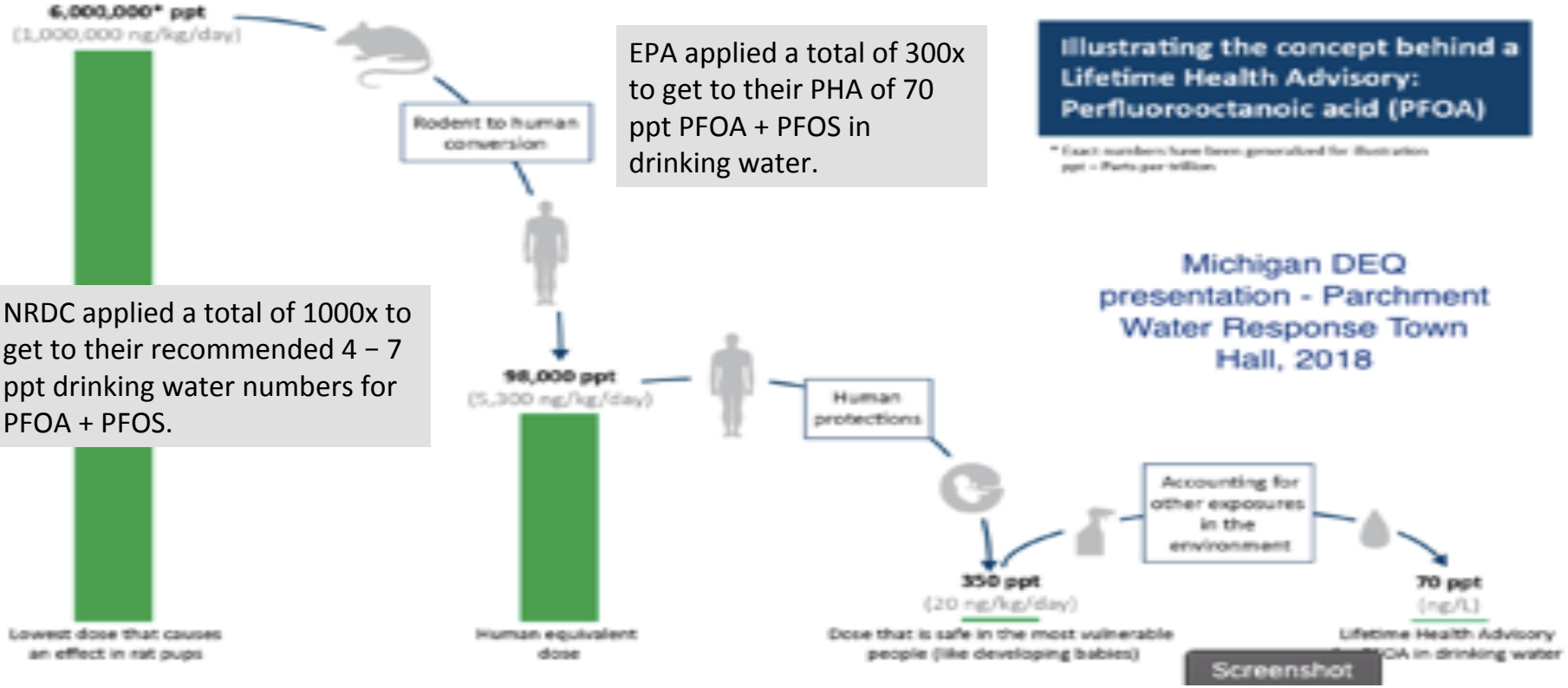
> **"I don't want people in my home drinking flame retardant that we know is carcinogenic."**
>
> — Robert F. Kennedy, Jr.

"It's like living in a science fiction nightmare," said Robert F. Kennedy, Jr. "In my own home I haven't been able to drink the water for a couple of years. I have to tell my kids not to drink the tap water—they're being raised on bottled water." Longtime Cape resident and president of the environmental organization Waterkeeper Alliance, Kennedy says people on the Cape are frightened.

Uncertainty factors applied

EPA applied a total of 300x to get to their PHA of 70 ppt PFOA + PFOS in drinking water.

NRDC applied a total of 1000x to get to their recommended 4 – 7 ppt drinking water numbers for PFOA + PFOS.



> **"A heavy burden falls on communities like Hyannis that have already been exposed to PFAS for decades already."**
>
> — Sue Phelan, GreenCape director

The EPA estimates the PFAS class to be made up of 5,000 chemicals. Phelan believes regulating each chemical individually will only prolong exposure.

"A heavy burden falls on communities like Hyannis that have already been exposed to PFAS for decades already," said Phelan.

"AFFF [firefighting] foams contain possibly up to 40 different PFASs and that is the source of contamination in my community," said Phelan.

How are you *feeling* now, and how is it different from when we started the article?

> **"We are sick. We need help."**
>
> — Kristen Mello, Westfield, Massachusetts resident

"In May 2016, the EPA set a health advisory of 70 ppt for PFOA and PFOS in drinking water. That advisory was much lower than the provisional combined level of 600 ppt. But EPA health advisories are not enforceable. However, water supplies like Hyannis fell out of compliance under this new recommendation. In June 2018, MassDEP issued a similar public health guideline of 70 ppt for 5 of the roughly 5000 PFAS chemicals. Many attendees of the meeting expressed hope that MassDEP will establish a Maximum Contaminant Level (MCL) of 1 part per trillion (ppt) for the entire PFAS class of chemicals."

Are you *thinking* about this?

Dan Santos is director of public works for the town of Barnstable. Hyannis is a village within Barnstable and as such, Santos is responsible for its water supply. He agrees that a Maximum Contaminant Level (MCL) should be instituted for PFAS when suitable. However, he sees a problem with regulators suddenly lowering the admissible standard.

"With the level so low and with the ubiquitous nature of PFASs in our environment I'm not sure there's any water supply that's not going to have PFAS in it," said Santos.

The widespread use of these chemicals in the United States since the 1940s has led to their discovery in more than 98 percent of Americans, according to the EPA and the National Center for Biotechnology Information (NCBI).

Santos is concerned that a dramatic reduction in what is considered acceptable could force him to shut off the water—again.

In 2016, Santos had to make a quick decision. When the EPA issued its dramatically lower PFAS health advisory, the Hyannis water system was out of compliance for the advisable limit of PFAS chemicals in its drinking water. Santos had to decide whether to keep the water running. Since the EPA's health advisory is not enforceable, Barnstable would have been within its rights to maintain water use. As a precaution, Santos chose to shut off wells. This is a situation he would like to avoid.

This is the last sixth of the article.

Journalists are supposed to provide more than one perspective. Does this article do that?

The ending paragraphs:

"When it comes to Massachusetts as a whole, residents are waiting to see if state officials will decide to regulate PFAS as one class of chemicals.

"MassDEP expects to respond to petitioners by January 28, 2019."

Appropriate risk communications raise public concern to an appropriate level, so people take the appropriate actions to reduce risk.

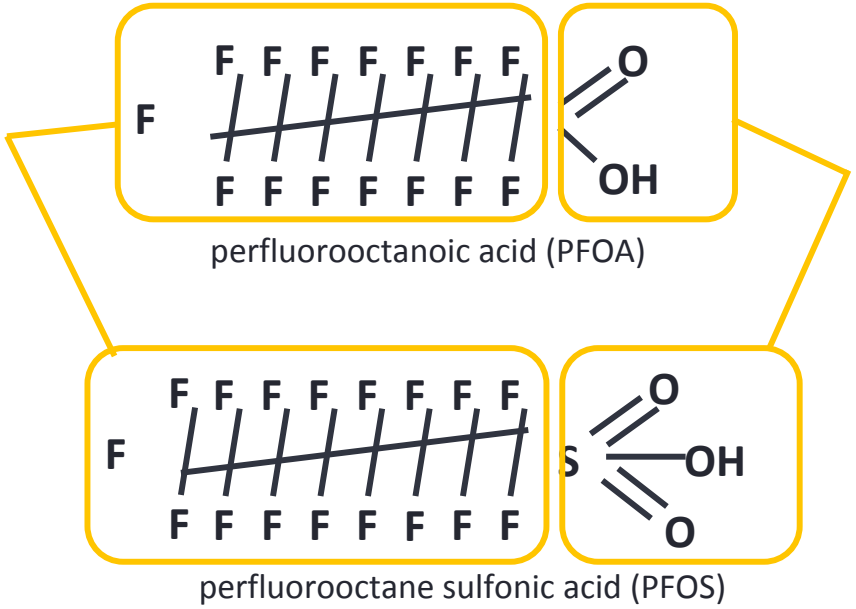
Does this article do that?

Turn to your identified neighbor.
How does he / she feel about this, in comparison to you?
(Take 3 minutes to discuss.)

PFAS – The Basics

PFAS = Per- and Poly- Fluorinated Alkylated (Fluoroalkyl) Substances
includes the subset of PFCs – Perfluorinated Compounds (but PFAS is a better term)

Fluorocarbon tail
- Strong bonds
- Hydrophobic
- Oleophobic
- Varying length



Functional group
- Strong to weak acids
- Hydrophilic

Also Note:
Precursors
& Substitutes –
Gen-X, Adona, et al.

