5. LFG Properties and Movement (English)

**Introduction**

- **LFG Generation**
- **LFG Migration**
- **Landfill Gas as Liability: Environmental Issues; Safety Concerns**
- **Landfill Gas as an Asset; Energy Recovery**

### Molecular Makeup of Different types of Municipal Refuse

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass % (dry basis)</th>
<th>C</th>
<th>H</th>
<th>O</th>
<th>N</th>
<th>S</th>
<th>Ash</th>
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<tbody>
<tr>
<td>Organic</td>
<td></td>
<td></td>
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<tr>
<td>Food waste</td>
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<td>6.40</td>
<td>37.60</td>
<td>2.60</td>
<td>0.40</td>
<td>5.00</td>
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<td>6.00</td>
<td>44.00</td>
<td>0.30</td>
<td>0.20</td>
<td>8.00</td>
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<td>5.90</td>
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<td>10.00</td>
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<td>Textiles</td>
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<td>4.60</td>
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<tr>
<td>Rubber</td>
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<td>0.00</td>
<td>2.00</td>
<td>0.00</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>Leather</td>
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<td>8.00</td>
<td>11.60</td>
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<td>Yard waste</td>
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<td>38.00</td>
<td>3.40</td>
<td>0.30</td>
<td>4.50</td>
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<tr>
<td>Wood</td>
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<td>42.70</td>
<td>0.20</td>
<td>0.10</td>
<td>1.50</td>
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</tr>
</tbody>
</table>

### Refuse Decomposition

- **Aerobic Phase** - Early phase of refuse decomposition can continue to occur in areas where air infiltrates the landfill
  
  \[
  \text{Cellulose} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{Heat} \quad (130 \text{ deg F} \to 160 \text{ deg F})
  \]

- **Transition Phase** - Fermentation

- **Anaerobic Phase** - After all \( \text{O}_2 \) is consumed, landfill gas is produced anaerobically. Anaerobically means without oxygen.
  
  \[
  \text{C}_n\text{H}_m\text{O}_q \rightarrow \text{CH}_4 + \text{CO}_2
  \]
  
  \( \text{Waste} \quad \text{(Methane)} \quad \text{(Carbon Dioxide)} \)

### Landfill Gas Generation

- Amount of LFG production is governed by amount of waste
- Rate of LFG production is governed by: age of waste; moisture content; temperature; \( \text{pH} \); and other factors
- These factors cannot be easily modified
- A modeling assumption is that LFG production peaks about 1 year after waste placement and decreases 2% to 8% per year thereafter

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5. LFG Properties and Movement (English)

LFG Composition - GHG Effect
- Methane (CH₄) 45 to 58% 23x
- Carbon Dioxide (CO₂) 35 to 45% 1x
- Oxygen (O₂) < 1 to 5%
- Nitrogen < 1 to 5%
- Hydrogen < 1 to 5%
- Water Vapor 1 to 5%
- Trace Constituent < 1 to 3%

Landfill Gas Characteristics
- As-Produced:
  - Methane 55% to 60%
  - Carbon Dioxide 45% to 40%
- Immediate Additions:
  - Moisture
  - Volatile organic compounds (NMOCs)
  - Hydrogen Sulfide (H₂S)
- Dilution:
  - Nitrogen
  - Oxygen

Landfill Gas Characteristics
- Moisture - The maximum amount of moisture that gas can hold is primarily a function of gas temperature
- Volatile Organic Compounds (VOCs) – VOCs are stripped from the waste by the LFG
  - Hydrogen Sulfide (H₂S)
  - Odor

Landfill Gas Characteristics
- Hydrogen (H₂)
- Oxygen (O₂)
- Nitrogen (N₂)

LFG Movement
- Once generated, LFG cannot be contained within the landfill.
- LFG seeks to escape the landfill via the path of least resistance. Two routes:
  1. Migration into the soils which may lead into structures
  2. Through the landfill cover into the atmosphere.

Landfill Gas Characteristics
- Advection (pressure)
- Diffusion (concentration)

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**LFG Movement**

- Advective flows will predominate diffusive flows
- Internal gas pressures vary greatly and depend on:
  - LFG generation rate
  - Barriers to LFG movement, i.e., perched water, cover, liners, leachate.
- LFG pressures range from atmospheric to several inches of water column, although isolated readings can be in the PSI range.

**Landfill Gas Movement – Pressure Impact**

**Landfill Gas Movement – Concentration Impact**

**LFG Movement**

**LFG Liabilities**

- Explosion and Fire Hazards
- Toxic Hazards
- Asphyxiation Hazards
- Smog Formation
- Greenhouse Effect
- Odors
- Vegetation Damage
- Groundwater Contamination

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LFG Assets

- Energy (CH₄ = 1012 Btu/scf)
  - High Btu - pipeline quality gas
  - Medium Btu - direct sale industrial fuel
  - On-site electric generation
  - CNG/LNG
  - Leachate Evaporation