LESSON 1:
Biochemistry of Waste

LESSON 2:
Understanding Methane Digestion

LESSON 3:
Waste Trade-offs
LESSON
#1
Biochemistry of Waste

NATIONAL LEARNING STANDARDS:

High School:

CCSS.ELA-LITERACY.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

CCSS.ELA-LITERACY.RST.11-12.5: Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.

LEARNING OBJECTIVES:

1. Students will explore the impact of different combinations of enzymes and bacteria on the breakdown of waste products.

2. Students will be able to explain how limiting factors and environmental conditions affect the breakdown of waste products.

3. Students will design an experiment gathering data to verify and support a hypothesis about the ways in which limiting factors and/or environmental conditions impact chemical digestion of waste.

KEY TERMS:

Biochemistry Enzyme Bacteria
Chemical digestion Molecules Substrate
Active site pH Acidic, Basic, Neutral

BACKGROUND INFORMATION:


• https://pdb101.rcsb.org/motm/57

• https://www.cpalms.org/Public/PreviewResourceLesson/Preview/131030

• http://brilliantbiologystudent.weebly.com/effect-of-temperature.html

• https://www.cpalms.org/Public/PreviewResourceLesson/Preview/129074

MATERIALS:

- Safety goggles
- Potatoes (cut into small pieces)
- Scalpel (to cut potatoes)
- 3% hydrogen peroxide ($\text{H}_2\text{O}_2$)
- Test tubes (and rack)
- Hot water bath
- Ice water bath
- pH paper or test strip
- Ruler
- Marker, pen, or pencil
- Test tube clamps
- Hydrochloric acid (HCl)
- Sodium hydroxide (NaOH)
- Small pebble (e.g., aquarium gravel)
I. Students will complete a K-W-L chart for enzyme activity, using relevant vocabulary and activating prior knowledge.
   a. Students should complete the KWL chart “What Does an Enzyme Do”?
   b. Example chart:

<table>
<thead>
<tr>
<th>What Does an Enzyme Do?</th>
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</thead>
</table>

   c. Discuss the details of the activity. Be sure to review the procedure and safety concerns carefully.
   d. Discuss the following:
      - What are other types of enzymes?
      - How can this activity be applied to reducing food waste?
      - Are all enzymes impacted by limiting factors, such as pH and temperature?
Catalysts are substances that speed up chemical reactions. Organic catalysts are called enzymes. Catalase is an enzyme typically found in many plant and animal tissues. Its purpose is to destroy toxic substances that are introduced into cells and to destroy cellular debris. Catalase works using the following reaction:

$$2\text{H}_2\text{O}_2 \text{ (catalase)} \rightarrow 2\text{H}_2\text{O} + \text{O}_2$$

Discuss the image below and its relation to the above reaction.

Discuss the graph.

Prompts include:
- What was being tested?
- What do the X and Y axes labels mean?
- What does the curve show?
- What conclusions could the researcher make?

Independent Practice:

Part A – Exploring Catalase Activity
1. Using four test tubes, set up the following:
   a. Tube A – 3 cm of H₂O₂ and pebble
   b. Tube B – 3 cm of H₂O₂ and small potato cube
   c. Tube C – 3 cm of H₂O₂ and chopped/mashed potato cube
   d. Tube D – 3 cm of water and chopped/mashed potato cube
2. Observe reactions for approximately five minutes. Bubbles emitted will be oxygen gas.
   Take numerical data (i.e., height of bubbles) and qualitative data (i.e., any observations about quality of bubbles) during the first minute and during the fifth minute.

Part B – Effect of Temperature on an Enzyme
1. Using three test tubes, set up each tube with 3 cm of potato and five drops of water.
   a. Tube 1 – will be placed in a hot water bath for five minutes.
   b. Tube 2 – will be placed in an ice water bath for five minutes.
   c. Tube 3 – will be placed at room temperature for five minutes.
   d. After five minutes, add approximately 3 cm of H₂O₂ to each test tube.
   e. Wait five additional minutes and record the height of the bubbles in each tube.