More than 3,000 PFAS compounds identified

Slide courtesy Steve Zemba, Sanborn Head

PFAS – The Basics

- Water soluble, hydrophobic, lipophobic, bind to proteins
- Persistent – C8 and lower versions do not degrade
- Not volatile, resists photolysis & hydrolysis
- Transport pathways: air deposition, leaching & groundwater, surface water
- Human exposure through drinking water (focus), food & food packaging, indoor dust & product exposure, use of consumer products
- Sorption & solubility differences
- 3000+ varieties, co-contaminants
- Destroyed at ~1000° C
- No natural counterparts

https://fluorocouncil.com/

Major sources of PFAS in the environment:

Cottage Grove, MN

Parkersburg, WV

EPA reaches new C8 deal with DuPont

on January 16, 2017 at 4:54 pm

The Washington Works DuPont plant in Parkersburg, West Virginia, on Wednesday, August 5, 2015. Photo: Maddie McGarvey for The Intercept/Investigative Fund

PARKERSBURG, WV — "Less than two weeks before the Obama administration leaves office, the U.S. Environmental Protection Agency on Monday said it had reached a new agreement with DuPont Co. regarding pollution of drinking water in the Mid-Ohio Valley with the toxic chemical C8 from the company's manufacturing plant near Parkersburg.

EPA said in a news release that it had amended its 2009 agreement with DuPont to reflect a lower level of C8 exposure recommended in an EPA health advisory issued last year. While more protective than the previous agreement with DuPont, the new number would allow larger

LAWSUITS CHARGE THAT 3M KN ABOUT THE DANGERS OF ITS CH

Sharon Lerner

FOR DECADES, 3M was the primary producer of C8, or PFOA, and was the sole producer of a related chemical known as PFOS. But while DuPont was caught up in a massive class-action suit over C8, 3M has largely avoided public scrutiny and serious legal or financial consequences for its role in developing and selling these industrial pollutants.

In February, however, a state court in Minnesota, where the company is headquartered, allowed a lawsuit against 3M to move forward. And late last year, lawyers filed a class-action suit in Decatur, Alabama, home to one of 3M's biggest plants. Both lawsuits charge that 3M knew about the health hazards posed by the perfluorinated chemicals it was manufacturing and using to make carpet coating, Scotchgard, firefighting foam, and other products — and that the company knew the chemicals were spreading beyond its sites. With PFCs cropping up in drinking water around the country and all over the world, the two lawsuits raise the possibility that 3M may finally be held accountable in a court of law.

State Attorney General Lori Swanson first filed the lawsuit against 3M on behalf of the people of Minnesota in 2010, claiming that the company polluted more than 100 square miles of groundwater near its plant in Cottage Grove, Minnesota, as well as four aquifers serving as drinking water for some 125,000 people in the Twin Cities. The suit charges that the company piped PFC-polluted wastewater into a stream that flows into the Mississippi River and disposed of it on land near the river, which allowed it to leach into the river.

Based on the company's own research, the complaint argues, 3M "knew or should have known" that PFCs harm human health and the environme Flip P that the chemicals would leach from their disposal sit

Major source of PFAS in the environment: AFFF

Pease AFB, NH

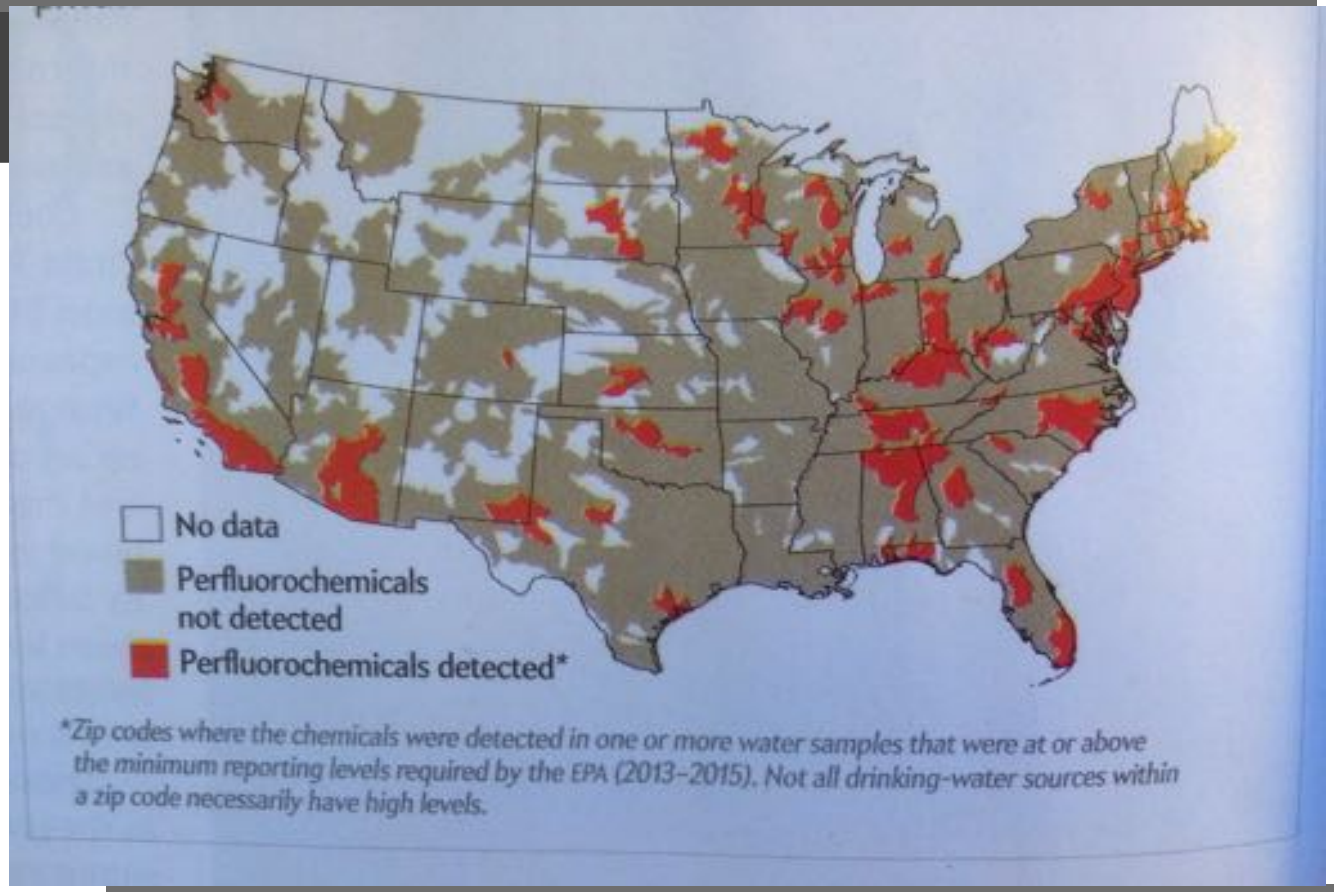
https://www.youtube.com/watch?v=8W_zJfJGhSI&feature=youtu.be

Composts, digestates, biosolids, & residuals mirror modern life.

- If they contain any feedstocks from society, they contain PFAS from our modern environments. We know this now, because of advances in analytical chemistry.

nebiosolids.org

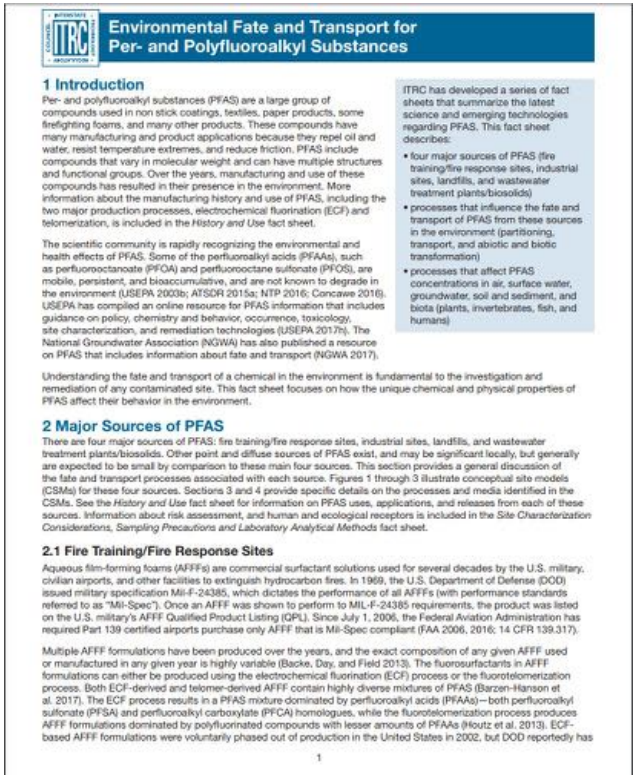
Known U. S. PFAS hot spots, 2016. More found since.



Interstate Technology Regulatory Council's (ITRC) fact sheets

Helpful resources

http://pfas-1.itrcweb.org/



ITRC

Environmental Fate and Transport for Per- and Polyfluoroalkyl Substances

1 Introduction

Per- and polyfluoroalkyl substances (PFAS) are a large group of compounds used in non stick coatings, textiles, paper products, some firefighting foams, and many other products. These compounds have many manufacturing and product applications because they repel oil and water, resist temperature extremes, and reduce friction. PFAS include compounds that vary in molecular weight and can have multiple structures and functional groups. Over the years, manufacturing and use of these compounds has resulted in their presence in the environment. More information about the manufacturing history and use of PFAS, including the two major production processes, electrochemical fluorination (ECF) and telomerization, is included in the *History and Use* fact sheet.

The scientific community is rapidly recognizing the environmental and health effects of PFAS. Some of the perfluoroalkyl acids (PFAAs), such as perfluorooctanoate (PFOA) and perfluorooctane sulfonate (PFOS), are mobile, persistent, and bioaccumulative, and are not known to degrade in the environment (USEPA 2003b; ATSDR 2015a; NTP 2016; Concawe 2016). USEPA has compiled an online resource for PFAS information that includes guidance on policy, chemistry and behavior, occurrence, toxicology, site characterization, and remediation technologies (USEPA 2017h). The National Groundwater Association (NGWA) has also published a resource on PFAS that includes information about fate and transport (NGWA 2017).

