

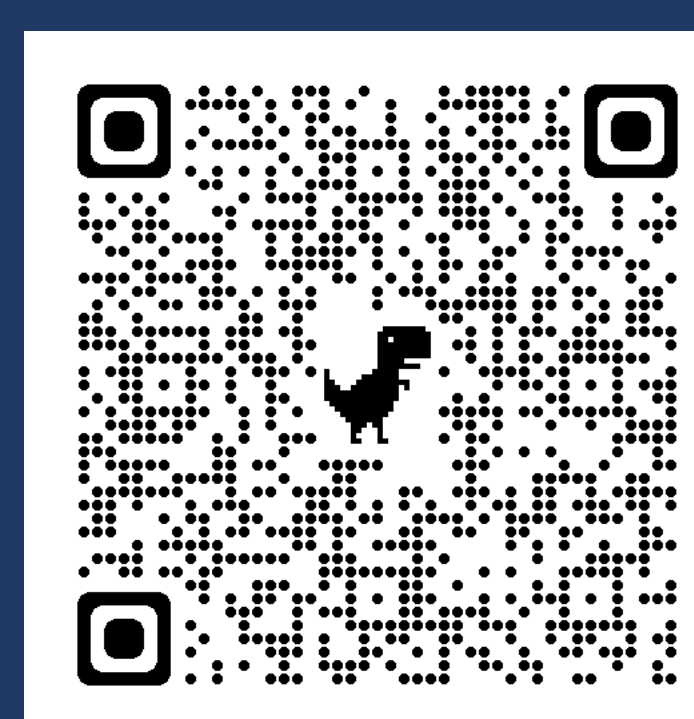
Evidence of compost contamination with per- and polyfluoroalkyl substances (PFAS) from “compostable” food serviceware

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Introduction

- PFAS have been used to waterproof and greaseproof food serviceware for decades. This includes coatings on serviceware designed to be compostable.
- PFAS compounds are not readily decomposed during composting due to the strength of carbon-fluorine bonds.
 - Persistence in finished compost is of concern.
- No PFAS thresholds have been set for composts.
 - Maine previously restricted land application of biosolids to less than 1900, 5.2, and 2.5 $\mu\text{g}/\text{kg}$ (ppb) of PFBS, PFOS, and PFOA.
 - Maine’s remedial action guidelines to avoid contamination of groundwater are 7100, 3.6, and 1.7 $\mu\text{g}/\text{kg}$ (ppb) of PFBS, PFOS, and PFOA in soil
- Denmark is the only country to prohibit intentional use of PFAS in food serviceware. They set an indicator value of 20,000 μg total organic fluorine (TOF) per kg of material (20 ppm). This is 5 \times lower than the 100,000 $\mu\text{g}/\text{kg}$ TOF (100 ppm) certification maximums set in 2020 by the Biodegradable Products Institute and the Compost Manufacturing Alliance.
- Strakova *et al.* found compostable serviceware exhibiting oil beading to range from 560 to 1200 mg TOF/kg. The dominant identified PFAS was 6:2 FTOH, which ranged from 92 to 4766 $\mu\text{g}/\text{kg}$ (median 580 $\mu\text{g}/\text{kg}$).
 - Note the 6:2 FTOH was 1000 times less than the TOF value
 - Many fluorinated organics are not being quantified by LC-MS/MS
- Schwartz-Narbonne *et al.* found the highest levels of total F (1–1.3 g F/m²) in four molded fiber bowls that were marketed as compostable. Analysis of 55 PFAS by LC-MS/MS only identified 0.02%–0.06% of the total F. Hydrolysis enabled identification of 2.4%–5.6% of the total F by freeing 6:2 FTOH, 6:2 FTMAc, and 6:2 FTAc from larger compounds, likely side-chain fluorinated polymers.
- The Maine Organic Farmers and Gardeners Association (MOFGA) has held an annual agricultural fair emphasizing sustainable rural living since 1977, attracting tens of thousands of attendees.
 - Fair organizers have always composted food waste, eventually including compostable single-use food serviceware — the provision of which was a requirement for food vendors.
 - Dissatisfactory compostability of serviceware led to separated composting of serviceware and food wastes starting in 2015.
- As PFAS contamination of agricultural land became a topic of great public concern in Maine in 2022, MOFGA tested its most recent compost (from 2019) and detected relatively high levels of PFAS.
 - Subsequent testing was done to confirm the results, and to assess contamination of earlier composts

- Serviceware since 2015 was placed in a 30 yard³ roll-off open top dumpster, and compacted by tractor weight.
- In 2015, food serviceware was composted with dairy bedding sand (removed from a manure lagoon and rain-washed). “Dirty sand” was added to serviceware at \sim 1:1 ratio by volume.
- After 2015, food serviceware was composted with dairy manure from a local farm, at \sim 20 yard³ of manure to 30 yard³ of serviceware.