Part C – Effect of pH on Enzyme
1. Using three test tubes, set up each tube with 3 cm of potato.
   a. Tube 1 – add 10 drops of HCl
   b. Tube 2 – add 10 drops of NaOH
   c. Tube 3 – add 10 drops of distilled water
2. Mix the contents of each tube by gently swirling. Test the pH of each tube using pH paper or a test strip. Record this information as acidic, basic, or neutral.
3. Wait two minutes, then add approximately 3 cm of H₂O₂ to each tube.
4. Wait five minutes, then measure and record the height of the bubbles.
Wrap-up (Review, Assess, Challenge):

- Students will record three things they learned about how enzymes break down organic material and turn in their paper as they leave the classroom.
- Your ticket out the door today is to write down and turn in three things you learned from today’s lesson.
- Have three people share and collect the papers as students walk out the door.
## What Does an Enzyme Do?

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</table>
CATALASE WORKS USING THE FOLLOWING REACTION:

\[ 2\text{H}_2\text{O}_2 \text{ (catalase)} \rightarrow 2\text{H}_2\text{O} + \text{O}_2 \]

1. What are the reactants of the reaction?
2. What are the products of the reaction?
3. Explain how catalase works using the reaction above.

How does the image below relate to the above reaction?

USE THE GRAPH TO ANSWER THE QUESTIONS THAT FOLLOW:

- What was being tested?
- What do the X and Y axes labels mean?
- What does the curve show?
- What conclusions could the researcher make?
- What is optimum temperature (related to enzymes)?
- What is the optimum temperature the enzyme shown on the graph?

Understanding Methane Digestion

NATIONAL LEARNING STANDARDS:
High School:
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LEARNING OBJECTIVES:
1. Students will research the ways in which methane is digested.
2. Students will identify the various methods for methane collection in various settings (e.g., landfills, poop lagoons, wastewater treatment facilities, etc.).
3. Students will explore the creative ways collected methane is recycled and utilized based on location and product need.

KEY TERMS:
Methane digestion Anaerobic digestion Landfill Poop lagoon
Wastewater treatment facility Watt Digestate

BACKGROUND INFORMATION:
The word anaerobic means “in the absence of oxygen.” Anaerobic digestion is the process by which organic matter such as animal or food waste is broken down without oxygen by microorganisms. Anaerobic digestion can be used to manage waste or to produce fuels.

MATERIALS:
- Computer with internet access
- Posterboard
- Coloring supplies (pens, markers, crayons, colored pencils)
- Access to a printer (if needed)
1. Show students the “Basic Anaerobic Digester System Flow” diagram.
2. Discuss the basics of anaerobic digestion.
   a. Prompts include:
      - What is anaerobic digestion?
      - What types of material can be digested (digester inputs)?
      - What products can be made from liquid digestate? Solid?
      - How can biogas be used locally or in industry?
      - Why is it necessary to remove H₂O, H₂S, and CO₂ from digester inputs?

I. Read about the “Sacramento Case Study,”
2. Working in partners, students will write a brief summary.
3. Ask students to share their summary with another group to compare/contrast the information in the case study.
LESSON #2  Understanding Methane Digestion

Independent Practice:

1. Assign students to small research groups to investigate the unique ways that waste products are being developed globally. There are three research groups: landfills, pool lagoons, and wastewater treatment facilities.

2. Students should take one of the locations listed and investigate the ways in which waste is creatively repurposed creatively (see Activity Sheet 3).

3. Students will be developing a poster to be shared with the class in the style of a gallery walk (i.e., students can go to each poster, read the information, and casually discuss with one another).
   a. Items to include on the poster include:
      - Type of facility (landfill, pool lagoon, or wastewater treatment).
      - What are three things that these locations had in common regarding waste repurposing?
      - What are three things that were different about each location’s waste repurposing?
      - In general, what are the environmental benefits of waste repurposing at these facilities?
      - In general, what are the economic benefits of waste repurposing at these facilities?

LESSON #2  Understanding Methane Digestion

Wrap-up (Review, Assess, Challenge):

1. After the gallery walk, ask students to include one thing they found most interesting from each of the locations they did NOT research.
   a. What are two things you found most interesting? Please include one element from each of the locations that you did NOT participate in the research for.

