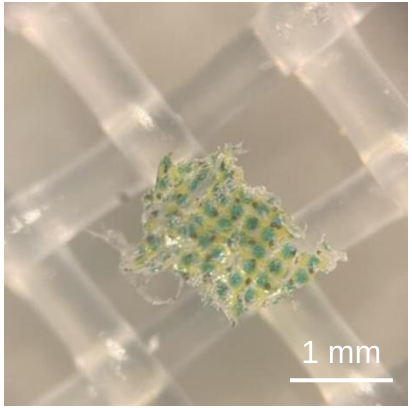
Microplastics in composts, digestates, & food wastes



Eric Roy, PhD, PE
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University of Vermont

Our team's recent & ongoing microplastics research

- **Comprehensive literature review**
  - ~150 papers reviewed by team.
  - Covers microplastics in composts, digestates, food waste, & agricultural soils.
  - Makes recommendations for better linking science & policy.
- **Quantification of microplastics in depackaged food waste, digestate, and composts**
  - Biogas potential and microplastic content of mechanically depackaged food waste.
  - Microplastics in compost: A state-wide survey across Vermont.
  - EPA-funded project underway includes biogas potential & microplastic characterization for food & beverage waste.
- **Linking life cycle assessment of food waste management with microplastics mass balance** (Porterfield & Roy, in progress)

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REVIEW & ANALYSIS

Microplastics in composts, digestates, and food wastes: A review

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Abstract

Diverting food waste from landfills to composting or anaerobic digestion can reduce greenhouse gas emissions, enable the recovery of energy in usable forms, and create nutrient-rich soil amendments. However, many food waste streams are mixed with plastic packaging, raising concerns that food waste-derived composts and digestates may inadvertently introduce microplastics into agricultural soils. Research on the occurrence of microplastics in food waste-derived soil amendments is in an early phase and the relative importance of this potential pathway of microplastics to agricultural soils needs further clarification. In this paper, we review what is known and what is not known about the abundance of microplastics in composts, digestates, and food wastes and their effects on agricultural soils. Additionally, we highlight future research needs and suggest ways to harmonize microplastic abundance and ecotoxicity studies with the design of related policies. This review is novel in that it focuses on quantitative measures of microplastics in composts, digestates, and food wastes and discusses limitations of existing methods and implications for policy.

How much microplastic contamination has been observed in composts, digestates, & food waste?

- 16 studies providing original data on microplastics in organic residuals were identified and reviewed.
- **Count values – typical ranges reported**
  - 12 to 82,800 particles per dry kg of green waste-derived compost
  - 20 to 30,000 particles per dry kg in composts made with food waste
  - 70 to 1,670 particles per dry kg digestate
  - 40 to 1,400 particles per dry kg food waste
- **% by mass – typical ranges reported**
  - 0.0002% to 0.14% by dry weight in composts
  - 0.01% by dry weight (1-5 mm) to 0.25% by dry weight in digestates
  - 0.025% in homogenized food waste to 5.6% w/w in source separated household biowaste (*higher value not directly measured – estimated by mass balance)
- **Key takeaway:** Microplastic contamination is a systemic challenge not limited to any one food waste processing strategy.

Porterfield et al. (2023a)

Additional key takeaways from literature review

- **Variability in estimates** can likely be driven by multiple factors, including feedstock, processing, and methods used (e.g., size fractions included)
- **No standard methods.** Researchers are using a variety of methods for isolating, identifying, and characterizing microplastics in complex organic matrices (Junhao et al., 2021; Ruggero et al., 2020).
- **Units matter.** Only a third of studies reviewed report values in both units of abundance (count MPs per dry kg) and mass (mass MP per dry kg)
- **Policies focus on weight-based limits.** This is incongruent with many studies quantifying only count-based estimates.
- **There is some evidence that microplastics may adversely affect soils and plants**; however, lack of common units between microplastic ecotoxicity and abundance studies precludes rigorous assessment.