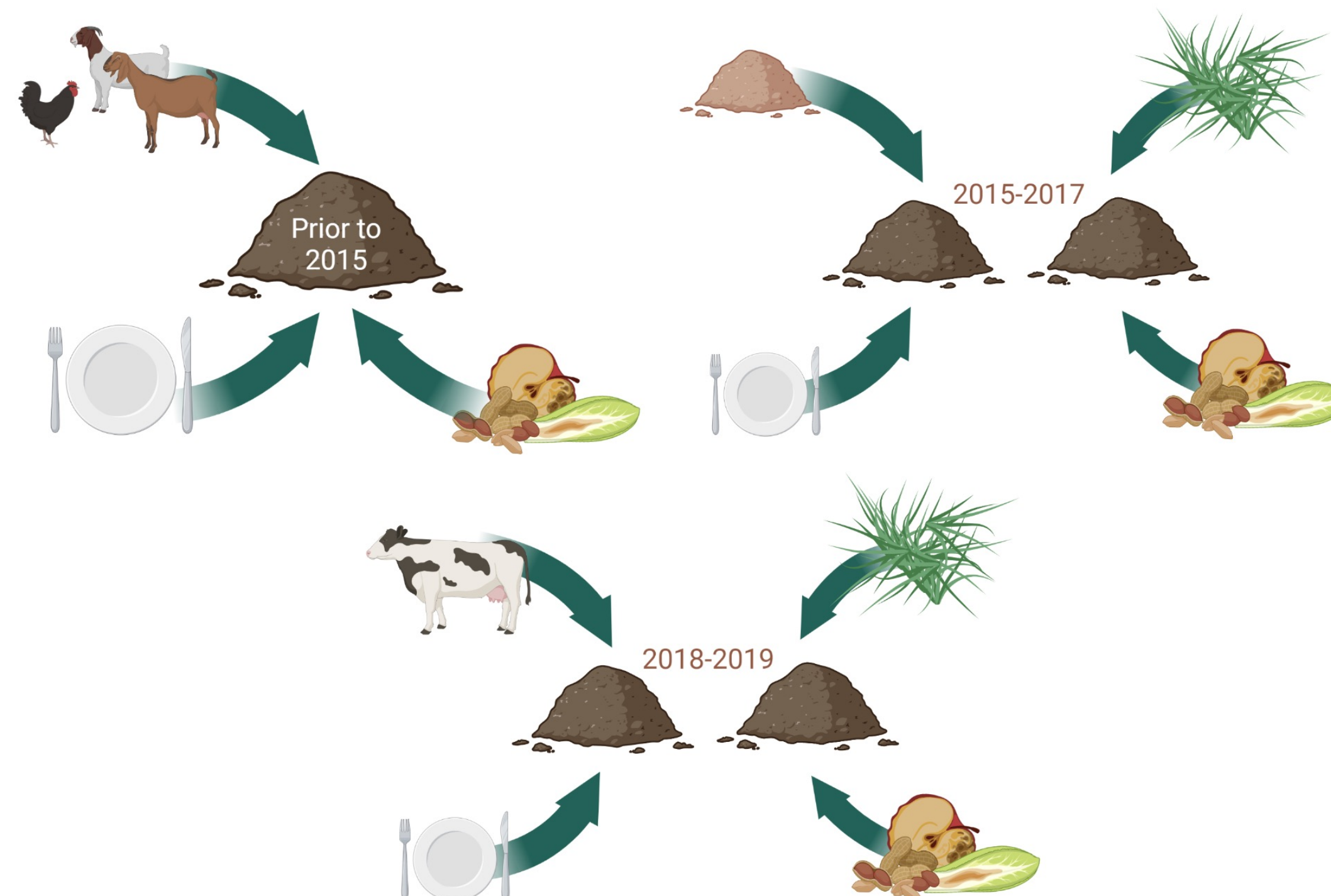


Figure 1. Compost components. All compost prior to 2015 included food waste, serviceware, grass clippings and display animal bedding and manure. In the years 2015 - 2017, food waste and serviceware were separated with food waste, grass clippings, and display animal bedding and manure composted together, and serviceware was composted with sand from a manure lagoon. In 2018 and beyond, food waste was composted in the same manner and serviceware was composted with dairy manure.

