PFAS for Composters: A Chemistry Primer—and an Uncertain Future

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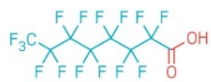
Introduction

Per- and polyfluoroalkyl Substance (PFAS) are also colloquially known as "forever chemicals," given their slow degradation properties in nature. They might also accurately be described as "everywhere chemicals," given their widespread, worldwide consumer and manufacturing uses for decades. While much of the recent PFAS focus has been on their potentially harmful human effects on drinking water, other sources are being scrutinized as well; compost products are no exception.

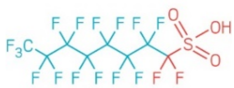
Industry-wide disruptions in compost production caused by persistent contaminants are nothing new. The presence of PFAS in finished compost, however, presents new challenges. The ubiquitous nature of these chemicals, the uncertain health concerns surrounding them, and the varying regulatory responses of state and federal oversight agencies put PFAS at or near the top of most "to do" lists in the composting production and distribution industry. This all might leave those in the composting industry asking:

'What's the science behind PFAS identification and remediation? Where might PFAS regulation and oversight be heading? What lessons from the past can composters apply as regulators scramble to respond to PFAS[1] ?' This paper provides a better technical understanding of what PFAS is, how it is used, why PFAS chemical characteristics make them a unique problem, and, finally, some ways for composters to get ahead of the issue and prepare for industry changes that continue to unfold.

PFAS: What Are They?



Perfluorooctanoic acid, PFOA, CAS 335-67-1



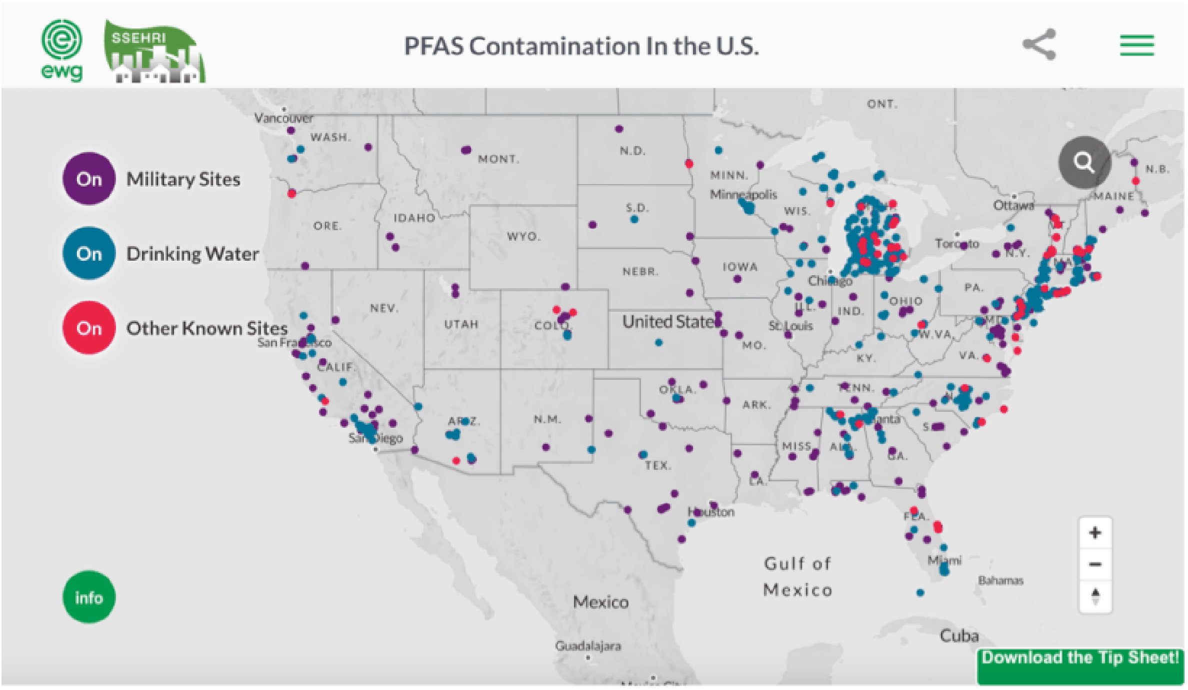
Perfluorooctane sulfonic acid, PFOS, CAS 1763-23-1

