Air Emissions from Landfill-Gas-to-Energy Engines: A Health Risk?

Federation of New York Solid Waste Associations
Solid Waste & Recycling Conference

May 18, 2016

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Motivation

- **Benefits of Landfill Gas-to-Energy**
  - Alternative to flaring
  - Electricity generation
  - Lower greenhouse gas emissions

- **Potential Environmental Impacts**
  - Combustion pollutants – CO, NOx
  - Air toxics concerns – formaldehyde
Outline

- Formaldehyde characteristics
  - Sources
  - Toxicity
  - Background concentrations
- Landfill gas-to-energy example
  - Emissions
  - Ambient impacts
  - Control options
Formaldehyde

- Hazardous Air Pollutant
- Ubiquitous in outdoor and indoor air
- Highly soluble gas at ambient conditions
- Odor threshold: 600 – 1,200 µg/m³
- Atmospheric sources include:
  - Fuel combustion
  - Building materials
  - Chemical formation
Sources of Formaldehyde in Air (MA)
2011 EPA National Air Toxics Assessment

- Modeled statewide average concentration = 1.2 µg/m³
- Secondary = chemical reactions
Formaldehyde Toxicity

- **Strong respiratory irritant**
  - OSHA PEL: 900 µg/m³
  - California REL: 9 µg/m³
  - ATSDR MRL: 10 µg/m³
  - EPA draft RfC: 3 – 11 µg/m³

- **Carcinogenicity**
  - EPA in 1989: Probable in humans (Class B1)
  - IARC in 2004: Human carcinogen
  - EPA in 2010: Human carcinogen
  - Unit risk factors
    - EPA Current: 0.000013 m³/µg
    - EPA Draft: 0.00011 m³/µg
# Formaldehyde State Guidelines

<table>
<thead>
<tr>
<th>State</th>
<th>Annual (µg/m³)</th>
<th>Short-Term Concentration (µg/m³)</th>
<th>Period (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>9</td>
<td>55, 9</td>
<td>1, 8</td>
</tr>
<tr>
<td>Connecticut</td>
<td>0.08</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Louisiana</td>
<td>7.7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>0.08</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>New York</td>
<td>0.06</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Texas</td>
<td>1.5</td>
<td>15</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Background Air Quality

- Formaldehyde common indoors & outdoors at levels > 1 µg/m³
- Indoor levels can be much greater than outdoor levels due to releases from resin-based building materials (e.g., pressed board)

from CARB (2004) 1 ppb = 1.2 µg/m³
Case-Specific Example

- New landfill gas-to-energy engines in MA
- First LFTGE project in MA required to evaluate formaldehyde impacts
- Compare to state guidelines
  - 0.08 µg/m³ annual AAL
  - 2 µg/m³ 24-hr TEL
- Preliminary modeling
  - AAL and TEL exceeded

[Image of a large engine]
Site-Specific Risk Assessment

- Consider more realistic exposure
  - 30 years v. 70-year lifetime
- Health endpoints/targets
  - Long-term risk of cancer – 10 per million target
  - Short-term irritation effects – hazard quotient 1
- Use current toxicity data
  - EPA cancer unit risk factor 0.000013 µg/m³
  - ATSDR Minimum Risk Level 10 µg/m³
- Consider site-specific background
Formaldehyde Outdoor Background
DEP monitoring data and EPA 2011 NATA model

Local background ~ 2 µg/m³
# Formaldehyde Emission Test Results

National Association of Clean Air Agencies and Pennsylvania Waste Industries Association compilations

<table>
<thead>
<tr>
<th>State</th>
<th># Tests</th>
<th>Formaldehyde Emissions (g/bhp-hr)</th>
<th></th>
<th></th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Average</td>
<td></td>
</tr>
<tr>
<td>Arkansas</td>
<td>1</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
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<tr>
<td>Delaware</td>
<td>7</td>
<td>0.20</td>
<td>0.50</td>
<td>0.34</td>
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</tr>
<tr>
<td>Iowa</td>
<td>1</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>Maryland</td>
<td>1</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
<td></td>
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<tr>
<td>Michigan</td>
<td>14</td>
<td>0.11</td>
<td>0.39</td>
<td>0.30</td>
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<tr>
<td>New Jersey</td>
<td>3</td>
<td>0.22</td>
<td>0.25</td>
<td>0.23</td>
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<tr>
<td>Pennsylvania</td>
<td>28</td>
<td>0.007</td>
<td>0.33</td>
<td>0.11</td>
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<tr>
<td>Wisconsin</td>
<td>9</td>
<td>0.20</td>
<td>0.78</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Weighted Average =&gt;</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Preliminary Dispersion Modeling
Modeling Scenarios and Methods

- CAT 3520 engines (2,240 hp each)
  - 1 existing
  - 1 to 3 new
- 9.5–19 tons/yr formaldehyde (most of VOCs ?)
- AERMOD with 5-years meteorological data
- Worst-case short-term (24-hr) and average long-term impacts (per basis of TEL and AAL)
- Receptor locations: Fenceline vs. residences
3-Engine Simulations: Preliminary Results

24-hr

Brown: > 2 µg/m³
Green: > 8 µg/m³
Blue: > 10 µg/m³ (none)