- All composts in all years were entirely rain-fed, with no additional water applied.
- All samples were sent to Alpha Analytical, Inc. for analysis of 28 PFAS compounds, using an LC-MS/MS method modified from the EPA method 537.

Results & Discussion

- PFAS analysis results (Fig. 2) show that serviceware composts can contain 20–45 times the total PFAS concentration compared to compost made primarily with food waste.
- 2019 compost had markedly higher levels of shorter-chained PFBA, PFPeA, and PFHxA. Older, more weathered composts from 2014-2017 had greater concentrations of longer-chained PFNA, PFDA, and PFDaA.
 - Shorter chain PFAS may have a greater tendency to leach into water systems, as they are less likely to sorb to soil and compost particles.
 - Differences in PFAS profiles between batches could be due to a longer maturation time resulting in higher concentrations of larger, immobile compounds and leaching of smaller molecules as compost continues to mineralize.
 - Alternatively, this result could reflect a shift in commercial PFAS usage from larger to smaller molecules over time.
- Choi *et al.* found composts with food packaging to contain about an order of magnitude greater concentrations of PFAAs than composts which did not include food packaging. Despite significant dilution from co-composting with relatively uncontaminated manure, we report total PFAA concentrations in serviceware inclusive composts (209–453 $\mu\text{g}/\text{kg}$) ranging from 2.5 \times to 5.8 \times the maximum concentration of total PFAAs (75 $\mu\text{g}/\text{kg}$) reported by Choi *et al.*
 - In both cases, PFOA levels found in serviceware inclusive composts were at least as great as the 2.5 $\mu\text{g}/\text{kg}$ regulatory threshold previously set for biosolids by the state of Maine, with our report showing that compost made with serviceware can exceed that threshold 18 times over.

- While results from 2019 serviceware inclusive compost are concerning, this likely represents a near-to-worst-case scenario. Most serviceware composting instances will not involve the separation and consolidation of serviceware from the overall compostable waste stream.
 - Had these serviceware composts utilized a more nitrogen-rich co-composting material to begin the composting process, less co-composting material would have been needed, and the PFAS concentrations in the final composts could very well have been even greater.
- Unlike biosolids, which are diluted during incorporation into soil, compost is also used at times as a standalone growing medium in raised beds or in no-till deep compost mulch systems. This could exacerbate potential for plant uptake, surface runoff, or leaching to groundwater.
- Another aspect regarding PFAS-contaminated soil or compost, infrequently discussed—but of potential concern—are possible health risks to farmers and composting facility workers stemming from inhalation and/or ingestion of contaminated organic matter, which is easily made windborne, and may leave considerable residue on hands.