2. Collect the papers as students walk out the door.
Activity Sheet 1

Understanding Methane Digestion

Basic Anaerobic Digester System Flow Diagram

Digester Inputs (manure, organic substrates)

Aerobic Digester

Biogas

Condensing temperature (N2 & H2)

Processing

to remove CO2

Biogas

Biomethane

Gasoline

Natural gas pipeline quality, vehicle fuel (CNG/LNG), feedstock

Medium-BTU Biogas

Boiler, heat, chiller, etc.

Electricity

Internal combustion engine (early stage: microturbines, fuel cells)

Recepiption

Use

Medium & High-BTU Biogas

Energy company, electric utility, natural gas pipeline, vehicle fueling stations

Fertilizer for field or greenhouse crops, flush water

Compost

Soil Amendment

Reused bedding

Feed as plant-based products

Concentrated Fertilizer

Advanced Treatment

Lagoon/liquid storage

Discharge

Reuse

Liquids

Solids

Solids Separator

Case Example: Sacramento

Hailed in 2013 as the largest anaerobic digestion system of its kind in North America, the Sacramento BioDigester started in 2012 with the capacity to process 10,000 tons of food waste per year and was expanded to four times that size in early 2015. The 40,000 ton input capacity includes food waste from area restaurants, food processors, hospitals, international airport, elementary schools and supermarkets.

The 730,000 gallons of biofuel produced annually are used at an onsite fueling station to fuel all of the natural gas trucks of the local trash and recycling collection fleet (24 of 55 trucks), as well as a portion of the city’s and county’s waste fleets, security cars, California State University Sacramento commuter buses (6 buses), two local catering companies and local school buses (exclusive contract with Sacramento School District’s 6-12 buses, backup provider for Elk Grove’s 6-12 buses). The waste gas (not clean enough to use for transportation fuel) is used to produce one million kilowatts of electricity which powers both the facility and the fueling station. The digestate is used to produce eight million gallons of organic soils and fertilizers for Sacramento area farms.

The project was undertaken as a partnership between CleanWorld and Atlas Disposal, and began as a proposal for repurposing an under-utilized waste transfer station owned by the county. CleanWorld and Atlas Disposal each received grants from the California Energy Commission and Recycled Market Development Zone loans from CalRecycle to help fund the digester and fueling station.

What is Carbon Intensity?

The term carbon intensity refers to the amount of carbon, by weight, emitted per unit of energy consumed. For example, biomethane used as a transportation fuel for agency fleets or to generate electricity results in low carbon intensity because it emits less carbon on a life cycle basis.

Biomethane is also a component of California’s Low Carbon Fuel Standard Program, which is intended to lower the greenhouse gas emissions from petroleum-based transportation fuels. Within the Low Carbon Fuel Standard Program the carbon intensity of “High Solids Anaerobic Digestion” is considered negative, meaning that it “displaces” more greenhouse gas emissions than it generates. Fuels such as this are referred to as “carbon negative” and can be produced or purchased by producers of petroleum-based fuels to reduce the overall carbon intensity of their products to levels required by the Low Carbon Fuel Standard.

Design an informational poster using the information obtained in your research to share with the class.

Your poster should include the following:

- Type of facility (i.e., landfill, poo lagoon, or wastewater treatment).
- What are three things that these locations had in common regarding waste repurposing?
- What are three things that were different about each location’s waste repurposing?
- In general, what are the environmental benefits of waste repurposing at these facilities?
- In general, what are the economic benefits of waste repurposing at these facilities?

Be ready to share your poster with the class. Make sure all group members contribute to research and development of the final product.

<table>
<thead>
<tr>
<th>Location</th>
<th>Waste product inputs at location?</th>
<th>How is this waste repurposed?</th>
<th>Environmental Benefits</th>
<th>Economic Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cranberry Creek</td>
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<tr>
<td>Mostoller</td>
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<td>Star Ridge</td>
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<td>Greentree</td>
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<tr>
<td>Emerald Park</td>
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<tr>
<td>North Landfill (Louisiana)</td>
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### Activity Sheet 3

#### Understanding Methane Digestion

**LESSON #2**

**Design an informational poster using the information obtained in your research to share with the class.**

Your poster should include the following:

- Type of facility (i.e., landfill, poo lagoon, or wastewater treatment).
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**POO LAGOON**