Porterfield et al. (2023a)

Measuring microplastics: Prerequisite for monitoring and regulation

- NO standard method for measuring microplastics in complex organic matrices like food waste and digestate
  - Methods for water samples or mineral soil cannot simply be applied to organic residuals
  - Multiple options exist, all far from perfect
  - Can result in different units (count per mass, % weight per weight)

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Research Article

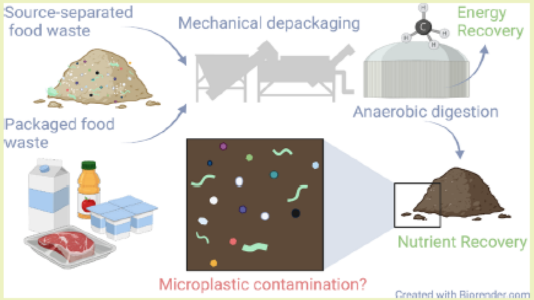
Organics Recycling Tradeoffs: Biogas Potential and Microplastic Content of Mechanically Depackaged Food Waste

Katherine K. Porterfield,* Matthew J. Scarborough, and Eric D. Roy

Cite This: https://doi.org/10.1021/acssuschemeng.3c01710

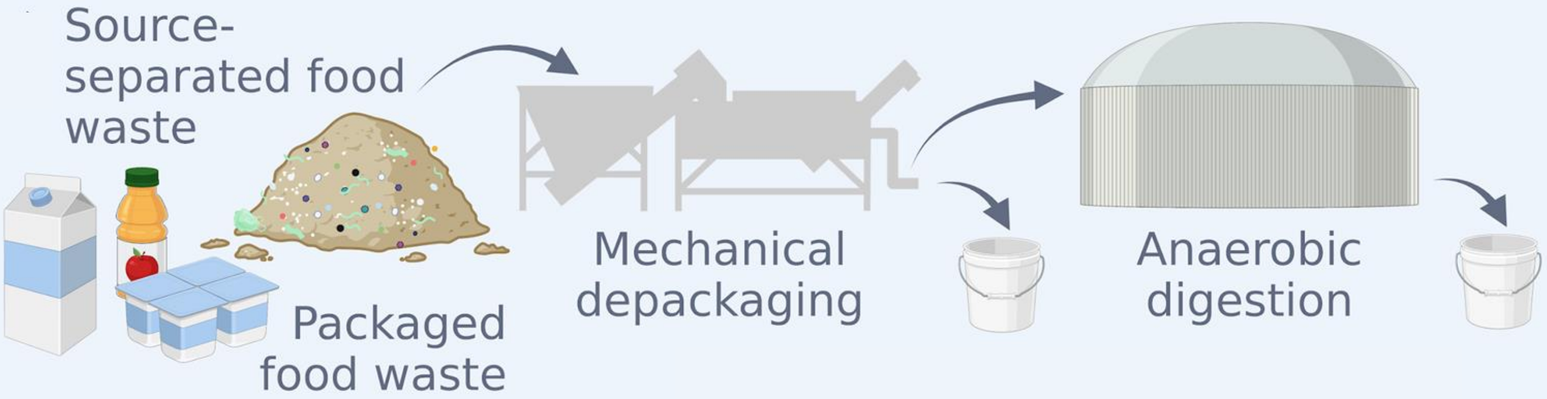
Read Online

ABSTRACT: Mechanical depackagers separate valuable organics from residual food packaging, creating new opportunities to recover energy (i.e., biogas) and nutrients (i.e., digestate) via anaerobic digestion (AD). However, the possibility of imperfect separation has raised concerns that digestate derived from depackaged food waste may contain microplastics (plastic particles <5 mm). To better understand this tradeoff, we evaluated biochemical methane potential (BMP) and other key AD parameters as well as plastic (0.5−1, 1−5, and >5 mm) content of two mechanically depackaged food waste streams and a derived digestate. The depackaged pre- and post-consumer organics had BMPs of 453 ± 52 and 435 ± 37 NmL CH_4 g^{-1} VS, respectively, indicating substantial potential for energy recovery via AD. However, plastic was found in both depackaged waste streams (0.19 ± 0.13 and 0.062 ± 0.05% w/w, respectively, for pre- and post-consumer) and the derived digestate (0.018 ± 0.019% w/w). While low on a mass basis, plastic contamination could limit digestate reuse options, potentially undercutting the environmental benefits of AD. Further work is needed to standardize methods for measuring the plastic content in organic residuals and to evaluate the life cycle costs and benefits of using mechanical depackaging to increase food waste diversion to AD.