ITRC has developed a series of fact sheets that summarize the latest science and emerging technologies regarding PFAS. This fact sheet describes:

- four major sources of PFAS (fire training/fire response sites, industrial sites, landfills, and wastewater treatment plants/biosolids)
- processes that influence the fate and transport of PFAS from these sources in the environment (partitioning, transport, and abiotic and biotic transformation)
- processes that affect PFAS concentrations in air, surface water, groundwater, soil and sediment, and biota (plants, invertebrates, fish, and humans)

Understanding the fate and transport of a chemical in the environment is fundamental to the investigation and remediation of any contaminated site. This fact sheet focuses on how the unique chemical and physical properties of PFAS affect their behavior in the environment.

2 Major Sources of PFAS

There are four major sources of PFAS: fire training/fire response sites, industrial sites, landfills, and wastewater treatment plants/biosolids. Other point and diffuse sources of PFAS exist, and may be significant locally, but generally are expected to be small by comparison to these main four sources. This section provides a general discussion of the fate and transport processes associated with each source. Figures 1 through 3 illustrate conceptual site models (CSMs) for these four sources. Sections 3 and 4 provide specific details on the processes and media identified in the CSMs. See the *History and Use* fact sheet for information on PFAS uses, applications, and releases from each of these sources. Information about risk assessment, and human and ecological receptors is included in the *Site Characterization Considerations, Sampling Precautions and Laboratory Analytical Methods* fact sheet.

2.1 Fire Training/Fire Response Sites

Aqueous film-forming foams (AFFFs) are commercial surfactant solutions used for several decades by the U.S. military, civilian airports, and other facilities to extinguish hydrocarbon fires. In 1969, the U.S. Department of Defense (DOD) issued military specification Mil-F-24385, which dictates the performance of all AFFFs (with performance standards referred to as "Mil-Spec"). Once an AFFF was shown to perform to MIL-F-24385 requirements, the product was listed on the U.S. military's AFFF Qualified Product Listing (QPL). Since July 1, 2006, the Federal Aviation Administration has required Part 139 certified airports purchase only AFFF that is Mil-Spec compliant (FAA 2006, 2016; 14 CFR 139.317).

Multiple AFFF formulations have been produced over the years, and the exact composition of any given AFFF used or manufactured in any given year is highly variable (Backe, Day, and Field 2013). The fluorosurfactants in AFFF formulations can either be produced using the electrochemical fluorination (ECF) process or the fluorotelomerization process. Both ECF-derived and telomer-derived AFFF contain highly diverse mixtures of PFAS (Barzen-Hanson et al. 2017). The ECF process results in a PFAS mixture dominated by perfluoroalkyl acids (PFAAs)—both perfluoroalkyl sulfonate (PFSA) and perfluoroalkyl carboxylate (PFCA) homologues, while the fluorotelomerization process produces AFFF formulations dominated by polyfluorinated compounds with lesser amounts of PFAAs (Houtz et al. 2013). ECF-based AFFF formulations were voluntarily phased out of production in the United States in 2002, but DOD reportedly has

1

PFAS and Recycling: Putting Them in Perspective

A NEBRA Fact Sheet • March 22, 2018
Find out more: https://www.nebiosolids.org or call 603-323-7654

North East Biosolids & Residuals Association

Recycling organic "wastes" benefits society and the environment. Throughout the U. S. and Canada, biosolids[1] (treated wastewater solids), paper mill residuals, composts, and other organic residuals are commonly recycled to soils. This recycling does amazing things. It enhances soil health, recycles nutrients, sequesters carbon, reduces fertilizer & pesticide use, strengthens farm economies, restores vitality to degraded lands, and puts to productive use residuals that every community has to manage. (Wastewater treatment is a vital public health service, and it creates residual solids that have to be managed!) Sustainability & healthy soils require recycling organic residuals. Properly treated and tested, they are not "wastes."

Biosolids & residuals - like animal manures - are recycled on farms, building healthy soils.

Trace PFAS are in biosolids, paper mill residuals

Of course they are, because these materials reflect t

PFAS are a family of chemical compounds co
encounter in our daily lives, which is
trace amounts (parts per bil
They are also som
two most

up in
er residuals.
less precise term). The
recently gained attention
g water by industries, including at
Merrimack and Pease Tradeport, NH. Other
sulted from the use of PFAS-containing aqueous film-
firefighting, especially at military sites and airports. Because of
nd throughout the world, including in the most remote environments.
Biosolids and other residuals are not *sources* of PFAS; they convey them. In the
ot industrially-impacted) in concentrations of tens to hundreds of parts per billion (ppb).
st biosolids show significantly lower levels (Figure 1), likely due to the phase-out of PFOA and PFOS
data show no evidence that routine recycling of modern biosolids and residuals leads to groundwater impacts
n the U. S. EPA health advisory level[2].

their extensiv
However,
2000s, PFA
Recent test
over the pas
at levels grea

Download at:
https://www.nebiosolids.org/nebra-publications

[1] About biosolids

Biosolids have been widely used on farms and other lands across North America for decades. Sixty percent (60%) of U. S. wastewater solids are applied to soils. Seattle, San Francisco, Los Angeles, Denver, Chicago, Boston, Concord, Augusta, Burlington, and hundreds of other communities recycle their biosolids. Many major land grant universities have studied biosolids use on soils and accept the practice, finding little risk when used according to regulations. Every U. S. state and Canadian province regulates and allows biosolids use on soils. U. S. EPA, USDA, and U. S. FDA all support biosolids recycling. Thousands of research publications over 45+ years and two major reviews by the National Academy of Sciences have found biosolids use on soils presents "negligible risk" and that "there is no documented scientific evidence that the Part 503 rule [federal regulation] has failed to protect public health." https://www.nebiosolids.org/resources/#/scientific-basis-for-biosolids-use/

the level of health risk?

There is debate. That is not ours to figure out. But we are commenting to ensure no rush to judgment without good science.

nebra Recycled org

from EPA

Sources of PFAS Exposure for Humans

- Best documented source is contaminated drinking water near industrial production facilities or waste disposal e.g., Cottage Grove, Minnesota; Parkersburg, West Virginia; Dalton, Georgia; Decatur, Alabama; Arnsberg, Germany; Osaka, Japan *Lindstrom et al. 2011, Environ. Sci. & Technol. (45) 8015 – 8021*
- Food is also implicated in many studies, especially fish from contaminated waters, items contaminated by food packaging, and breast milk *Fromme et al. 2009, Inter. J. Hyg. & Envr. Heath (212) 239-270; Mogensen et al. 2015, Environ. Sci. & Technol. (49) 10466 - 10473*
- House dust may also be an important route of exposure – especially for children who ingest relatively higher levels of dust via hand-to-mouth activity *Shoeib et al. 2011, Environ. Sci. & Technol. (45) 7999 - 8005*
- Workplace exposures significant for some sectors: manufacturing or services making or directly using PFAS, apparel sales, waste treatment *Nilsson et al. 2013 Environ. Sci.: Processes Impacts, 15, 814-822*

34

Slide by Mark Strynar, U. S. EPA
October 17, 2017

PFAS Health Risks - Summary

- Toxicity of PFOA & PFOS not certain
  - Epidemiological studies and laboratory animal studies have not shown consistent and conclusive findings
  - Cancer incidence studies in NY, NH, and MN not indicative of PFAS effects
  - If PFAS is causing health effects, the effects appear to be subtle
  - Current risk-based standards/guidelines for PFOA and PFOS are protective (e.g. EPA's PHA, Health Canada's numbers)
- Reasons for concern
  - PFAS in drinking water elevates PFAS in blood
  - Little data for PFAS other than PFOA and PFOS; unknowns → caution