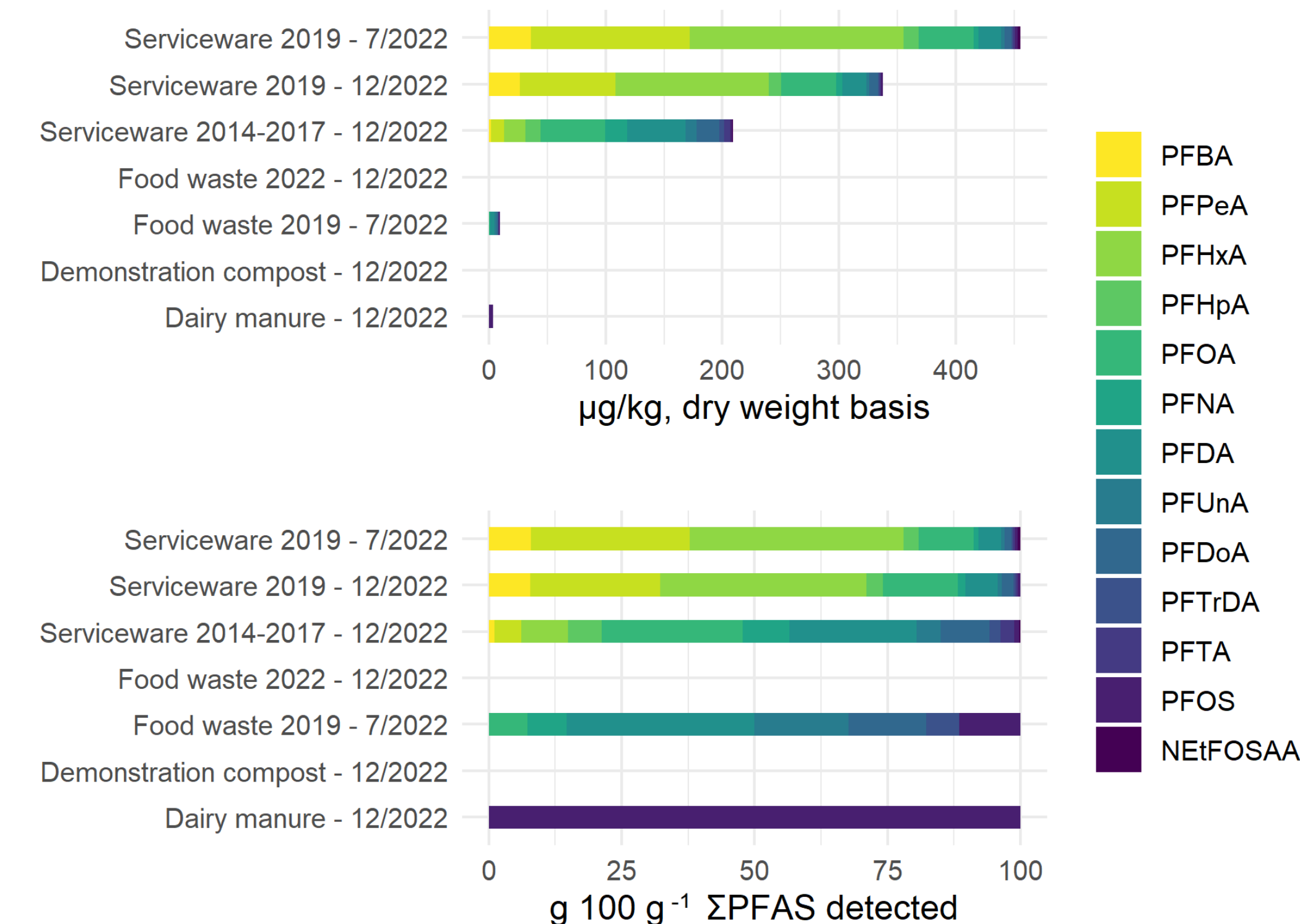


Figure 2. Analysis of 28 PFAS compounds from compost and manure samples, each a composite of ten representative subsamples, presented on $\mu\text{g}/\text{kg}$ dry weight basis and as a proportion of ΣPFAS detected. PFPeA and PFOA values in 07/22 sampling of Serviceware 2019 compost should be considered estimated, as they were re-extracted on dilution with the method required holding time exceeded in order to quantitate the results within the calibration range.

Conclusions

- We found compost made from manure and compostable serviceware contaminated with 20 - 45 times more PFAS chemicals than separated food waste composted with grass clippings and manure.
- In European and Canadian surveys of PFAS in food serviceware, <1% of TOF present and <6% of total F present, respectively, could be assigned to specific PFAS compounds, suggesting a large quantity of PFAS compounds in use, but not easily targeted for analysis
- Compostable serviceware is a potential source of PFAS contamination of composted food waste, and current guidelines limiting the amounts of fluorinated organics in compostable serviceware are insufficient to prevent contamination of compost with PFAS at levels above Maine’s PFOA screening threshold for soil remedial action to prevent leaching to groundwater, and Maine’s former screening threshold for biosolids.

References

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Method

TABLE I. Compost components.

Compost	Years	Components
Combined food waste and serviceware	2014 and prior	Food waste, serviceware, grass clippings, display animal bedding, and manure
Food waste	2015–2019, 2022	Food waste, grass clippings, display animal bedding, and manure
Serviceware	2015	Serviceware and sand from a manure lagoon (1:1)
Serviceware	2016–2019	Serviceware and dairy manure (3:2)