

Microbes and Manure = Biofuel

Anaerobic Respiration

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Grade Level	9th – 12th Grade	**Time Frame**	3-20 class period(s)
Course	Environmental Science	**Duration**	200 minutes

Essential Question

Can waste be converted and used for energy?

Summary

In this lesson, students explore gas production by micro-organisms by designing and experimenting with biogas digesters made from small water bottles.

Snapshot

Engage

Students observe a demo of a mini biogas digester, a "burping bottle."

Explore

Students design and conduct their own experiments to test variables in biogas production.

Explain

Students watch videos, read about the science of biogas, and continue collecting experimental data.

Extend

Students continue to collect data from their experiments and read multiple articles about converting manure to energy. Students also submit proposals for their final presentations.

Evaluate

Students conduct a Gallery Walk to share the results of their in-class experiments and prepare a presentation advocating the use of biogas digestion in their community.

Standards

ACT College and Career Readiness Standards - Science (6-12)

IOD403: Translate information into a table, graph, or diagram
SIN503: Determine the experimental conditions that would produce specified results
EMI502: Determine whether presented information, or new information, supports or contradicts a simple hypothesis or conclusion, and why

Next Generation Science Standards (Grades 9, 10, 11, 12)

HS-PS3-1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Oklahoma Academic Standards for Science (Grades 9, 10, 11, 12)

PS.PS3.1: Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.
PH.PS3.3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
EN.LS2.7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Attachments

- Biogas Digester Experiment—Microbes and Manure = Biofuel - Spanish.docx
- Biogas Digester Experiment—Microbes and Manure = Biofuel.docx
- Lesson Slides—Microbes and Manure Biofuel.pptx
- Poster Rubric—Microbes and Manure = Biofuel - Spanish.docx
- Poster Rubric—Microbes and Manure = Biofuel.docx
- Presentation Rubric—Microbes and Manure = Biofuel - Spanish.docx
- Presentation Rubric—Microbes and Manure = Biofuel.docx
- Sample Biogas Digester Experiment—Microbes and Manure = Biofuel - Spanish.docx
- Sample Biogas Digester Experiment—Microbes and Manure = Biofuel .docx

Materials

- Small water bottles
- Scales/balances
- Manure (cow or horse is easiest to find)
- Funnels
- Gloves
- Goggles
- Water
- Lighter or matches
- Beaker
- Paper
- Food waste
- Wood chips
- Apple cider
- Plastic

- Oatmeal
- Other sources of organic and inorganic materials the students can use when designing and testing their biogas digesters
- Balloons that will fit over the mouth of a water bottle
- Student devices with internet access
- Computer presentation software (Google Slides, Microsoft Word, etc.)
- Markers, crayons, and colored pencils
- Over-sized sticky notes, butcher paper, or bulletin board paper

OPTION 2: For SME Review:

- **For Biogas Digester Experiments:**
  - Small water bottles
  - Scales/balances
  - Manure (cow or horse recommended)
  - Funnels
  - Gloves and goggles
  - Water
  - Shredded newspaper (preferred carbon source)
  - Balloons that fit over water bottle mouths
  - Optional inputs: food waste, wood chips, oatmeal, apple cider, plastic, or other materials for testing
- **For Demonstrations (teacher use only):**
  - Lighter or long matches
  - Beaker
- **For Presentations:**
  - Student devices with internet access
  - Computer presentation software (Google Slides, PowerPoint, etc.)
  - Oversized sticky notes, butcher paper, or bulletin board paper
  - Markers, crayons, or colored pencils

Lab Preparation

Prepare the demo biogas digester **4–5 days before class**. It's best to have several bottles for each class, so every student can experience the demonstration.

1. In a small container, mix manure and water until the mixture has a smoothie-like consistency. There is no exact ratio, just add enough water to achieve the correct texture.
2. Use a funnel to pour the mixture into an empty water bottle.
3. Add shredded or cut-up paper to the bottle. Newspaper works best because it breaks down more easily than notebook or copy paper. The paper serves as a carbon food source for the microorganisms in the manure.
4. Seal the bottle and allow it to sit undisturbed for 4–5 days before beginning the Engage portion of the lesson.