Slide courtesy Steve Zemba, Sanborn Head

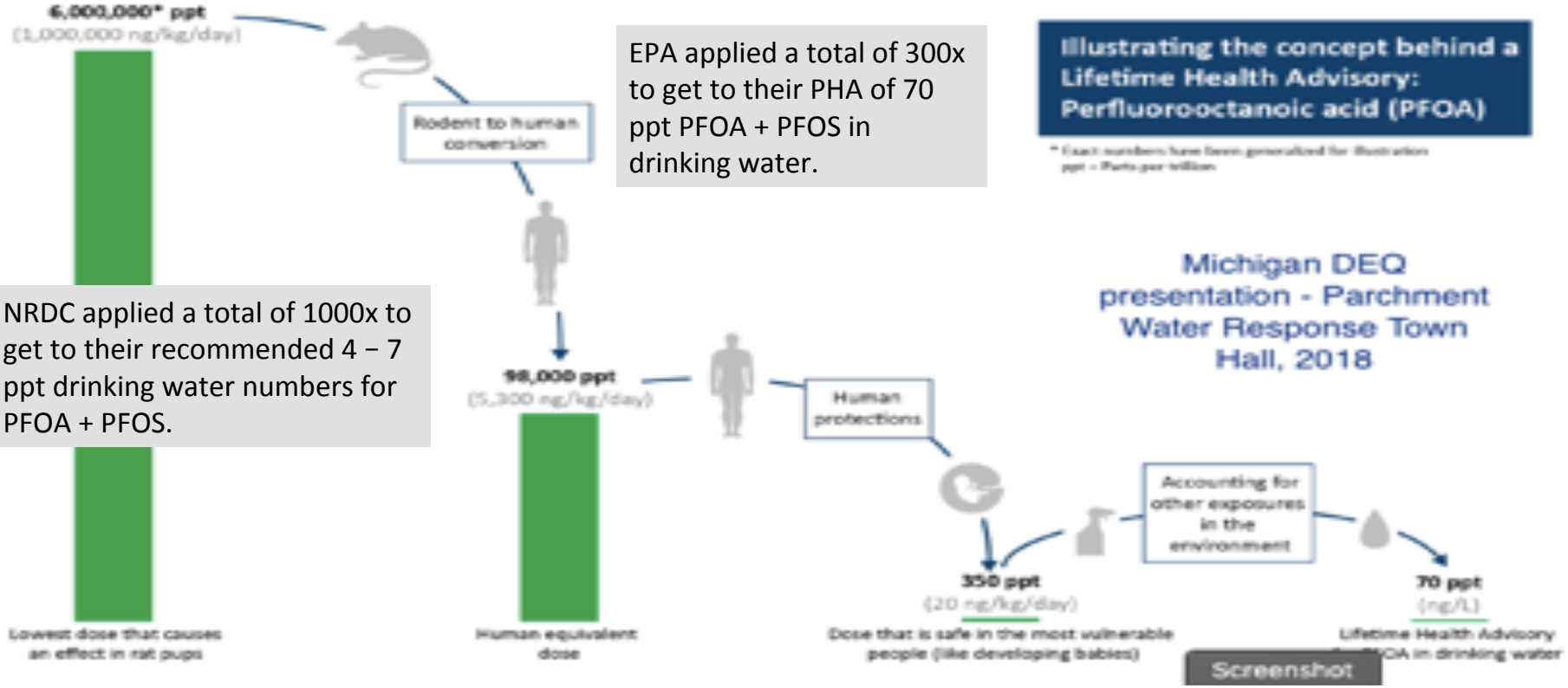
Findings of the Australian Health Expert Panel – quite a contrast to current level of high concern in some of U. S.

- Limited evidence
- Associations with several health outcomes, in particular: increased cholesterol, increased uric acid, reduced kidney function, altered markers of immunological response, levels of thyroid and sex hormone levels, later menarche and earlier menopause, and lower birth weight.
- Differences between those with the highest and lowest exposures are generally small, with the highest groups generally still being within the normal ranges for the whole population.
- There is no current evidence that supports a large impact on an individual's health. In particular, there is no current evidence that suggests an increase in overall cancer risk.
- Possible association with an increased risk of two uncommon cancers (testicular and kidney)… evidence is very weak, inconsistent
- The evidence does not support any specific biochemical or disease screening, or health interventions, for highly exposed groups (except for research purposes).

Uncertainty factors applied

EPA applied a total of 300x to get to their PHA of 70 ppt PFOA + PFOS in drinking water.

NRDC applied a total of 1000x to get to their recommended 4 – 7 ppt drinking water numbers for PFOA + PFOS.



The major health concern now is drinking water

- EPA initial health advisory pre-2016:

  PFOA + PFOS = 600 ng/L (ppt) screening level

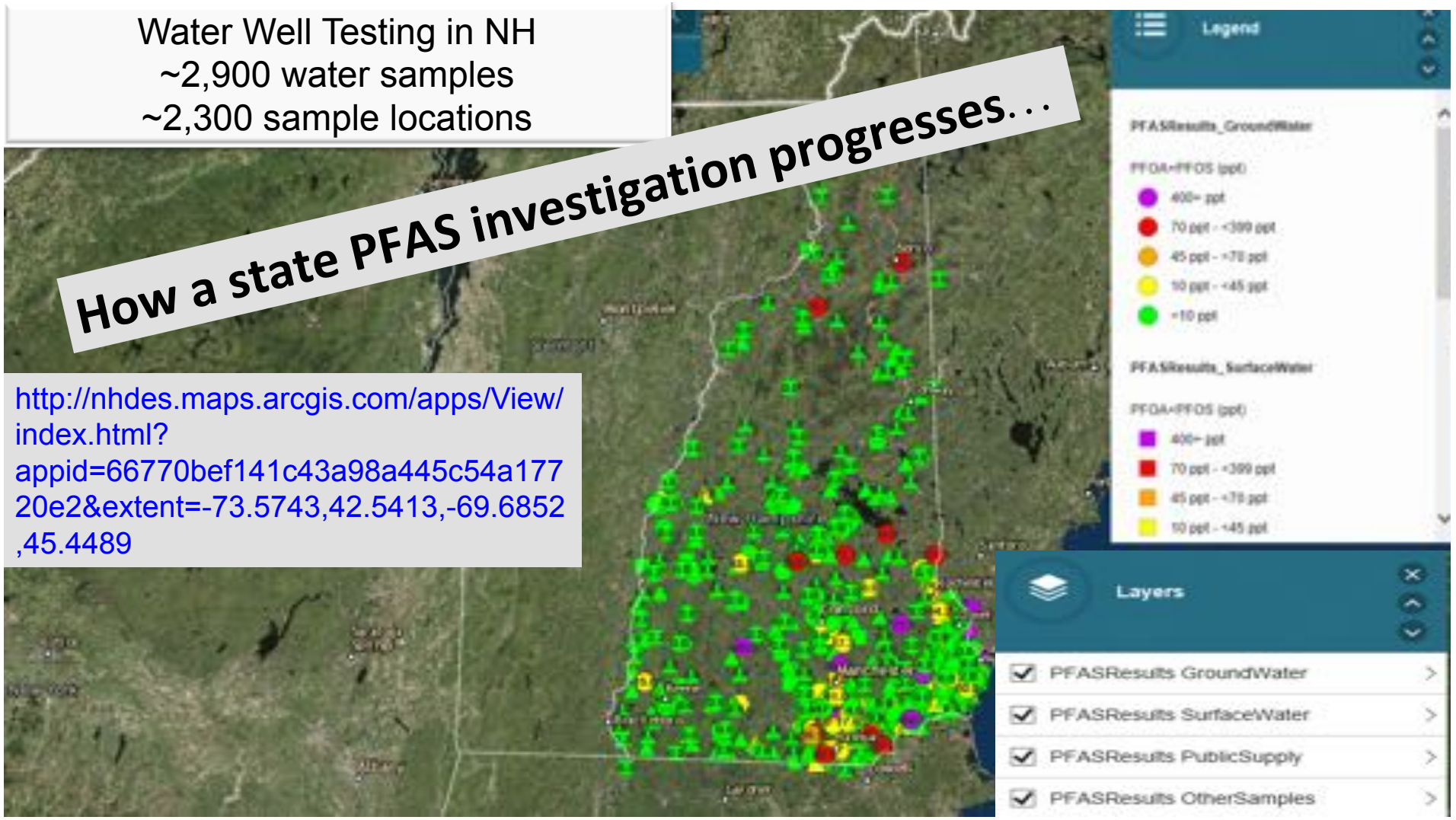
- EPA long-term public health advisory May 2016
  PFOA + PFOS = 70 ng/L (ppt) screening level

- Driven by research like the C8 study around Parkersburg, WV

- Many water utilities & well owners suddenly had to act

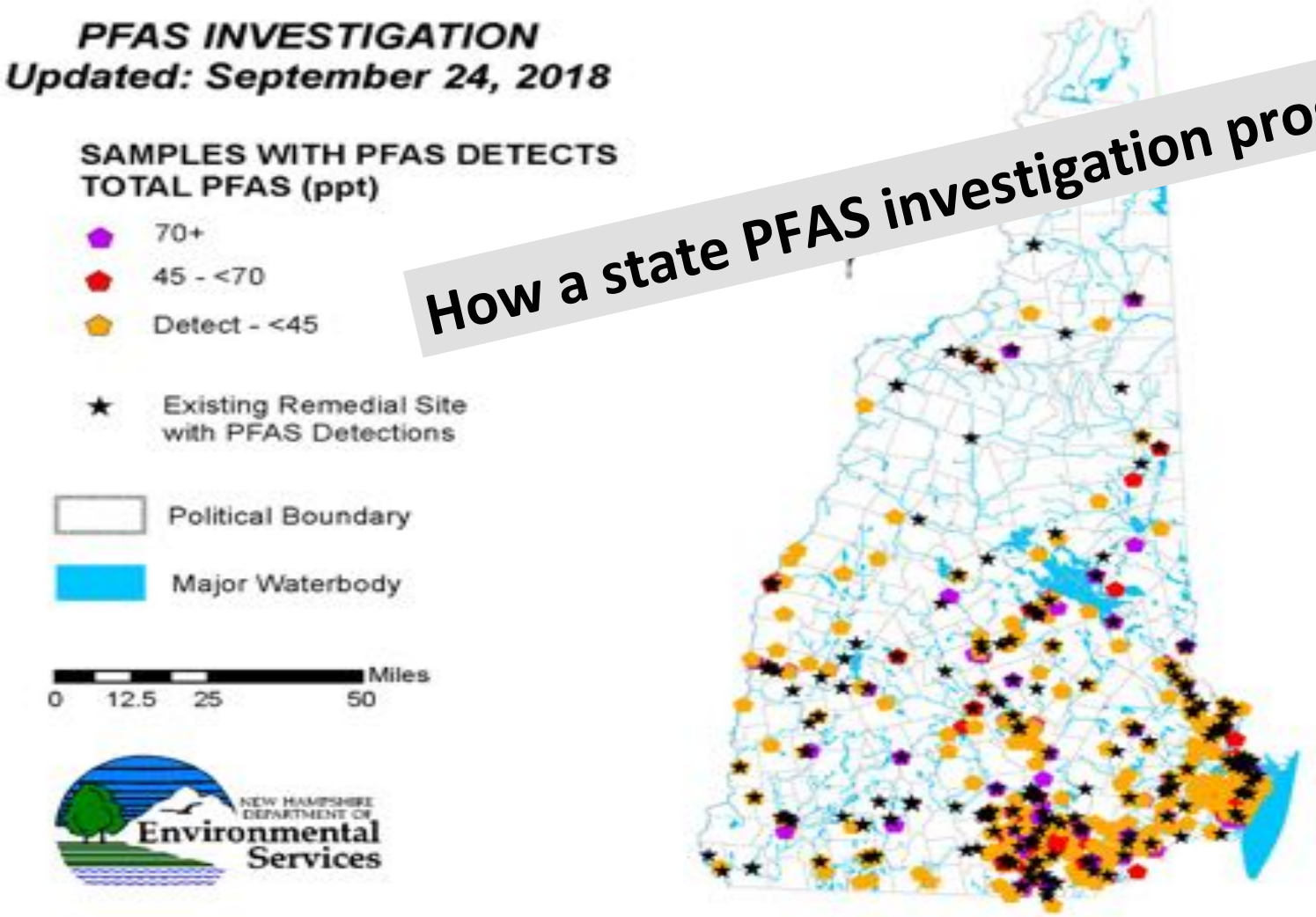
Water Well Testing in NH
~2,900 water samples
~2,300 sample locations