KEYWORDS: *microplastics, food waste, mechanical depackaging, anaerobic digestion, resource recovery and reuse*

Methods



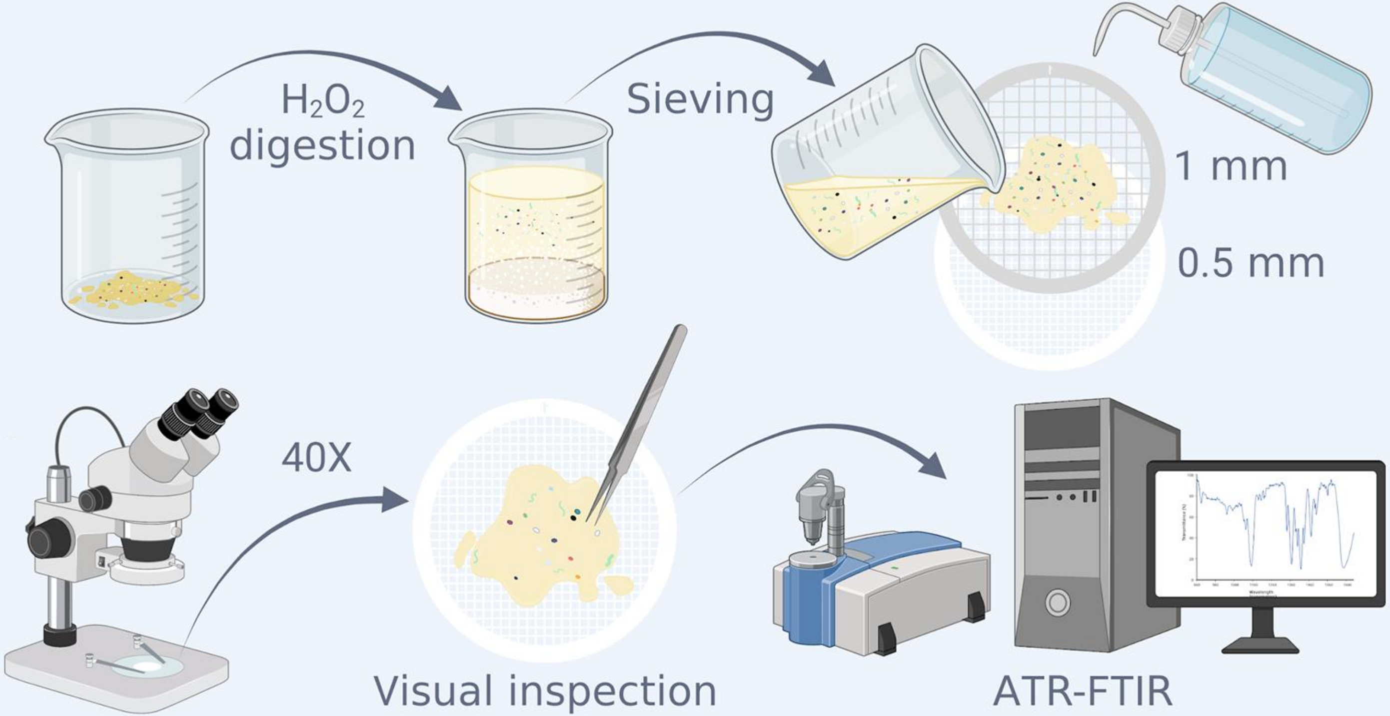
Sample Collection
- Pre-consumer ice cream pints and post-consumer food scraps
- Digestate

Biochemical Methane Potential (BMP)
- A measure of energy recovery potential using AD