<table>
<thead>
<tr>
<th>Location</th>
<th>Waste product inputs at location?</th>
<th>How is this waste repurposed?</th>
<th>Environmental Benefits</th>
<th>Economic Benefits</th>
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<tbody>
<tr>
<td>Duke Energy (North Carolina)</td>
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<td>Toronto Zoo</td>
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<td>Smithfield Foods</td>
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<td>Reinford Farms</td>
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<td>Goodrich Family Farm and Middlebury College (Vermont)</td>
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<tr>
<td>Amana Farms (Iowa)</td>
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</tbody>
</table>
Design an informational poster using the information obtained in your research to share with the class. Your poster should include the following:

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### WASTEWATER TREATMENT FACILITIES

<table>
<thead>
<tr>
<th>Location</th>
<th>Waste product inputs at location?</th>
<th>How is this waste repurposed? What is it being used for?</th>
<th>Environmental Benefits</th>
<th>Economic Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deer Island Treatment Plant</td>
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<tr>
<td>Rich Earth Institute</td>
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<td>Xiangyang, China</td>
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<tr>
<td>Marselisborg Wastewater Treatment Plant (Denmark)</td>
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<tr>
<td>Cambodian National Biodigester Program</td>
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<tr>
<td>Metro Vancouver Canada</td>
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LEsson

Understanding Methane Digestion

Resources


https://www.epa.gov/agstar/how-does-anaerobic-digestion-work


https://www.smithfieldfoods.com/turning-manure-into-energy

https://www.reinfordfarms.com/


LESSON #3 Waste Trade-offs

NATIONAL LEARNING STANDARDS:
High School:
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LEARNING OBJECTIVES:
1. Students will explore the trade-offs at the global, national, and local levels of not reusing waste products.
2. Students will develop a mini-business plan comparing traditional MSW management costs/efficiencies and to those with a more unconventional model.

KEY TERMS:
Trade-off        Waste diversion        MSW management
Waste stream     Business plan

BACKGROUND INFORMATION:

MATERIALS:
- Computer with internet access AND Microsoft Excel
1. Students will record three things they know about MSW management practices in their local community.
   a. What are three things you know about the management practices of municipal solid waste (MSW) in your community?

2. Have three people share their thoughts and collect the papers from each student.
1. Direct students to the GHG Calculator for Communities.

2. Show them the features of the program and discuss what components and features are available.
   a. Be sure to discuss how to read results from the spreadsheet as data is entered.
   b. Be sure to discuss how to interpret results when values are changed.
1. Students will develop a modified business plan to evaluate the trade-offs of using traditional MSW practices versus unconventional models for MSW management.

2. Business plan outlines should include the following:
   a. Business Description
      - Type of business
      - Location
      - Description of services
      - Cost and pricing strategies
   b. Market and Industry Analysis
      - Customer needs
      - Trends in market
      - Competition
      - Labor requirements
   c. Financials
      - Risks
      - Expenses
      - Capital requirements for startup
   d. Timeline of implementation
   e. Project drawings and prototypes

3. Use the GHG Calculator for Communities to provide data to support your MSW modifications included in your business plan.

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**Wrap-up (Review, Assess, Challenge):**

1. Have students complete a graphical analysis using Activity Sheet 3.

2. Students will use the pie chart to determine areas that contribute most greatly to the waste stream of Wake County.

3. Based on their research, students should propose possible solutions to reducing waste in this area of concern.
Activity Sheet I

Waste Trade-offs

Business Plan Template

Develop a modified business plan to evaluate the trade-offs of using traditional MSW practices vs. unconventional models for MSW management.

Your business plan should include the following:

A. Business Description
   i. Type of business
   ii. Location
   iii. Description of services
   iv. Cost and pricing strategies

B. Market and Industry Analysis
   i. Customer needs
   ii. Trends in market
   iii. Competition
   iv. Labor requirements

C. Financials
   i. Risks
   ii. Expenses
   iii. Capital requirements for startup

D. Timeline of Implementation

E. Project Drawings and Prototypes
### Activity Sheet 2

**Area that contributes to waste stream of Wake County?**

**Possible Solution for Waste Reduction**

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<tr>
<th>Area</th>
<th>Solution</th>
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Resources


https://www.tandfonline.com/doi/full/10.1080/14615517.2013.764633


http://compost.css.cornell.edu/MSWFactSheets/msw.fs3.html


https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2935121/