Impact of Food Waste Diversion on Landfill Gas and Leachate from Simulated Landfills

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GHG Reporting Program – MSW Landfills

Graph showing GHG emissions and facilities reporting from 2010 to 2017. The emissions trend shows a slight decrease over the years.
Landfill disposal is increasing
Waste 101

• Municipal solid waste (MSW) is common, household garbage
  – Food
  – Paper and packaging
  – Clothes
  – Plastics
  – Glass

• MSW is generated at homes, businesses, hotels, conferences, etc.

• In the US, 80% of MSW is landfilled
  – 20% is incinerated
Food waste in states

- Vermont
  - 2020 residential ban on food waste disposal

- Massachusetts
  - Commercial Food Material Disposal Ban
  - MassDEP regulations ban disposal of food and other organic wastes from businesses and institutions that dispose of more than one ton of these materials per week.
  - [https://www.mass.gov/guides/commercial-food-material-disposal-ban](https://www.mass.gov/guides/commercial-food-material-disposal-ban)

- California
  - Mandatory Commercial Organics Recycling
  - [https://www.calrecycle.ca.gov/recycle/commercial/organics](https://www.calrecycle.ca.gov/recycle/commercial/organics)
Landfill GHG Emission Factors

• $L_0$ – methane generation potential ($m^3 \text{CH}_4$/Mg waste)
  – Volume of methane per ton of garbage landfilled

• $k$ – methane generation rate constant ($yr^{-1}$)
  – Rate at which that garbage decays in a landfill
Modeling Landfill CH4 Generation and Emissions

- **Generation**
  - First-Order Decay kinetics
- **Collection** = assume or measure
- **Oxidation** = (Gen – Col) \* OXF
- **Emissions** = Gen – Col – Ox

\[ Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_i \left( \frac{M_j}{10} \right) e^{-kt_{ij}} \]
MSW Component Decay Rates

Data source: Intergovernmental Panel on Climate Change, 2006

Data source: US EPA - GHGRP, 2010
What’s the problem?

- Food contains:
  - lots of moisture
  - Nutrients (N, P, S)
    - Nitrogen
    - Phosphorous
    - Sulfur
  - Degrades quickly
- Model assumes each waste stream decays independently of the others
Composition hasn’t changed

[Bar chart showing waste composition from 2012 to 2015. Each bar is divided into segments for food, paper, yard, metals, textiles, other, plastics, wood, and glass. The chart indicates that the composition hasn’t changed significantly over the years.]
Model food waste diversion without changing emission factors

Difference between the two is due to the less tons going to landfill.
Is our modeling practice correct?

• Can we accurately model landfill diversion programs with the model? ➠ Seems unlikely

What’s the solution?

• Examine new emission factors
Biochemical methane potential assays
Biochemical methane potentials

![Graph showing cumulative CH4 generation (mL) over time for different materials: Food, Paper, Yard, Wood, Cotton, and Inert.](image)

- **Cumulative CH4 generation (mL)**
- **0 5 10 15 20 25 30**

Legend:
- Food
- Paper
- Yard
- Wood
- Cotton
- Inert
# Getting $L_0$ from BMP

<table>
<thead>
<tr>
<th>MSW</th>
<th>Waste Composition (%)</th>
<th>Moisture (%)</th>
<th>Mass of water</th>
<th>Mass of solid</th>
<th>BMP (mL CH4/g dry mass)</th>
<th>mL CH4</th>
<th>$L_0$</th>
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<td><strong>81.1</strong></td>
<td><strong>63</strong></td>
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</tbody>
</table>

\[
\frac{81 \text{ mL CH}_4}{g \text{ dry waste}} \times \frac{78 \text{ g dry waste}}{100 \text{ g wet waste}} = \frac{63 \text{ mL CH}_4}{g \text{ wet waste}}
\]

\[
L_0 = \frac{63 \text{ m}^3 \text{ CH}_4}{g \text{ wet waste}}
\]
Getting $L_0$ from BMP w/o food waste

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<td><strong>42</strong></td>
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\[
\frac{46.8 \text{ mL CH}_4}{\text{g dry waste}} \times \frac{70.3 \text{ g dry waste}}{78.0 \text{ g wet waste}} = \frac{42 \text{ mL CH}_4}{\text{g wet waste}}
\]

\[
L_0 = \frac{42 \text{ m}^3 \text{ CH}_4}{\text{g wet waste}}
\]
What did we learn?

- MSW with food waste (normal MSW)
  - $L_0 = 63 \text{ m}^3/\text{Mg} \text{ waste}$
- MSW without food waste (future MSW stream)
  - $L_0 = 42 \text{ m}^3/\text{Mg} \text{ waste}$

Could expect a 33% decrease in $L_0$ with diversion of all food waste from landfills

Let’s just throw them all in a reactor and see what happens.
Let’s run a mix of each: with and w/o food waste

Cumulative Methane Generation (mL)

- MSW: 2069 mL
- MSW w/o food: 1431 mL

% difference = -31%
BMPs are good for one thing

• Determining the ultimate amount of methane we can generate from a material

• BMPs are substrate-limited
  – Excess moisture
  – Neutral pH
  – All nutrient req’mts

• Bad for estimating the rate of decay
How do we estimate decay?
Simulated Landfills CH4 generation

Cumulative CH4 Generation (L)

- MSW
- MSW w/o Food

Lag phase, pH below 7
Linear regression to get $k$

Carbon Half-life = 365 days

$y = -0.0019x + 0.016$

Carbon Half-life = 578 days

$y = -0.0012x + 0.0023$
No-food emission factors: less emissions up front, more emissions later

Better opportunities to install gas collection systems before emissions start
Conclusions

• Removing food waste reduces methane potential ($L_0$) by 33% and slows the rate ($k$) of decay by 37%
  – AP-42 Inventory:
    – $L_0 = 100$
    – $k = 0.04$

• Broader effects for
  – Energy recovery
  – Emissions of NMOCS
  – Leachate quality and quantity
  – Slope stabilization
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