Plastic Analysis
- No standard methods exist

Porterfield et al., 2023b, Created with BioRender.com

Quantifying plastic content



Plastic abundance
(particles/kg TS)

Plastic mass content
(%w/w TS)

Porterfield et al., 2023b, Created with BioRender.com

Depackaged pre- and post-consumer food wastes have high BMP = good energy recovery potential

Biochemical Methane Potential (BMP, NmL CH_4 g^{-1} VS)

- Depackaged pre-consumer ice cream pints: 453 ± 52
- Depackaged post-consumer food scraps: 435 ± 37

~2X BMP of dairy manure[1]
= high energy recovery potential

Porterfield, Roy et al. (2023b); [1]Kafle & Chen, 2016

Depackaged pre- and post-consumer food wastes contain microplastics

Plastic content (Total >0.5 mm)

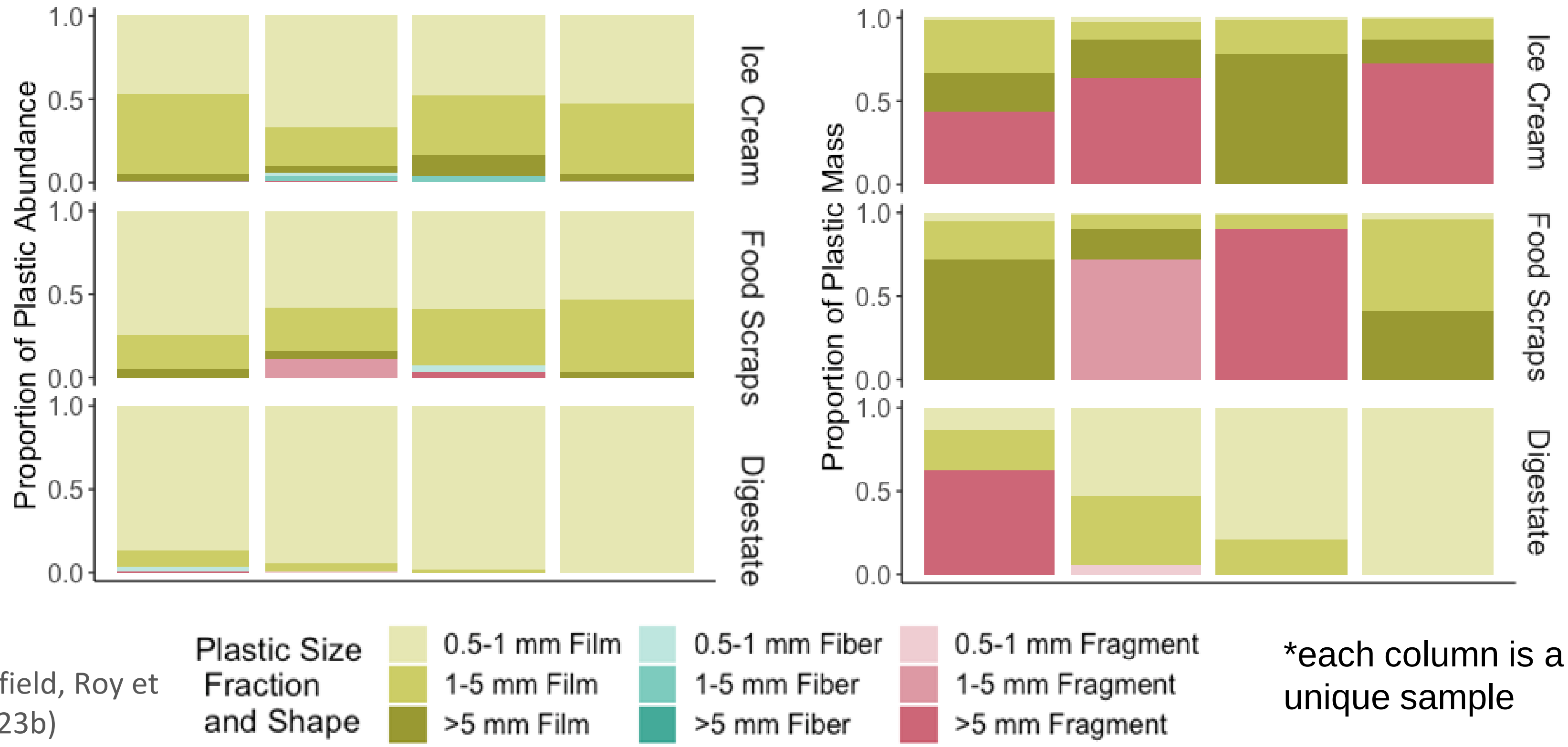
- Depackaged pre-consumer ice cream pints:
  - 11,000 ± 11,000 particles/kg TS
  - 0.19 ± 0.13% w/w TS
- Depackaged post-consumer food scraps:
  - 3,300 ± 1,100 particles/kg TS
  - 0.062 ± 0.05% w/w TS
- Digestate:
  - 12,000 ± 7,000 particles/kg TS
  - 0.018 ± 0.019% w/w TS

