Landfill Chemistry and Microbiology

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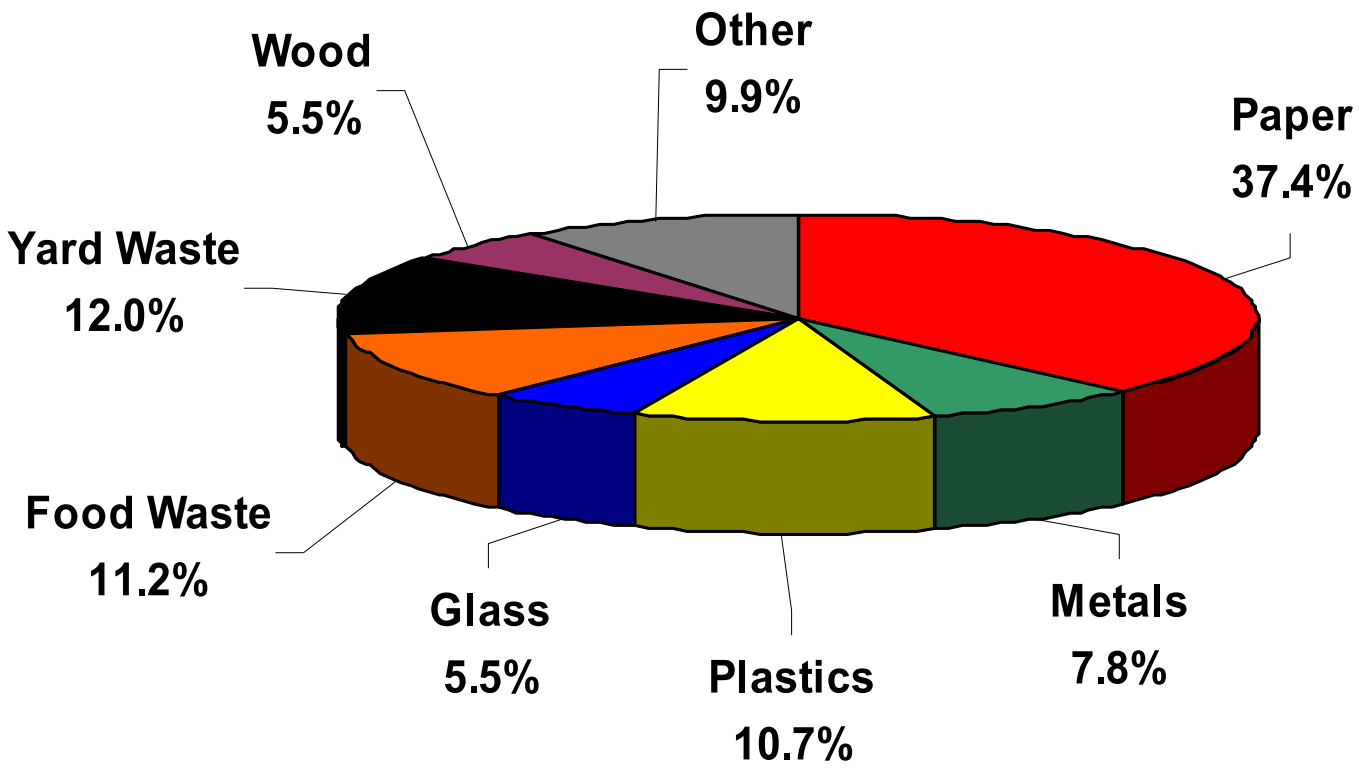
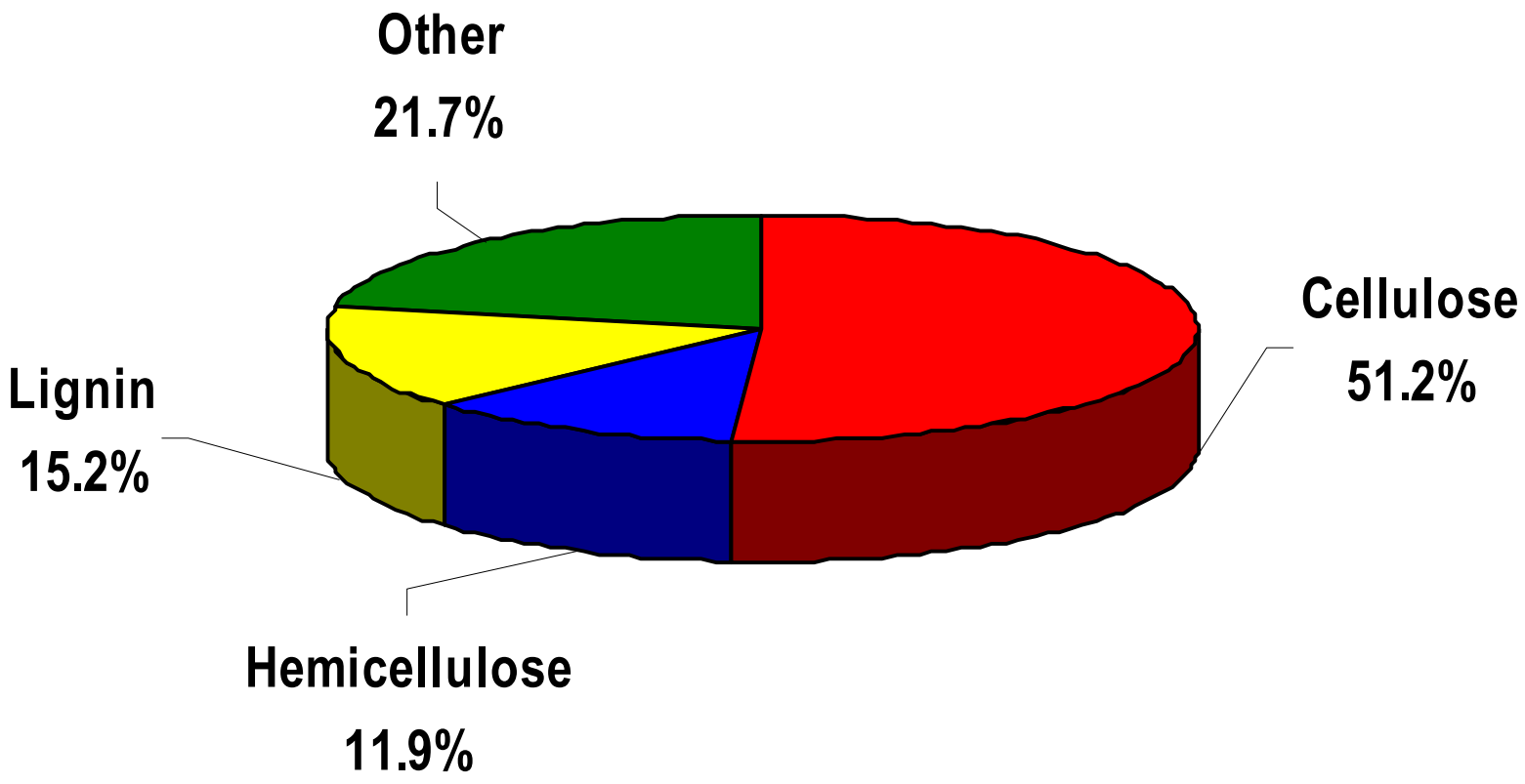
Objectives