Tip: Wear gloves when preparing the bottles, and store them in a place that is easy to clean in case of leaks or spills.

Engage

Teacher's Note: Background

This lesson focuses on *methanogens*, microorganisms that break down carbon sources for energy through anaerobic respiration (respiration without oxygen). This process, called *methanogenesis*, produces methane gas as a byproduct. In many places, methane is captured and used as fuel for cooking stoves and other purposes.

Teacher's Note: Caution

Occasionally the bottles burst due to the pressure that builds on the inside. Check the bottles daily, and if the pressure feels too high, carefully "burp" them to release a small amount of gas (not all). Store the bottles in a container—such as a box or large Tupperware—that is easy to clean in case one bursts.

Begin this lesson only after the bottles have sat for 4–5 days.

Use the attached **Lesson Slides** to introduce the lesson and review the essential question and learning objectives on **slides 3** and **4**.

Move to **slide 5**, show students a prepared bottle. Ask them to take out a piece of paper and record their observations as you "burp" the bottle. Hold the bottle out in front of you and gently unscrew the cap. This will release a small amount of methane, producing a sound similar to opening a soda bottle—but with a much different odor. Go around the room "burping" bottles for class.

Teacher's Note: Optional Demonstration

If possible, capture some methane and ignite it to demonstrate its energy potential. To do this, hold a beaker upside down over the bottle as you burp it. Because methane is lighter than air, it will rise into the beaker. Then, using a long lighter or match, ignite the gas. The flame will burn briefly. You may wish to dim the lights, since methane often burns with a blue flame.

This demonstration should be performed by the teacher only.

After you're done burping the bottle and igniting the gas, ask students to turn to their Elbow Partner and discuss these questions:

- What is responsible for the sound you heard and the odor you smelled?
- What elements do you think the gas is made of?
- Ask students if they think that gas can be utilized as a source of fuel to run industries, vehicles, or even farming operations?

Invite groups to share their responses with the class.

Teacher's Note: Guiding Students

Students will likely recognize that a gas is produced but may not know what type. The gas is methane, made of carbon and hydrogen (CH4). Don't tell them the name of the gas is "methane" quite yet. For the question about using the gas as a source of fuel, many students will be unsure, but if you've done the demo and ignited the methane, they will know that it is combustible. Tell them that the gas that comes from the bottle is made of the same elements as the gasoline that runs cars, carbon and hydrogen.

Clarify for students that you placed manure, water, and paper in the bottle and left it undisturbed for 4–5 days. Express to students that the paper serves as a food source for tiny organisms that are in the manure. As the organisms decompose the paper, they produce a gas. The water assists in the decomposition process.

Display **slide 6** and review the instructional strategy What Did I Learn Today? Ask students to use the same paper they made their original observations on to write down on explaining what they learned from this activity. Consider using their responses as an exit ticket.

Explore

Place students into groups of four and pass out the attached **Biogas Digester Experiment** handout to each student. Explain to students that they will be building mini biogas digesters using small water bottles. Their challenge is to design experiments that increase the rate of decomposition and gas production in the "burping bottles."

Display **slide 7** and review the guiding question: "Can you increase the rate of decomposition in the burping bottles?"

Move to **slide 8**, distribute the attached **Sample Biogas Digester Experiment** handout to each group. Tell students that a hypothesis is an educated guess or testable statement about what you think will happen in an experiment. Direct students' attention to the sample hypothesis and review it. Allow students time in their groups to come up with and write down their own hypothesis in the space provided on their Biogas Digester Experiment handout.

Teacher's Note: Sample Student Hypothesis

Sample hypotheses that students might develop for this investigation may include:

- Oatmeal will decompose faster than paper in bottles containing manure.
- Adding more water to the manure mixture will increase the rate at which paper decomposes.