Low contamination rates on a %w/w basis consistent with literature reports for similar materials[1]

Units matter

[1]Porterfield et al., 2023a

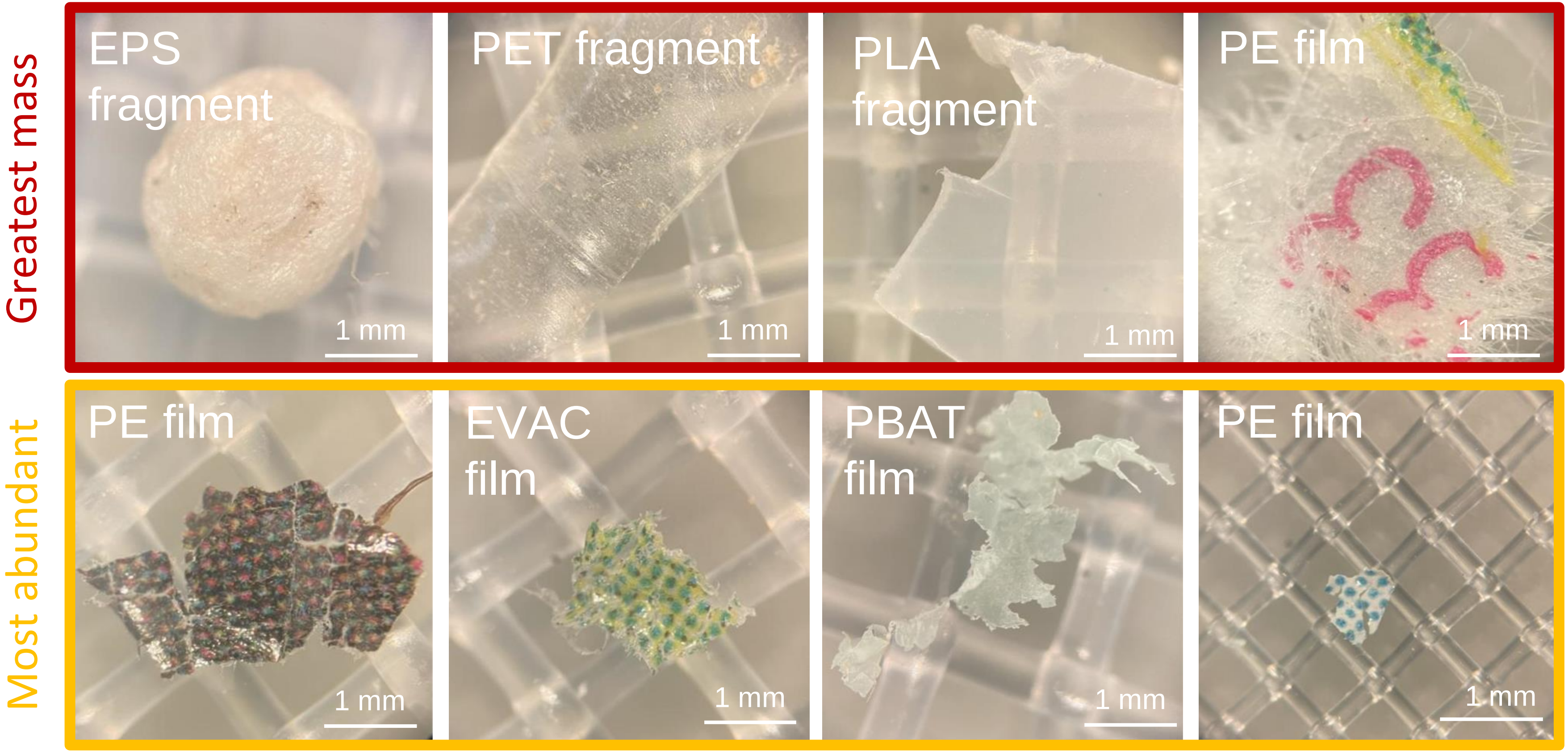
Small film plastics most abundant, but large fragments contribute disproportionately to %w/w