- How does refuse decompose?
  - Relationship between gas production, leachate composition and solids decomposition
  - What can we learn about the state of decomposition from gas and leachate data?

Refuse Composition



Refuse Composition



Organic Composition of Residential Refuse (% Dry Wt.)

	1989	1995	1997	1998	2000	2001	2001
Cellulose	51.2	38.5	28.8	48.2	36.7	43.9	43.5
Hemicellulose	11.9	8.7	9.0	10.6	6.7	10.0	8.4
Lignin	15.2	28.0	23.1	14.5	13.6	25.1	33.5
CH:L	4.15	1.68	1.64	4.06	3.19	2.15	1.55

Refuse Decomposition

Cellulose:

$$(C_6H_{10}O_5)_n + nH_2O \rightarrow 3n\ CO_2 + 3n\ CH_4$$

Hemicellulose:

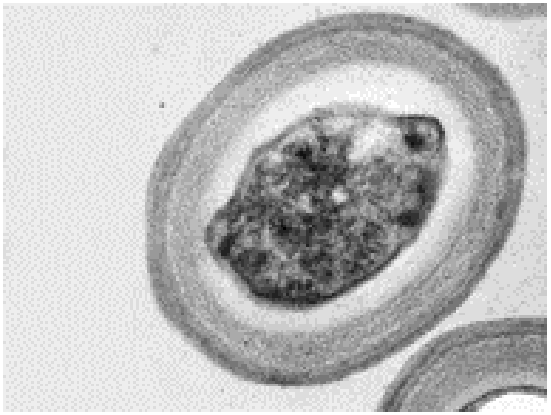
$$(C_5H_8O_4)_n + nH_2O \rightarrow 2.5n\ CO_2 + 2.5n\ CH_4$$

Microbiological Processes

I. Polymer Hydrolysis

polymers → soluble sugars, amino acids

cellulose
hemicellulose
proteins



For example,

$(C_6H_{10}O_5)_n + H_2O \rightarrow C_6H_{12}O_6 + (C_6H_{10}O_5)_{n-1}$

Microbiological Processes

II. Fermentation

sugars $\rightarrow$ volatile fatty acids

$(C_6H_{12}O_6) + 2H_2O \rightarrow CH_3CH_2CH_2COO^- + 2\,H_2 + 2HCO_3^- + 3H^+$