5-yr

Brown: > 0.08 µg/m³
Green: > 0.77 µg/m³
Blue: > 1.87 µg/m³ (none)
Maximum Residential Impacts
Preliminary Results (µg/m³)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>24-Hour Target: 8 RfC – background</th>
<th>5-yr Average Target: 1.87 30 yr, 10⁻⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Engines</td>
<td>1.4</td>
<td>0.14</td>
</tr>
<tr>
<td>3 Engines</td>
<td>2.2</td>
<td>0.24</td>
</tr>
<tr>
<td>4 Engines</td>
<td>2.9</td>
<td>0.31</td>
</tr>
</tbody>
</table>
Options to Reduce Formaldehyde Impacts

- Lean burn engines trade off NOx and CO emissions
  - CO and formaldehyde are both combustion byproducts
- Better engine maintenance and tuning
- Pre-combustion removal of siloxane gases (?)
- Post-combustion control (?)
  - Thermal oxidation – *cost prohibitive*
  - Catalytic oxidation – *technically infeasible*
- Changes to facility design
  - Raise stack/exhaust height
  - Increase buffer distance to fenceline
  - Site layout to minimize building downwash
Conclusions

- State guidelines for formaldehyde may be difficult to meet in permit modeling
  - Guidelines lower than background
  - Emissions from near-ground source
- Site-specific risk assessment may be able to demonstrate acceptable impacts
- Uncertainties relate to potential emissions variability and dispersion modeling
Quiz Question #1

What are the two principal health effects concerns over formaldehyde at ambient concentrations?

(a) it causes asphyxiation and paralysis
(b) it is a probable carcinogen
(c) it causes skin discoloration
(d) it causes blindness
(e) it is a respiratory irritant
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(b) it is a probable carcinogen
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(d) it causes blindness
(e) it is a respiratory irritant
Quiz Question #2

Which are likely emission sources of formaldehyde (check all that apply)?

(a) new building materials such as particle board products
(b) landfill gas-to-energy engines
(c) automobile exhaust
(d) gas-fired cook stoves
(e) chemical reactions in the atmosphere involving hydrocarbons
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(c) automobile exhaust  
(d) gas-fired cook stoves  
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Quiz Question #3

What level of formaldehyde is typically present in ambient air?

(a) a few ng/m$^3$
(b) a few µg/m$^3$
(c) a few mg/m$^3$
(d) a few g/m$^3$
(e) formaldehyde is typically not present in ambient air at measurable levels
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Quiz Question #4

How is formaldehyde regulated as an air pollutant (more than one answer may apply)?

(a) as a Criteria Pollutant subject to National Ambient Air Quality Standards
(b) as a Hazardous Air Pollutant subject to Maximum Achievable Control Technology
(c) as a Prevention of Significant Deterioration pollutant
(d) under New York’s Air Toxics Program (Part 212 Regulations)
(e) as an Ozone Depleting Substance
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Quiz Question #5

What are potential options to reduce exposure to formaldehyde from landfill-gas-to-energy emissions (more than one answer may apply)?

(a) install a Selective Catalytic Reduction (SCR) system
(b) raise the height of the engine exhaust point
(c) place the engine further away from the property line boundary
(d) tune and maintain the engine
(e) install a Catalytic Oxidation system
Quiz Question #5

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Your Questions?

- Contact for more information
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- Thanks to colleagues David Adams, Jeffrey Doris, Heather Billington, & Eric Steinhauser
Extra Slides
(for Questions, not Presentation)
Formaldehyde Outdoor Background
MA Data, 2013-2015 Average of Monthly Averages

Formaldehyde Monitoring Data
Overall monthly averages

Formaldehyde Concentration (µg/m³)

Lynn
Chicopee
Boston

24-hr TEL
Annual AAL
Formaldehyde Outdoor Background
RI Data, 2013-2015 Average of Monthly Averages
Formaldehyde Outdoor Background
VT Data, 2013-2015 Average of Monthly Averages

Formaldehyde Monitoring Data at VT Locations
Overall monthly averages

Formaldehyde Concentration (µg/m³)

- Underhill
- Burlington
- Rutland

24-hr TEL
Annual AAL
Formaldehyde Outdoor Background
NY Data, Average of 2013-2015 Data

Formaldehyde Monitoring Data at NY Locations
Averages over available 2013-2015 data

- NYC - Bronx
- NYC - Bronx
- NYC - Queens
- NYC - Staten Island
- Cheektowaga
- Tonawanda
- Tonawanda
- Rochester
- Rochester
- Albany
- Whiteface Mountain

24-hr TEL
Annual AAL
Formaldehyde Background
EPA 2011 NATA model (relative comparison)
Formaldehyde Background
2013 to 2015 DEP Lynn monitoring data

Lynn
Mean monthly concentration = 2.1 ug/m3, 50% > 2 ug/m3
Formaldehyde Background
2013 to 2015 DEP Chicopee monitoring data

Chicopee
Mean monthly concentration = 2.7 μg/m³, 73% > 2 μg/m³
Formaldehyde Background
2013 to 2015 DEP Boston monitoring data

Boston
Mean monthly concentration = 3.7 ug/m³, 94% > 2 ug/m³
2-Engine Simulations: Preliminary Results

24-hr

Brown: > 2 µg/m³
Green: > 8 µg/m³ (none)
Blue: > 10 µg/m³ (none)

5-yr

Brown: > 0.08 µg/m³
Green: > 0.77 µg/m³ (none)
Blue: > 1.87 µg/m³ (none)
4-Engine Simulations: Preliminary Results

24-hr

Brown: > 2 µg/m³
Green: > 8 µg/m³
Blue: > 10 µg/m³

5-yr

Brown: > 0.08 µg/m³
Green: > 0.77 µg/m³
Blue: > 1.87 µg/m³ (none)