Porterfield, Roy et al. (2023b)

*each column is a unique sample

Examples of plastic polymers identified



Porterfield, Roy et al. (2023b)

Compost Study: Research Questions

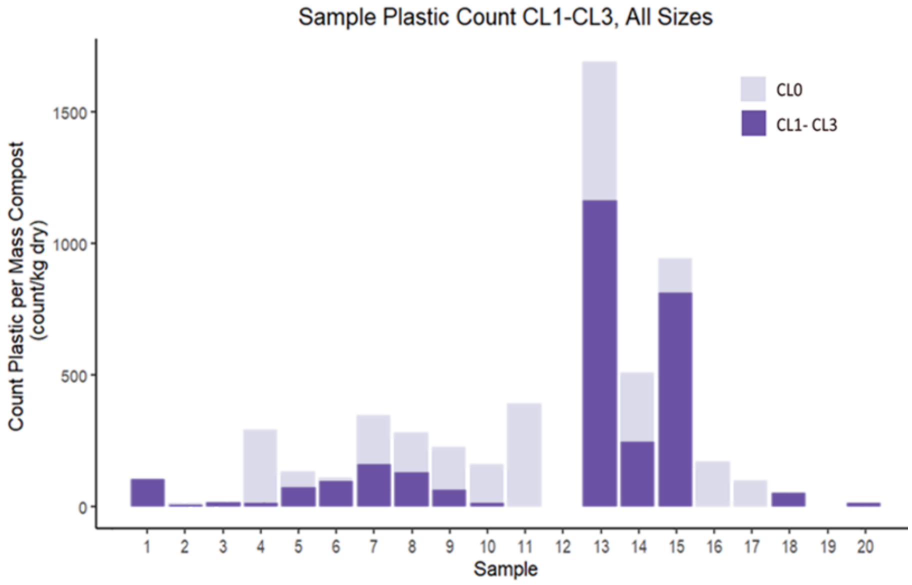
Q1. Are Vermont composts contaminated with microplastics?

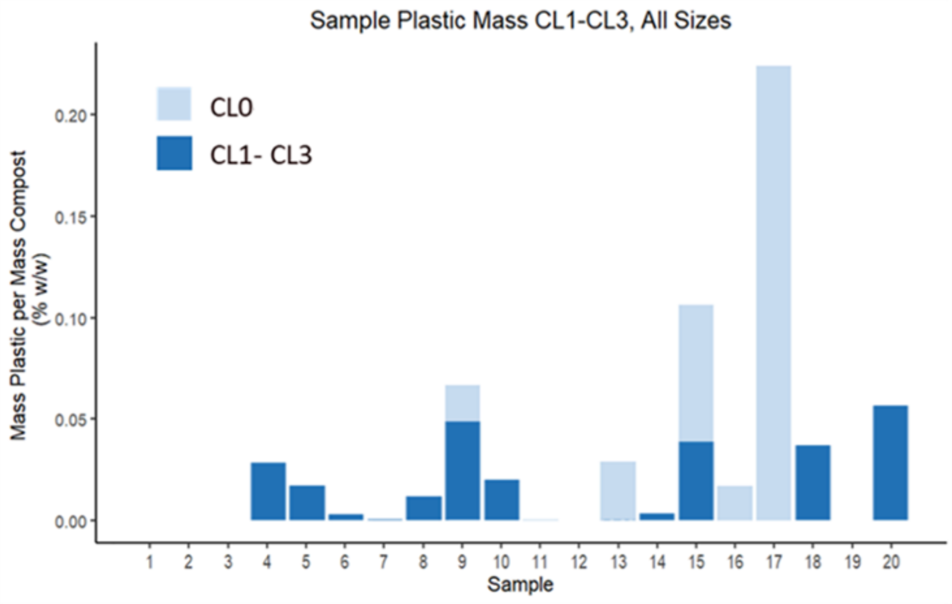
Q2. Are microplastics count & mass correlated?