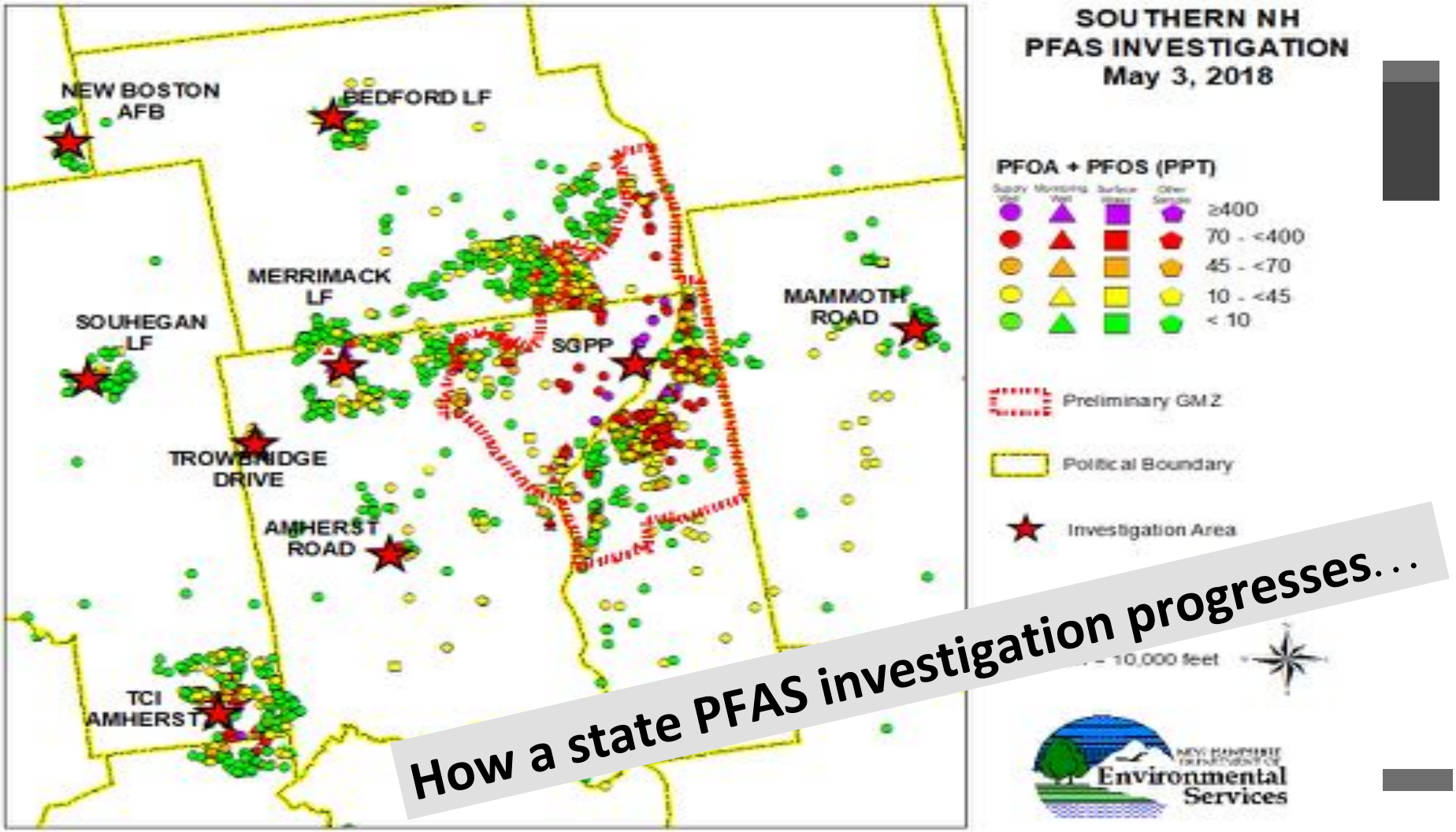
How a state PFAS investigation progresses. . .



http://nhdes.maps.arcgis.com/apps/View/index.html?appid=66770bef141c43a98a445c54a17720e2&extent=-73.5743,42.5413,-69.6852,45.4489

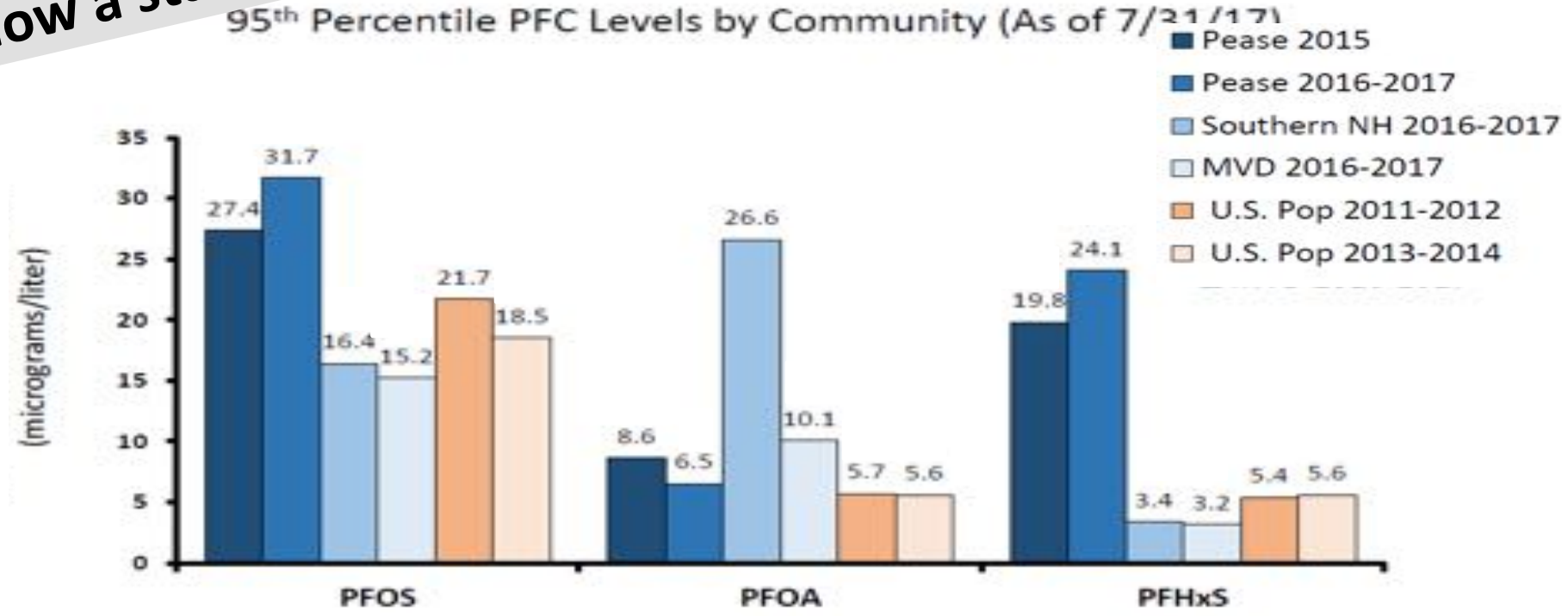
How a state PFAS investigation progresses. . .