Microbiological Processes

III. Acetate Production

$$CH_3CH_2CH_2COO^- + 2\,H_2O \rightarrow 2CH_3C00^- + H^+ + 2H_2$$

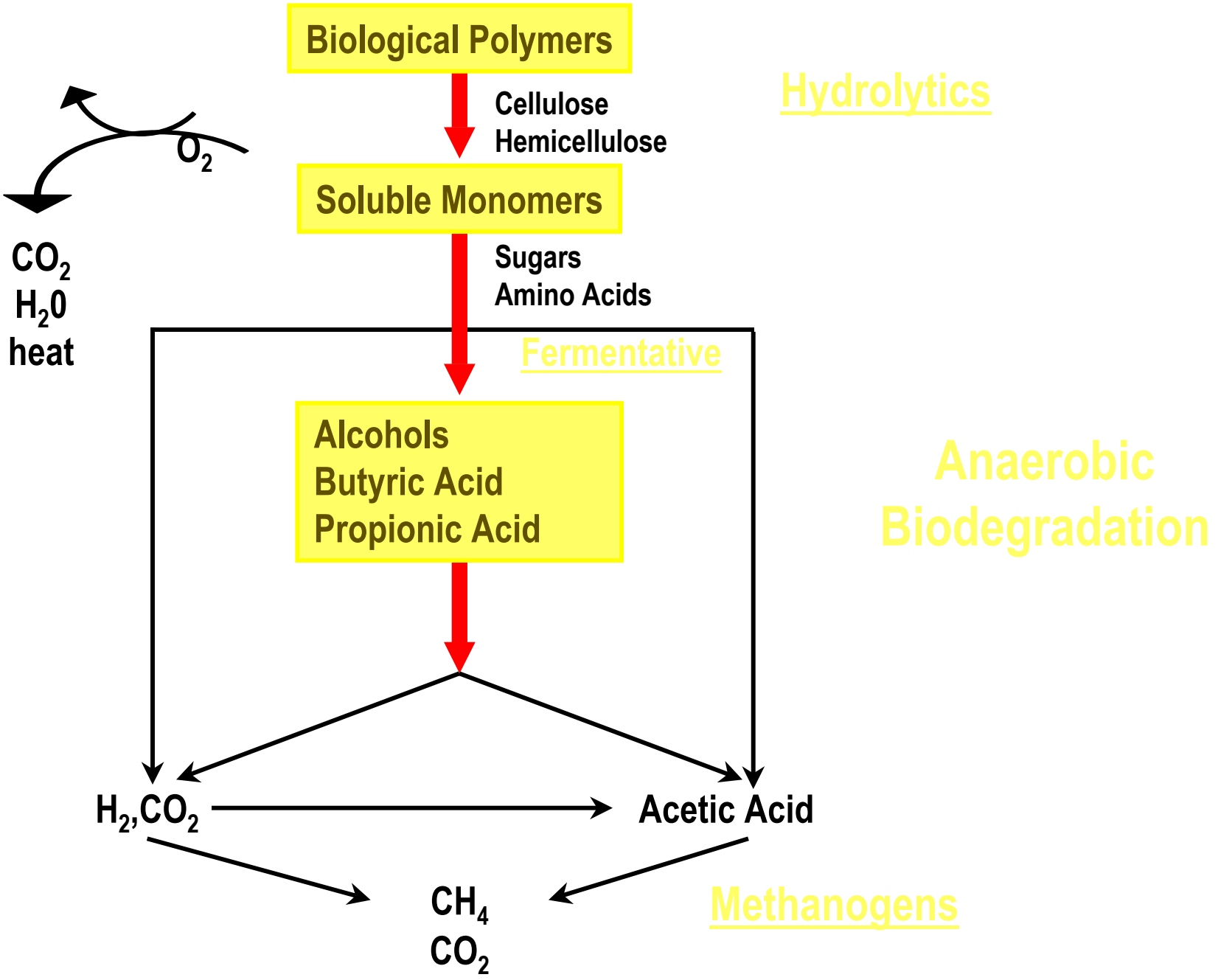
butyrate acetate

Microbiological Processes

IV. Methane Production

1. $CH_3COO^- + H_2O \rightarrow CH_4 + HCO_3^-$

2. $4H_2 + HCO_3^- + H^+ \rightarrow CH_4 + 3H_2O$


Biological Polymers
Cellulose
Hemicellulose
Hydrolytics
O_2
CO_2
H_20
heat
Soluble Monomers
Sugars
Amino Acids
Fermentative
Alcohols
Butyric Acid
Propionic Acid
Anaerobic
Biodegradation
H_2,CO_2
Acetic Acid
CH_4
CO_2
Methanogens

Where are we?

Paper, yard waste and food waste are comprised of cellulose and hemicellulose

These compounds are converted to CH_4 and CO_2 by bacteria under anaerobic conditions