Q3. What type of polymers are most common?

Compost microplastics counts & mass

DARKER SHADES = GREATER CONFIDENCE





Hobson, Porterfield, Roy et al. (in prep)

High food waste (n=14) vs. Low/no food waste (n=6)

Table 7*: Plastic Count and Mass per Dry Mass Compost for High Food Waste Composts*

	High FW	
Size Fraction	**By Count (count/dry kg)**	**By Mass (% w/w)**
0.5-1 mm	57 ± 97 (0-324)	0 ± 0.000 (0-0.000)
1-5 mm	126 ± 281 (0-982)	0.005 ± 0.011 (0-0.038)
>5 mm	8 ± 9 (0-27)	0.012 ± 0.019 (0-0.056)
Total	190 ± 363 (0-1201)	0.017 ± 0.020 (0-0.056)

Table 8*: Plastic Count and Mass per Dry Mass Compost for Low/No Food Waste Composts*

	Low/No FW	
Size Fraction	**By Count (count/dry kg)**	**By Mass (% w/w)**
0.5-1 mm	39 ± 61 (0-127)	0.0003 ± 0.0006 (0-0.0016)
1-5 mm	24 ± 51 (0-127)	0.0003 ± 0.0007 (0-0.0017)
>5 mm	2 ± 5 (0-13)	0.0033 ± 0.0081 (0-0.0198)
Total	65 ± 101 (0-255)	0.0038 ± 0.0079 (0-0.0198)

Hobson, Porterfield, Roy et al. (in prep), CL1-CL3

Key takeaways

- Microplastic contamination is a systemic challenge in organics recycling, and not necessarily linked to any single organics management strategy
- Not well understood extent to which organics recycling is an important flow of microplastics to the environment relative to other sources
- Food packaging likely the dominant source of microplastics (and PFAS) in food waste streams and derived composts or digestates

Ongoing Work: Life Cycle Assessment

Q1. What environmental **benefits** and **burdens** are associated with different food waste management strategies (i.e., landfilling, composting, anaerobic digestion)?