SOUTHERN NH
PFAS INVESTIGATION
May 3, 2018
PFOA + PFOS (PPT)
≥400
70 - <400
45 - <70
10 - <45
< 10
Preliminary GMZ
Political Boundary
Investigation Area
NEW BOSTON AFB
BEDFORD LF
MERRIMACK LF
SOUHEGAN LF
SGPP
MAMMOTH ROAD
TROWBRIDGE DRIVE
AMHERST ROAD
TCI AMHERST
How a state PFAS investigation progresses. . .
Environmental Services

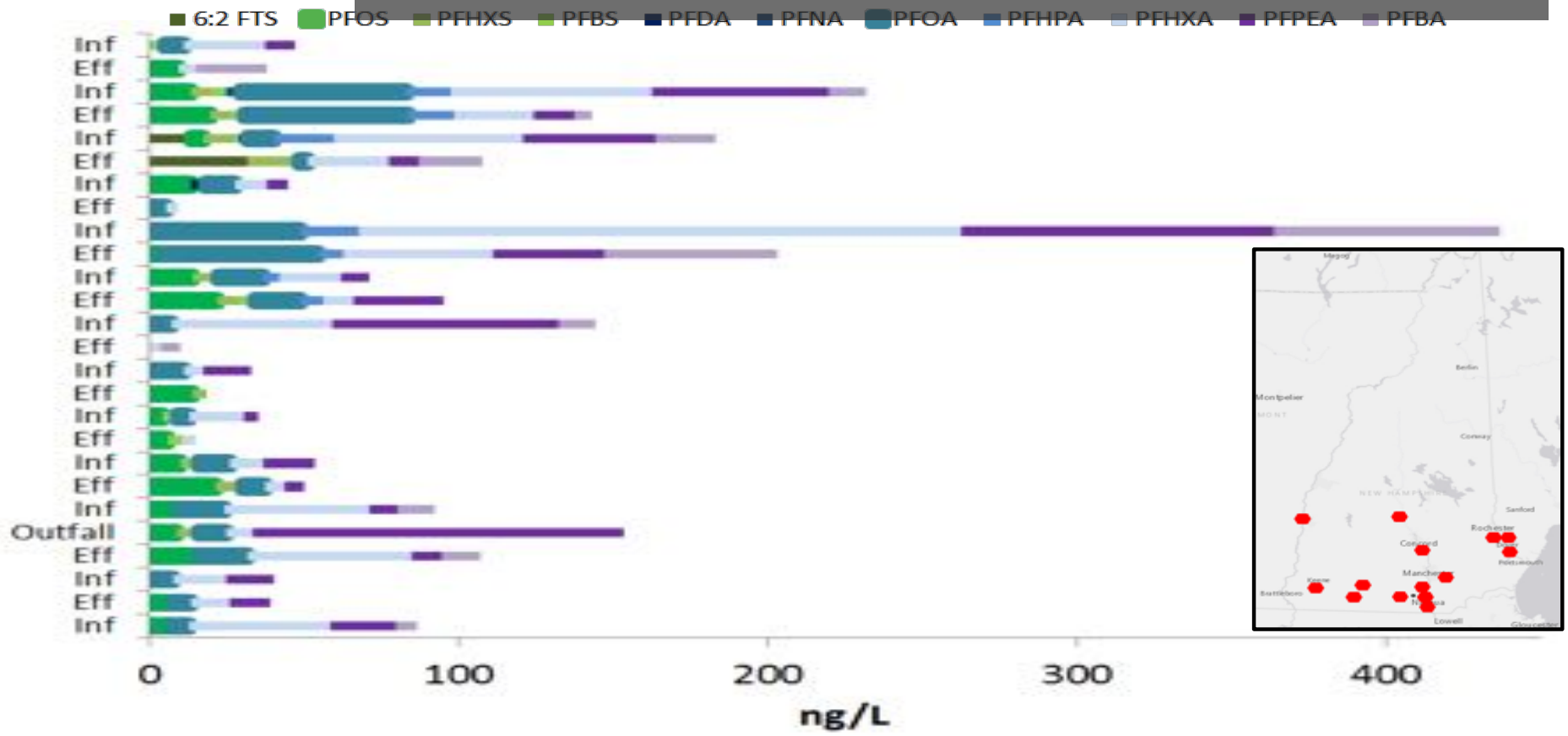
How a state PFAS investigation progresses. . .

Human Blood Testing in NH



https://www.dhhs.nh.gov/media/pr/2017/10102017-pfc-findings.htm

Wastewater Assessments



nebra Recycled organics: Tools for sustainability.

Northeast states evaluate locally…

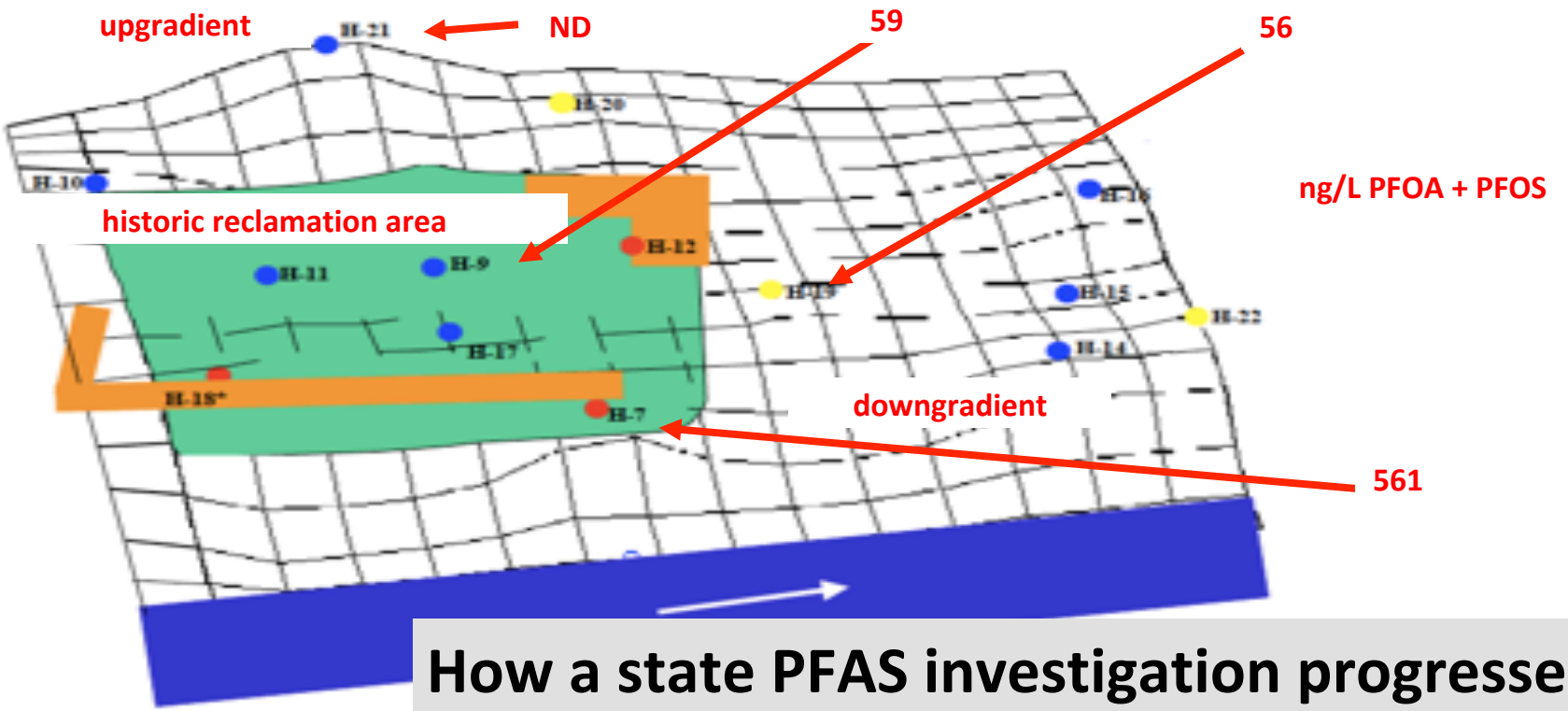
PFAS in wastewater - ppb

(presence further confirmed, 2017 NH DES data)

	PFBA C4	PFHPA C7	PFHXS C6-S	PFHXA C6	PFNA C9	PFOA C8	PFOS C8	PFPEA C5
Small City Influent	13	<4	<4	7	<4	6	6	5
Small City Effluent	7	<4	<4	46	<4	6	7	21
Mid-size City Influent	<9.6	7	7	10	<4.8	15	22	29
Mid-size City Effluent	<9.6	5	8	20	<4.8	15	14	9
Municipality with industrial impacts Influent	56	8	<4	49	<4	50	4	36
Municipality with industrial impacts Effluent	73	19	<4	195	<4	49	<4	101