PFAS are a class of man-made chemicals that includes PFOA, PFOS, GenX, and many other chemicals. They share the characteristic of having multiple carbon-fluorine bonds and go by many names: PFAS, PFCs, PFOS/PFOA. In fact, there are almost 5,000 different types of PFAS that have been created. These chemicals are ubiquitous in our environment and the data increasingly indicate that they are a threat to human health at very low levels.

First developed in the 1940s, they were first commercialized in the 1950s by the 3M Co. in waterproofing products such as Scotch Gard™. PFAS' next big success was as an Aqueous Film Forming Foam (AFFF) used in fighting fuel fires. The Navy had been working with 3M since 1960 to develop AFFF, but it was not implemented until 1967, when the USS Forrestal was nearly destroyed and 134 sailors died[2] in a catastrophic fuel fire aboard the supercarrier. Determined to reduce the risk of fuel fires aboard aircraft and naval vessels, the US Navy deployed AFFF, which could stop these fuel driven fires in less than a minute, aboard all of its vessels. This technology was adopted worldwide and required at facilities that store large amounts of fuels (air force bases, airports, fuel depots, refineries, etc.) Firefighters would routinely train[3] with AFFF on live practice fires and the resulting residue was allowed to drain to storm water systems. From there, it made its way into groundwater and drinking water systems nationwide. PFAS was also discharged[4] to surface water via industrial water outfalls and via aerial

[1] http://alterecho.com/home/article.php?idArticle=18
[2] https://www.history.navy.mil/browse-by-topic/disasters-and-phenomena/forrestal-fire.html
[3] https://www.faa.gov/documentLibrary/media/Advisory_Circular/150_5220_17b.pdf
[4] https://deq.nc.gov/state-seeks-stop-additional-chemical-discharges-cape-fear-river

deposition[5] from factories. According to the Environmental Working Group (EWG), as of January 2021, there were 2,337 PFAS affected locations in 49 US states[6].



Environmental Working Group, January 2021

While much of the attention garnered by PFAS has been focused on the issue of groundwater contamination by AFFF, there are many other sources of PFAS in the environment. Indeed, as proposed human health action levels for PFAS[7] have fallen to levels as low as 5 parts per trillion (ppt) in some states, we have begun to look for PFAS in other sources. PFAS are resistant to water, oil, chemicals, and heat (think Teflon®, a prime PFAS-containing product for decades until 2013). They are used in many non-AFFF applications[8] such as nonstick cookware, grease-resistant food packaging, stain-proof fabrics, electronics, construction materials, and waterproof clothing (Gore-Tex®, e.g.). Over 3,000 distinct PFAS chemicals have been used in industrial applications. There are many types of PFAS and we have a long way to go toward better understanding the environmental and toxicological properties. While most regulation

[5] https://ncpfastnetwork.com/files/2019/06/06_Turpin_Lightning-Talk.pdf
[6] https://www.ewg.org/interactive-maps/pfas_contamination/
[7] https://www.asdwa.org/pfas/
[8] https://fluorocouncil.com/wp-content/uploads/2017/03/Consolidated-application-page-1.pdf

and research has focused on a small group of compounds, there has been very little research[9] on the larger family of PFAS compounds.

The chemistry of PFAS substances is important to understanding its economic value and environmental fate, as well as its danger to human health. PFAS molecules have a long "tail" made up of carbon-fluorine bonds, which is both hydrophobic (water repelling) and oleophobic (oil repelling); they have a "head" group which is polar. The polar end of the molecule makes it very mobile in groundwater. This gives PFAS the ability to quickly move into drinking water aquifers and disperse, as well as to leach from compost into groundwater.

