5. LFG Properties and Movement (English)

Methane to Markets

Landfill Gas Properties and Movement

Introduction

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

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Molecular Makeup of Different types of Municipal Refuse

Component	Mass % (dry basis)					
	C	H	O	N	S	Ash
Organic						
Food waste	48.00	6.40	37.60	2.60	0.40	5.00
Paper	43.50	6.00	44.00	0.30	0.20	6.00
Cardboard	44.00	5.90	44.60	0.30	0.20	5.00
Plastics	60.00	7.20	22.80	0.00	0.00	10.00
Textiles	55.00	6.60	31.20	4.60	0.15	2.50
Rubber	78.00	10.00	0.00	2.00	0.00	10.00
Leather	60.00	8.00	11.60	10.00	0.40	10.00
Yard waste	47.80	6.00	38.00	3.40	0.30	4.50
Wood	49.50	6.00	42.70	0.20	0.10	1.50

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Refuse Decomposition

- Aerobic Phase - Early phase of refuse decomposition can continue to occur in areas where air infiltrates the landfill

Cellulose $\rightarrow CO_2 + H_2O$ + Heat (130 deg F – 160 deg F)

- Transition Phase - Fermentation
- Anaerobic Phase - After all O_2 is consumed, landfill gas is produced anaerobically. Anaerobically means without oxygen.

$C_NH_NO_N \rightarrow CH_4 + CO_2$
(Waste) (Methane) (Carbon Dioxide)

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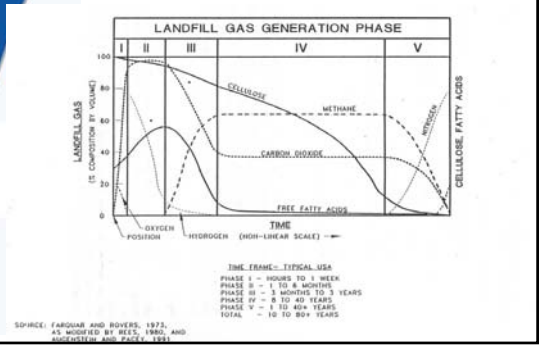
Landfill Gas Generation



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; pH; and other factors
- These factors cannot be easily modified
- A modeling assumption is that IFG production peaks about 1 year after waste placement and decreases 2% to 8% per year thereafter

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LFG Composition - GHG Effect

Methane (CH_4)	45 to 58%	23x
Carbon Dioxide (CO_2)	35 to 45%	1x
Oxygen (O_2)	< 1 to 5%	
Nitrogen	< 1 to 5%	
Hydrogen	< 1 to 5%	
Water Vapor	1 to 5%	
Trace Constituent	< 1 to 3%	

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Landfill Gas Characteristics

- As-Produced:
  - Methane 55% to 60%
  - Carbon Dioxide 45% to 40%
- Immediate Additions:
  - Moisture
  - Volatile organic compounds (NMOCs)
  - Hydrogen Sulfide (H_2S)
- Dilution:
  - Nitrogen
  - Oxygen

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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 (H_2S)
- Odor

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Landfill Gas Characteristics

- Hydrogen (H_2)
- Oxygen (O_2)
- Nitrogen (N_2)

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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.

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LFG Movement

- Advection (pressure)
- Diffusion (concentration)

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5. LFG Properties and Movement (English)

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.

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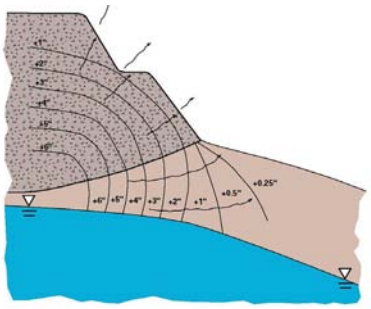
Landfill Gas Movement – Pressure Impact



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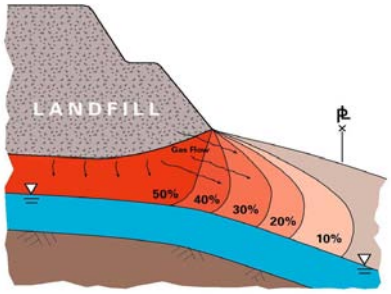
Landfill Gas Movement – Concentration Impact



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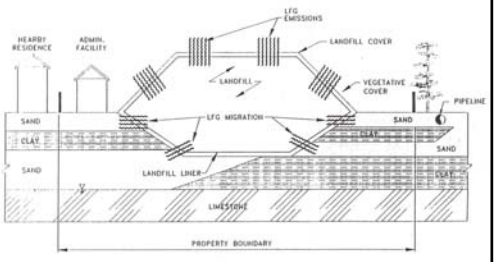
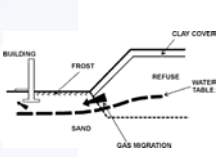
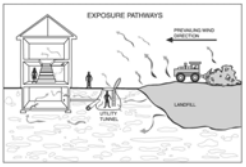
LFG Movement



LFG Movement





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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 (CH_4 = 1012 Btu/scf)
  - High Btu - pipeline quality gas
  - Medium Btu - direct sale industrial fuel
  - On-site electric generation
  - CNG/LNG
  - Leachate Evaporation

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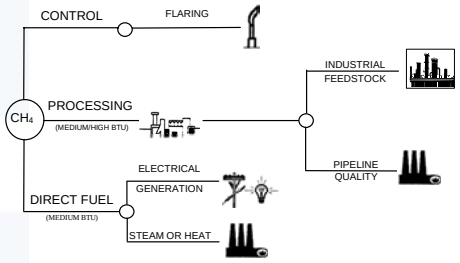
LFG Assets



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