Monitoring well testing at reclamation site

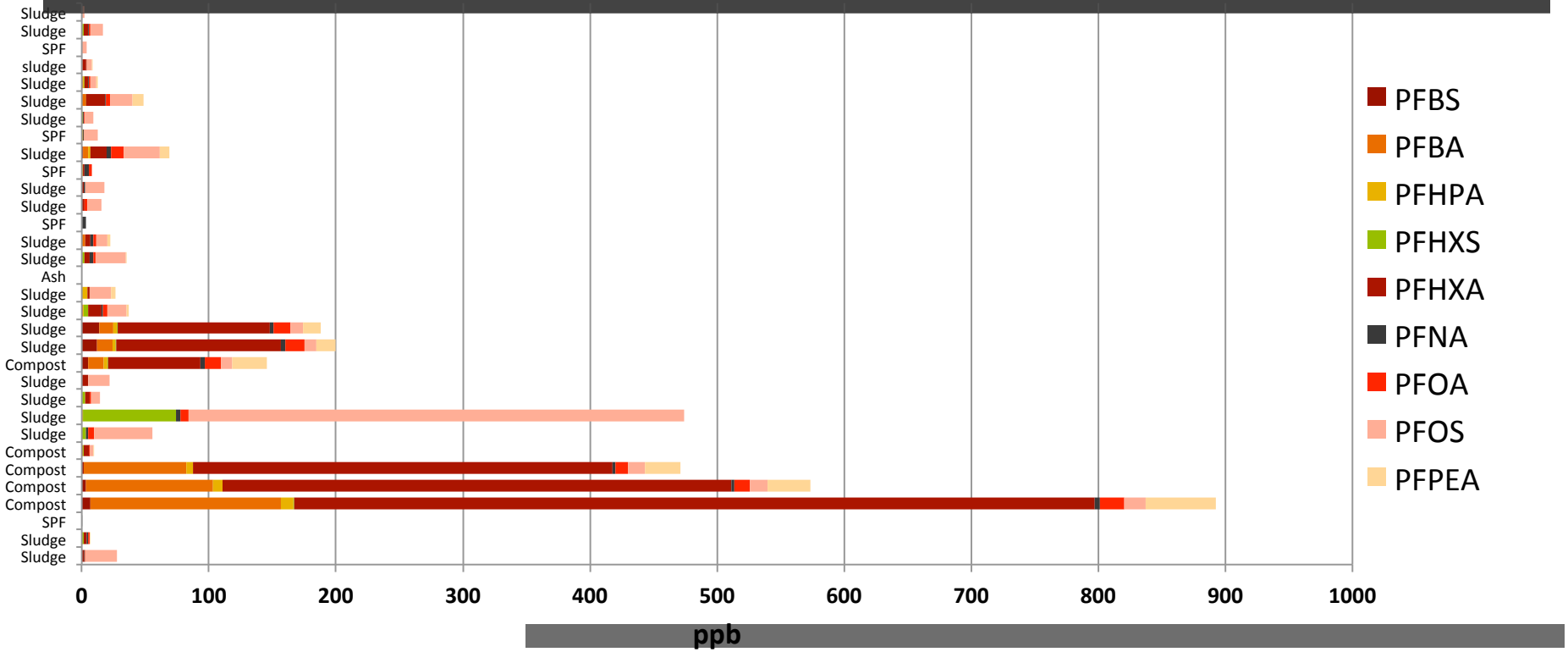
- Historic land application use to ~2001. Likely a worst-case scenario. No drinking water impacts found.

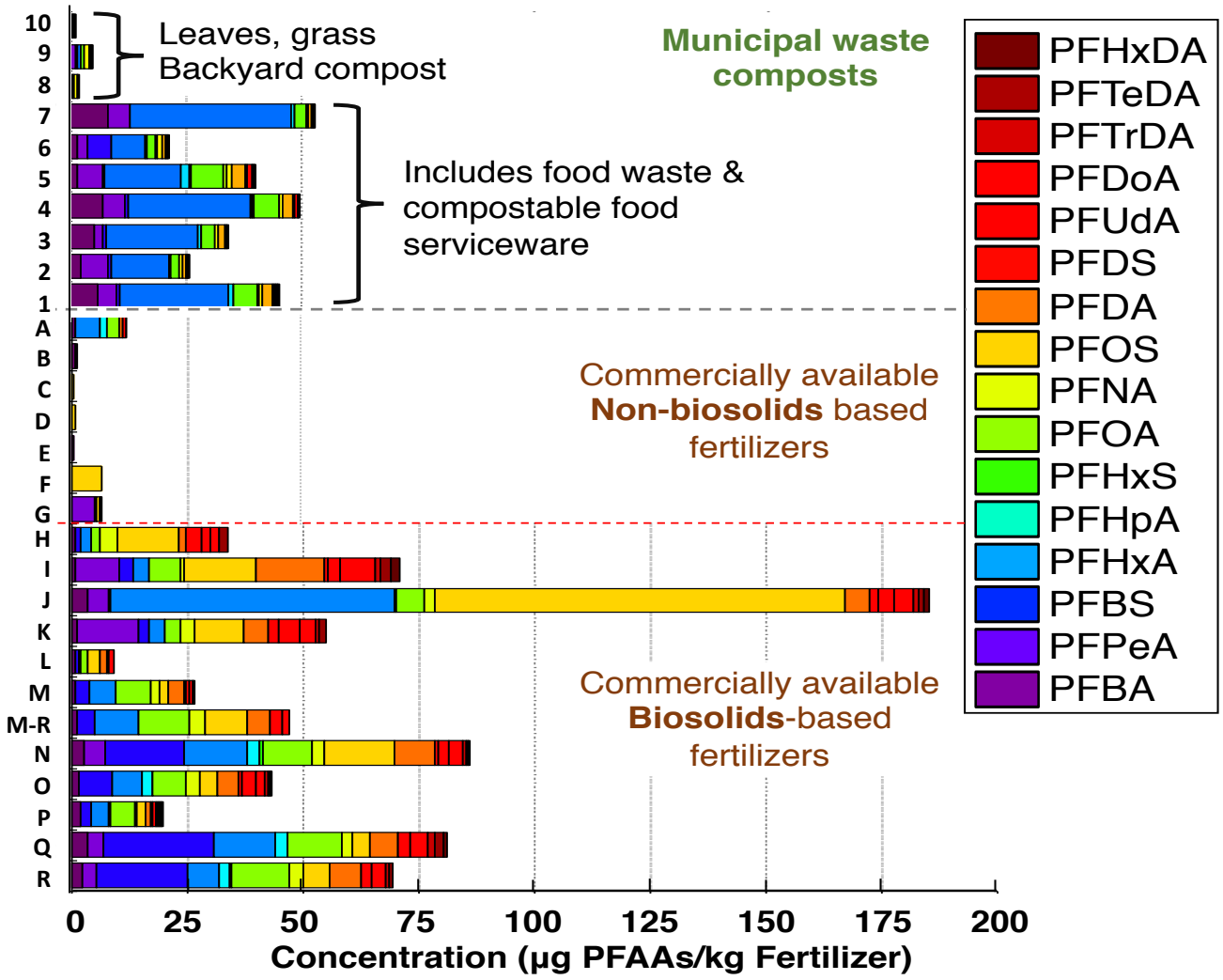


How a state PFAS investigation progresses…

nebra Recycled organics: Tools for sustainability.

Residuals Assessments - NH




10
9
8
7
6
5
4
3
2
1
A
B
C
D
E
F
G
H
I
J
K
L
M
M-R
N
O
P
Q
R
Leaves, grass
Backyard compost
Includes food waste &
compostable food
serviceware
Municipal waste
composts
Commercially available
Non-biosolids based
fertilizers
Commercially available
Biosolids-based
fertilizers
PFHxDA
PFTeDA
PFTrDA
PFDoA
PFUdA
PFDS
PFDA
PFOS
PFNA
PFOA
PFHxS
PFHpA
PFHxA
PFBS
PFPeA
PFBA
0
25
50
75
100
125
150
175
200
Concentration (µg PFAAs/kg Fertilizer)

Paper mill residuals & yard waste composting facility: water impacts…

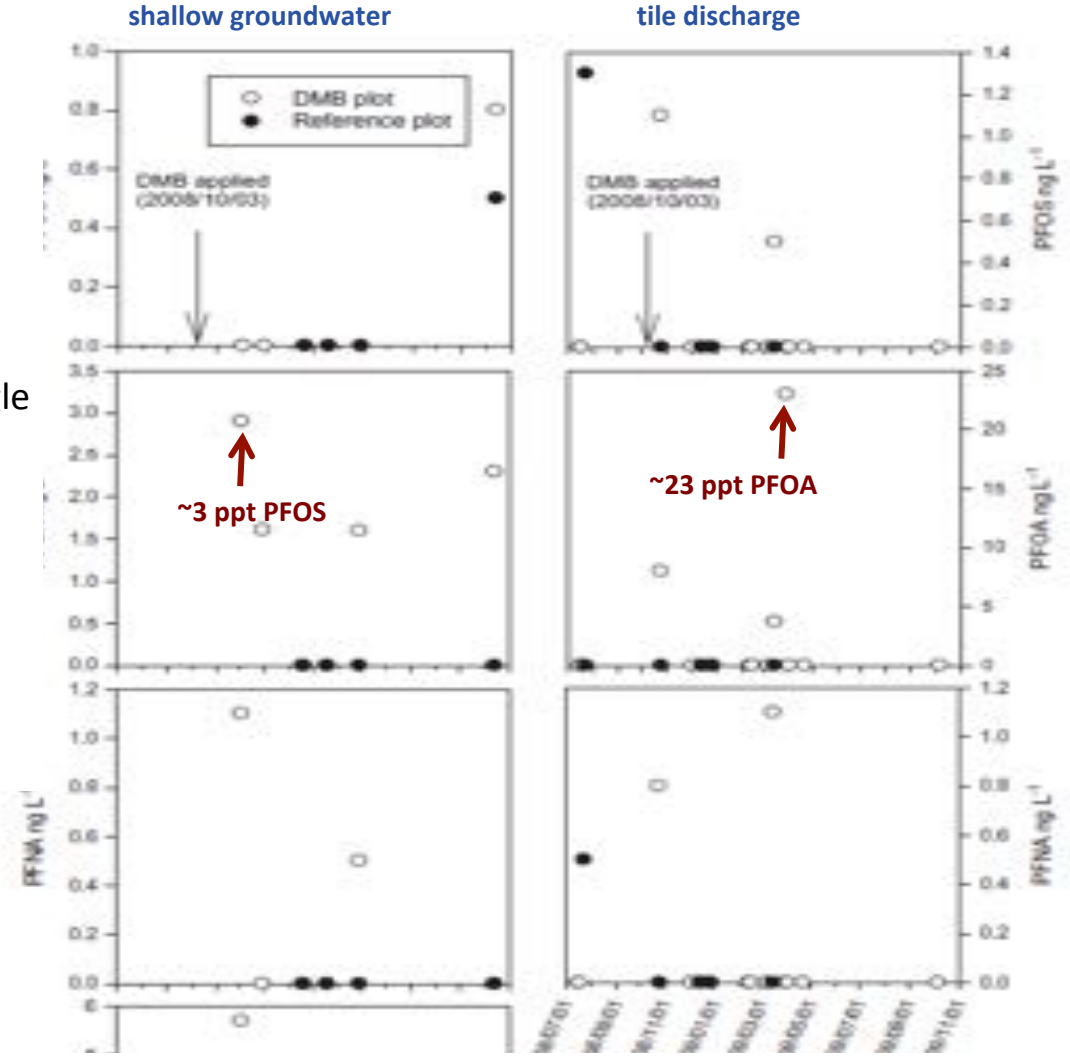
Regulatory response in March 2017 drove recycle paper mill residuals to landfill and composting business to lay off workers, due to non-drinking, surface water levels up to combined 240 ng/L (ppt) for PFOA & PFOS. (Not drinking water. Do we need to have all surface water meet drinking water screening?)