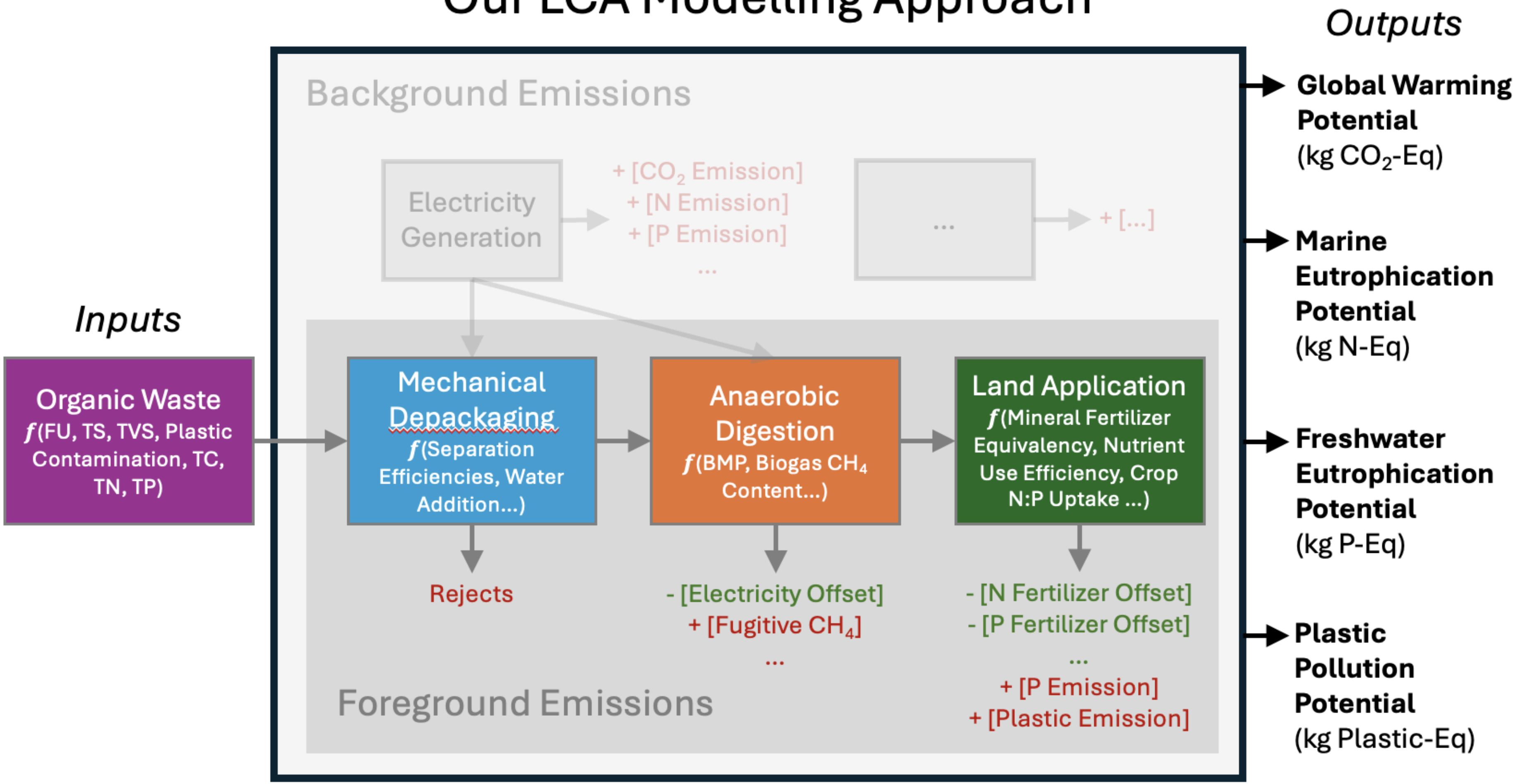
Q2. What is the flow of microplastics to agricultural soils under different management scenarios?

Q3. Do food waste stream characteristics (e.g., TS, contamination rate etc.) influence the optimal management strategy?

LCA Goal and Scope

- **Goal:** inform food waste management decisions in the state of VT under the new diversion mandates established by Act 148
- **Functional Unit:** 1 ton of mixed post-consumer food waste managed, including all contaminants therein
- **Scenarios:**
  - 1: Landfilling
  - 2: Anaerobic digestion
  - 3: Composting
- **Impact Categories:**
  - Global warming potential (units of kg CO_2 equivalents)
  - Eutrophication potential
    - Marine (units of kg N equivalents)
    - Freshwater units (units of kg P equivalents)
  - Plastic pollution (kg plastic)

Our LCA Modelling Approach



Porterfield & Roy (in preparation)

Our modelling approach is novel because…

Based in C:N:P ratios and mass balance principles

Can model food waste streams with different characteristics

Predicts plastic flow to agricultural soils resulting from land application of organic residuals

Generates a range of possible outcomes based on variability in the input parameters

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Counting microplastics under the microscope (Photo: Luke Awtry for Seven Days)

Questions?