Several groups of bacteria are

Refuse Decomposition

I. Aerobic Phase

O_2 depletion

temperature increase

high CO_2 production

minimal solids loss

Hybrid Systems

extend aerobic phase

Refuse Decomposition

II. Anaerobic Acid Phase

no oxygen infiltration

acids accumulate → acidic pH

little CO_2, no CH_4 production

possibly some H_2

minimal solids loss

Refuse Decomposition

III. Accelerated Methane Phase

gas composition ~ 50%/50% CH_4/CO_2

steep increase in methane production

decreasing leachate BOD, COD

pH ~ 7

significant solids decomposition begins

Refuse Decomposition

IV. Decelerated Methane Phase

gas composition ~ 50%/50% CH_4/CO_2

asymptotic decrease in methane production

low leachate BOD, COD

pH > 7

significant solids decomposition

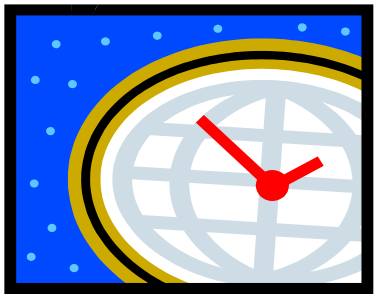
Refuse Decomposition

V. Complete Stabilization (Theoretical)

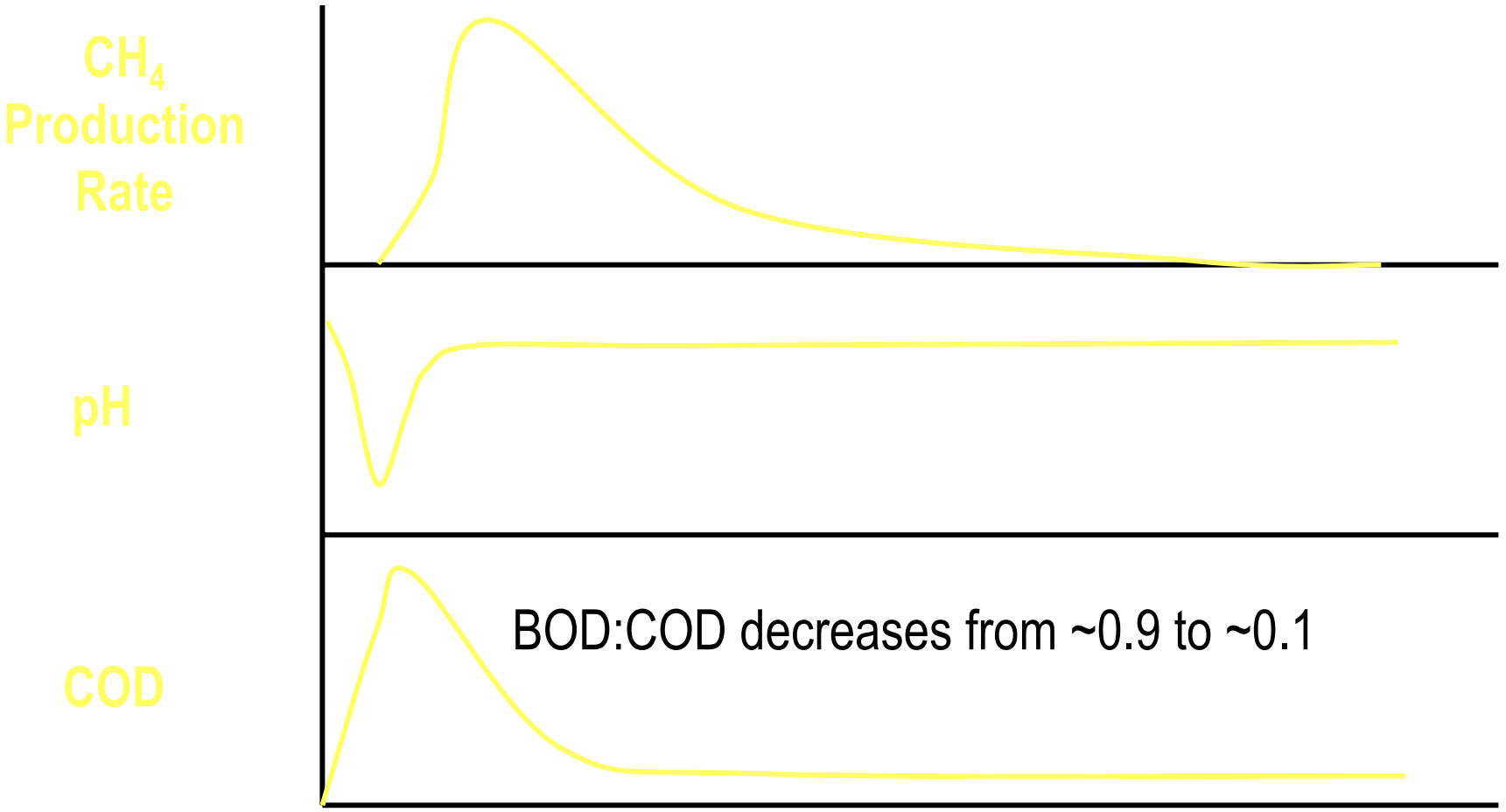
degradable solids completely consumed

O_2 infiltrates the landfill and is not consumed

may occur over geologic time
<u>if at all</u>



Trends in Methane, pH, and COD



Altering the Biology

- Leachate neutralization
- Initial aeration
- Liquids addition
  - Watch what you add!!

Summary

Decomposition occurs in a series of phases

Gas production and leachate quality are linked

- Leachate may reflect bottom lift

A landfill is a complex biological ecosystem

Additional Reading

1. Barlaz, M. A. and R. K. Ham, 1993, "Leachate and Gas Generation," in Geotechnical Practice for Waste Disposal, D. E. Daniel, ed., Chapman and Hall, London, p. 113 - 36.
2. Barlaz, M. A., 1996, “The Microbiology of Municipal Solid Waste Landfills,” in Solid Waste Microbiology, A. C. Palmisano and