How a state PFAS investigation progresses…

Application of typical biosolids finds:

- Perfluorinated chemicals detected in both groundwater and tile discharge after a single large biosolids application.
- Chemicals detected for months after the application.
- The contributions of leaching through the soil matrix and preferential flow through macropores are unknown.

Gottschall et. al. 2017.
***Sci. Total Environ.* 574:**
1345 – 1359



PFAS behavior in soils (Mobility/Leaching)

- Direct exposure to PFAS in soil is not generally a significant health risk pathway.
- But soil can be an important reservoir and continuing source to groundwater and/or surface water
  - ppb levels in soils can sustain ppt levels in groundwater for many years
  - precursors breaking down can lead to more PFOA, PFOS, and other shorter-chain versions in soils
- Sorption in the soil does occur and may best be described as a sorption equilibrium reaction
- PFAS sorption equilibria are influenced by:
  - **PFAS carbon chain length**
  - **Organic carbon content**
  - pH
  - [Ca^{+2}]
  - Clay content
  - Specific surface area
- More research needed.

nebra

What numbers there are… are all over the place

Drinking water:

- Canadian health guidance: 200 ppt PFOA, 600 ppt PFOS
- 70 ppt PFOA + PFOS − U. S. EPA public health advisory (screening level)
- 20 ppt for the sum of PFNA, PFOA, PFOS, PFHpA, PFHxS − VT standard

- Soil:
  - 300 ppb PFOA − the lowest state (VT) residential clean-up standard *based on dermal contact & ingestion − not leaching.*
  - 0.29 ppb for PFOA and 0.53 ppb for PFOS - Alaska proposed soil cleanup levels based on migration to groundwater (leaching)
  - 3 ppb each for PFOA and PFOS - Literature soil screening value (Xiao et al., 2015)
  - 72 ppb - NY state screening value in use for residuals under one permit

- Non-ag residual: 2.5 ppb for PFOA and 5.2 ppb for PFOS - ME screening value

Typical modern biosolids & paper mill residuals: 1's to low 10's ppb − no issue, *except maybe for leaching.*

Remember:

1 ppb = 1 second in 31.7 years

1 ppt = 1 second in 31,700 years

U. S. EPA – Analytical Methods

Info courtesy of Chris Impelliteri, U. S. EPA

1. **Direct injection (SW 846 Method 8327) for waters other than drinking water**
   - external lab validation − 6/7 data sets back… 5 look good… one lab had problem (precision all over the place)… trying to figure that out.
   - Optimistic for draft method out for public review by the end of 2018.
2. **Isotope Dilution Method (SW 846 8328) draft for waters other than drinking water and solids**
   - have done internal review
   - working with DOD on fast tracking external validation… DOD would rather see 8328 move ahead… EPA is working to include DOD concerns and options, so users can meet both DOD and EPA requirements. A lot of the DOD requirements will be optional.
   - will include GenX in this, but not Adona, because no radio-isotope available yet.
   - Looking at late winter, early spring release of draft. Validation will be a big effort.
3. **New report coming soon re PFAS data quality** − co-authored with DOD… tips on review of data packages for PFAS. Regardless of method used, it is essential to look at raw data − peak shapes should be same as the added standard, etc.

Summary: PFAS – we'll have to figure this out

1. Wastewater contains PFAS in the 10s of ppts+. Biosolids contain PFAS in the 10s ppbs. Even food waste composts may be in the single ppbs + range.
2. Some states are creating low drinking water and groundwater and other standards for the two prominent PFAS, PFOA & PFOS, in the 10s of parts per trillion (e.g. EPA's 70 ppt). Some are beginning to scrutinize other PFAS too.
3. Because PFAS are persistent and can leach some, biosolids may convey traces of PFOA and PFOS (and precursors) to surface or groundwater at levels relevant to the advisory levels or standards.
4. State regulatory overreactions – very low numerical standards for waters & soils – can lead to significant disruptions and eroded confidence in biosolids & composts.

nebra Recycled organics: Tools for sustainability.

Acknowledgements & Sources: PFAS slides

Inclusion on this list does not imply endorsement. Views expressed are those of the author only.

- Stephen Zemba and Harrison Roakes, Sanborn Head Assocs.
- Lawrence Zintek, U. S. EPA Region 5
- Linda Lee and Rooney Kim, Purdue University
- Sarita Croce, Merrimack, NH
- Shelagh Connelly, RMI
- Jeff McBurnie, Casella Organics
- *And many others (apologies for omissions):*

•Sally Brown, Univ. of WA
•NH DES
•Mike Person, MI DEQ
•Mark Russell, formerly Chemours
•Kerri Malinowski, ME DEP
•Layne Baroldi, Synagro
•Sally Rowland, NY DEC
•Stefanie Lamb, formerly NH BIA
•Andrew Carpenter, Northern Tilth
•Ed Topp, Agriculture & Agrifood Canada
•Charles Neslund, Eurofins

AND organizations across North America who are funding NEBRA's PFAS work in 2019.

THANK YOU!

Selected References

Analyzing PFAS in Wastewater, Solids, & Soils: State of the Science Webinar, NEBRA Webinar, Sept. 14, 2017

Buck, R., Franklin, J., Berger, U., Conder, Cousins, I., de Voogt, P., Jensen, A., Kannan, K., Mabury, S., van Leeuwenkket, S., 2011. Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins. *Integrated Environmental Assessment and Management*, Vol. 7, No. 4, 513–541.

Gottschall, N., Topp, E., Edwards, M., Payne, M., Kleywegt, S., Lapena, D.R., 2017. Brominated flame retardants and perfluoroalkyl acids in groundwater, tile drainage, soil, and crop grain following a high application of municipal biosolids to a field. *Science of the Total Environment*, 574, 1345–1359.

Lindstrom, A., Strynar, M., Delinsky, A., Nakayama, S., McMillan, L., Libelo, L., Neill, M., Thomas, L., 2011. Application of WWTP Biosolids and Resulting Perfluorinated Compound Contamination of Surface and Well Water in Decatur, Alabama, USA. *Environmental Science & Technology*, 45 (19), 8015–8021.

Puddephatt, Karen Joan, "Determining the Sustainability of Land-Applying Biosolids to Agricultural Lands Using Environmentally-Relevant Terrestrial Biota" (2013). Ryerson University: Theses and dissertations, Paper 1579.

Sepulvado, J., Blaine, A., Hundal, L., Higgins, C., 2011. Occurrence and Fate of Perfluorochemicals in Soil Following the Land Application of Municipal Biosolids. *Environmental Science and Technology*, *45* (19), 8106–8112.

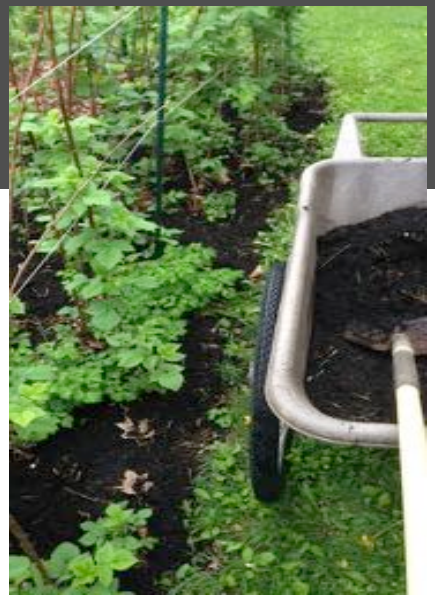
Venkatesan, K, and Halden, R., 2013. National inventory of perfluoroalkyl substances in archived U.S. biosolids from the 2001 EPA National Sewage Sludge Survey. *Journal of Hazardous Materials*, 252– 253, (2013), 413– 418.

Washington, J., Ellington, J., Hoon, Y., and Jenkins, T., 2009. Results of the Analyses of Surface Soil Samples from Near Decatur, Alabama for Fluorinated Organic Compounds. U.S. EPA, Office of Research and Development

Xiao, F., Simcik, M., Halbach, T., Gulliver, J., 2013. Perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA) in soils and groundwater of a U.S. metropolitan area: Migration and implications for human exposure. *Water Research*, 72 (2015), 64 74.

Xiao, F., Gulliver, J., Simcik, M., 2013. Transport of Perfluorochemicals to Surface and Subsurface Soils. Center for Transportation Studies University of Minnesota, Report No. CTS 13-17.

Zareitalabad, P., Siemens, J., Hamer, M., Amelung, W., 2013. Perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS) in surface waters, sediments, soils and wastewater – A review on concentrations and distribution coefficients. *Chemosphere* 91 (2013), 725–732.



Biosolids compost for my raspberries… still using it, even though I know it has PFAS in it. The benefits far outweigh the risks.

nebra
North East Biosolids & Residuals Association

Thank you.

Ned Beecher, Executive Director
NEBRA
Tamworth, NH
ned.beecher@nebiosolids.org
603-323-7654