The very qualities that make PFAS an attractive industrial material (durability, survival of high temperatures, and chemical resistance) are what make it difficult to remove and make it so persistent in the environment. Thus, the nickname "forever chemicals." PFAS also like to bond to proteins. This creates a bioaccumulation effect where organisms concentrate PFAS from their environment in their body tissue over time. Even as industry moves away from PFOS, PFOA and, even second generation Per- and polyfluoroalkyl substances like GenX, historic manufacture, use and disposal of these chemicals have led to widespread presence in the environment. Indeed, only the most pristine wilderness and rural areas do not have some amount of PFAS in the soil and water.

PFAS and Compost

As the nation becomes more concerned about PFAS contamination in water, soil, food packaging, and even food, it is not surprising to see it become a concern in finished compost as well. One of the top 10 trends in the Biocycle Composting Trends[10] for 2020 report was concern over PFAS contamination in finished compost. Compost customers have begun asking about PFAS in the compost they are purchasing and state regulators have begun to take an interest as well. And as another testament to its

[9] https://pubs.acs.org/doi/pdf/10.1021/acs.est.6b04806
[10] https://www.biocycle.net/2020/01/07/composting-trends-2020/

"forever" (and "everywhere") moniker, PFAS is ubiquitous in finished compost. In fact a study[11] in 2019 found PFAS in all of the compost samples it tested.

So, if PFAS is everywhere, some of the next questions become: How much PFAS is too much for finished compost? What level of PFAS is safe for agricultural use? How will regulators seek to limit PFAS contamination in compost, and what are the potential economic impacts of that? Will PFAS content reduce compost usage?

Where is the PFAS in finished compost coming from? There are several potential sources:

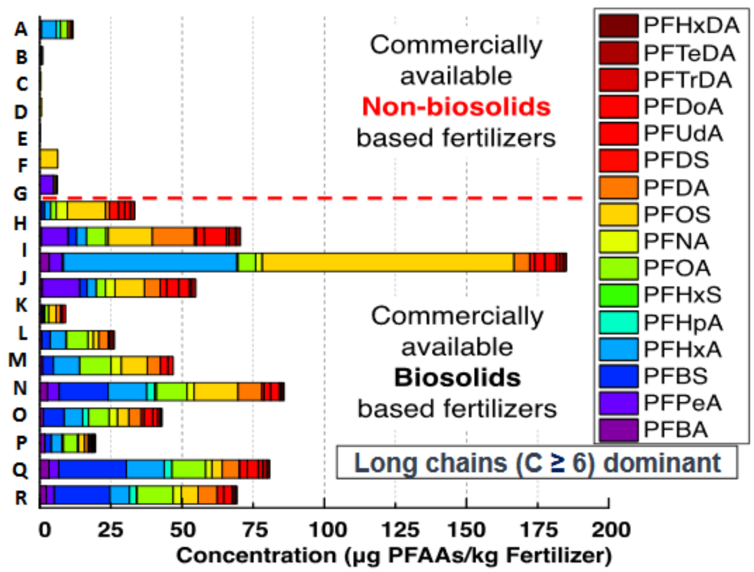
- PFAS are used extensively as a coating for disposable food contact surfaces,[12] such as wrappers, pizza boxes, microwaveable popcorn bags, and microwaveable containers, as well as coatings for "compostable" food packaging.
- PFAS have also been found in food produced at dairies[13] and farms[14] near PFAS impacted sites.
- Ground water and surface water from nearby PFAS contaminated sources.
- Aerial deposition[15] from industrial sources.
- Industrial residual feedstock, especially paper mill residuals[16].
- Biosolids, especially from wastewater systems that receive wastewater from fluorochemical facilities[17].

The durability discussed above also makes PFAS hard to destroy, even in compost. The high temperatures (180°F) and biological digestion that occurs during composting often destroys many organic contaminants, as well as kills weed seeds and plant viruses[18]—but fails to break down PFAS. This presents a unique challenge to the composting industry and will require a new approach to solve.

[11] https://pubs.acs.org/doi/abs/10.1021/acs.estlett.9b00280
[12] https://www.accessdata.fda.gov/scripts/fdcc/index.cfm?set=FCN&sort=FCN_No&order=DESC&startrow=1&type=basic&search=fluoro
[13] https://www.fda.gov/media/127850/download
[14] https://www.fda.gov/media/127848/download
[15] https://ncpfastnetwork.com/files/2019/06/06_Turpin_Lightning-Talk.pdf
[16] http://www.newea.org/wp-content/uploads/2018/10/NEWEA_ResMicro18_SConnelly.pdf
[17] https://www.ncbi.nlm.nih.gov/pubmed/21513287
[18] https://bsppjournals.onlinelibrary.wiley.com/doi/full/10.1111/j.0032-0862.2004.01059.x

So far, the largest concerns from state regulators concerning PFAS and compost tend to center on composts that take on feedstocks high in PFAS and could potentially leach into groundwater from composting operations, with windrows exposed to rainfall or from unlined stormwater reuse ponds. Examples would be biosolids from a wastewater system that accepts wastewater from industries using PFAS and paper mill residuals where PFAS was used in paper production. However, a 2014 study of commercially available fertilizers shows that biosolids in general tend to exhibit higher PFAS (also known as PFAAs) than other feedstocks.

Result: PFAAs in 2014 Commercial Fertilizers



*PFAA concentration in < 2mm fraction (36-80%) normalized to total mass (assumes PFAA is negligible in the fraction > 2 mm)

Kim Lazcano et al., Manuscript in preparation

Fertilizer	Description
A	Food and yard compost
B	Compost with untreated wood products
C	Manure compost
D	Manure and peat compost
E	Mushroom compost
F	Mushroom compost
G	Peat/compost based growing mix
H	Heat-dried granular biosolids
I	Heat-dried granular biosolids
J	Heat-dried granular biosolids
K	Heat-dried granular biosolids
L	Heat-dried granular biosolids
M	Biosolids blended with maple sawdust and aged bark
N	Composted biosolids with woodchips
O	Composted biosolids with woodchips
P	Composted biosolids with municipal solid waste
Q	Composted biosolids with residential yard trimmings
R	Composted biosolids with plant materials

The Regulatory Climate for PFAS—and What That Means for Composting

In 2019, the US Environmental Protection Agency unveiled its "PFAS Action Plan."[19] Although EPA has offered guidance and recommendations stemming from the action plan, many states have expressed disappointment in the federal government's PFAS regulation approach, stating that EPA has been slow to enact research and rules concerning PFAS. As a result, many states are moving forward with their own laws and regulations concerning PFAS. We expect this trend to continue, particularly in states that have PFAS in drinking water and are already looking at other sources. The Maine

[19] https://www.epa.gov/pfas/epas-pfas-action-plan

DEP, for example, has mandated PFAS testing with low screening levels (PFOA: 2.5 ppb and PFOS: 5.2 ppb) for all composting and land application facilities using biosolids and sewer sludges. Many more states have regulations in the works that will likely address composting.

With that background in mind, there are four important trends happening now that will continue to be closely scrutinized by the composting industry:

1. The more we look, the more we find PFAS in our environment and our bodies.
2. The levels at which we can detect PFAS are dropping as analytical methods improve.
3. As more human health data is acquired and analytical detection limits fall, the limits of PFAS that are considered acceptable are falling as well. Some states are proposing limits as low as 5 ppt in drinking water.
4. PFAS coated products continue to break down and release PFAS into groundwater and soil over time.

Additionally, as public concern over the presence of PFAS grows and regulations tighten, the uses and applications for PFAS and the amount of PFAS entering feedstocks will likely fall as well. This will be especially evident in a reduction of PFAS use in food contact surfaces and paper mill products. Moving against this trend will be falling regulatory limits for PFAS in soil.

PFAS regulation, implications for human health, method detection levels, and our understanding of PFAS' environmental fate are all developing and rapidly changing. As of December 2020, there are 142 current PFAS policies in 28 states and 38 adopted PFAS policies in 15 states. Many states have already enacted PFAS limits in drinking water[20]. As each state implements their own PFAS rules, the result will be an inconsistent patchwork of regulations, limits, and policies where PFAS is concerned.

[20] https://pfas-1.itrcweb.org/wp-content/uploads/2020/12/ITRCPFASWaterandSoilValuesTables_NOV-2020-FINAL.xlsx

Q&A for Composters

- *Does your compost have PFAS?* Almost certainly.
- *What actions should you take?* Start with evaluating your feedstocks:
    - Are you accepting paper mill residuals?
    - Has PFAS been detected nearby (within a mile)?
    - Are you composting biosolids or sludge? The highest PFAS concentrations are found in biosolids where industry is discharging PFAS to the municipal wastewater treatment system. Look for PFAS sources and sites in your area.
    - How do I know if there is PFAS in my area or feedstock sources? This can take a little detective work. A good first start is to check with your state environmental program. Search online for "PFAS" and the name of your state environmental program. Most states have a PFAS information page that lists all sites where it has been detected.
    - Consider doing some preliminary testing of your finished compost and suspected sources. Lawn clippings and chipped wood are almost certainly not an issue, but industrial residuals and biosolids may have PFAS. The memo[21] to composters from the Maine DEP has good guidance on sampling, labs, and methods.
- *Keep an eye on the trends* – PFAS requirements will likely tighten, manufacturers of food-contact compostables will begin dropping PFAS from products due to regulatory and consumer pressures (Amazon one of the most recent high-profile examples: https://www.ewg.org/release/amazon-ban-forever-chemicals-its-amazon-kitchen-brand[22]). The good news there is that feedstocks will likely become "cleaner" moving forward. There are many good sources of information both national: BioCycle, United States Composting Council (USCC)[23], and regional publications like North East Biosolids and Residuals Association (NEBRA)[24]. How will I know if

[21] https://www1.maine.gov/dep/spills/topics/pfas/03222019_Sludge_Memorandum.pdf
[22] https://www.ewg.org/release/amazon-ban-forever-chemicals-its-amazon-kitchen-brand
[23] https://www.compostingcouncil.org/page/pfas
[24] https://www.nebiosolids.org/pfas-biosolids

new regulations affect me? If you have a permit under land application, beneficial residual use, NPDES, etc., your regulator will notify you.

- *Will compost that is above residential or agricultural soil screening levels for PFAS be allowed for agricultural or residential use?* This is a huge unknown for the industry and regulations will be inconsistent, at first—especially in the earlier stages.
- *Does plant uptake of PFAS represent a threat to residential gardening or commercial agriculture?* There are some studies that show the ability for PFAS in the environment to make it into food sources such as plants at highly contaminated dairies[25] and farms[26] , while others show little or no impact. See the "Assessing PFAS in Food from Environmental Contamination through Sampling" section of the FDA PFAS information page: https://www.fda.gov/food/chemicals/and-polyfluoroalkyl-substances-pfas[27]

In summary, the road ahead for composters dealing with PFAS contamination is likely to be a changing landscape tied to state and local regulators, consumer demands, and progress in removing PFAS from food packaging. But as noted earlier, impurities and potential compost contamination is not entirely new. It has happened before with heavy metals from biosolids, PCBs and dioxins, as well as with persistent herbicides. Thus, we expect to see PFAS follow a similar pattern as previous contaminants: initial concern, strong response by some states and regulators, eventually followed by a general consensus that is reached on an approach to testing, and, finally wide-ranging regulations put in place by state and local regulators.

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[25] https://www.fda.gov/media/127850/download
[26] https://www.fda.gov/media/127848/download
[27] https://www.fda.gov/food/chemicals/and-polyfluoroalkyl-substances-pfas