Transition to **slide 9** and provide an overview of the possible digester inputs. Explain that students can adjust both the amount and type of materials used—such as the kind of manure, liquid, or carbon source. Offer examples of substitutions: apple cider instead of water, or plastic or oatmeal instead of paper. Students must also determine how they will measure both decomposition rate and gas production.

Teacher's Note: Testing Variables

Students can accomplish this by setting up two or more burping bottles. Each bottle should only test one variable. If the students change more than one variable and measure a change in gas production, they will not know which variable accounted for the change.

Students measure the rate of decomposition by recording the mass of the bottles every few days. They also measure the amount of gas produced by attaching a balloon to the top of each bottle. As decomposition happens, gas inflates the balloon, and students can measure its circumference.

Tell students to ensure that the balloons remain sealed until the end of the experiment to avoid gas loss and contamination.

There are numerous experiments students can conduct with the mini biogas digesters. The primary goal is for students to practice experimental design while observing how digesters break down organic materials and produce gas. Students will use their handouts to write a lab report following the components listed in the example provided. In the Evaluate phase, they will create posters and share their data with the class. If needed, graph paper is also attached to the lesson.

Teacher's Note: Activity Timing

The Explore phase will take about one to two weeks to yield measurable results. It is best to wait at least a week before continuing to the Explain phase. During this time, students should record observations daily or every other day.

Explain

Teacher's Note: Optional Videos

Choose one or two of the optional videos below to show your class. You may also provide the links for students to use in their own research.

- How does a biogas plant work?
- Biogas digester for a domestic home
- High rate recovery of biowaste to biogas and biofertilizer
- Animation of a simple telescoping biogas digester

Move to **slide 10** and review the 3-2-1 instructional strategy. Ask students to take out a piece of paper and complete this strategy while they watch a video.

After the video is over, invite a few students to share their 3-2-1 responses with the class.

Next, direct students to read the article: "Aerobic and Anaerobic Biodegradation."

Teacher's Note: Optional Facilitation

When reading the article, there may be some ideas and/or vocabulary that some students are unfamiliar with. Consider using a close reading strategy such as CUS and Discuss to help facilitate this portion of the lesson.

Display **slide 11**. After students have finished the reading, they should answer the questions below with their group.

1. What gas is produced in your bottles?
2. What happens to the gas when you release it from the bottle?
3. Is that gas beneficial for the environment?
4. How could we prevent the gas from entering the atmosphere?

Teacher's Note: Sample Student Responses

1. Methane and carbon dioxide are produced in the bottle experiments.
2. It is released into the air OR It goes back into the atmosphere.
3. Releasing this gas in the air can contribute to global warming. The gas has a bad smell that is not pleasing to people nearby.
4. Listen to student responses and guide them to an understanding that the gas can be trapped and used as a fuel source.

After students answer the questions in their groups, have a brief class discussion about each question, calling on groups to share their responses to the questions.

Extend

Linked below are four articles that cover how biogas digesters have been used at farms and homes, and how scientists hope to use the methane produced as fuel for space travel.

Display **slide 12** and review the Jigsaw instructional strategy with students. Assign each student in the group an article to read. After the students have read the article, they should come together as a group and discuss their articles.

1. Biogas Digester
2. Chapter 7 - Biogas Digesters
3. Human Poop-Powered Rocket May Fly Man to the Moon in the Future
4. Manure Digester Means Nebraska Farm is Powered by Pigs

After discussing the articles and reflecting on what they've learned in this lesson so far, move to **slide 13** and ask groups to brainstorm ideas for ways that biogas digesters could be used in or around their communities. Tell students to keep in mind that they will create a visual presentation for the class based on what they decide.

Once groups have chosen their focus, transition to **slide 14** and review the Two-Minute Paper instructional strategy. Ask each group to take out one piece of paper and work together to respond to this prompt:

- In one paragraph or less, explain where a biogas digester is needed in our community, why it will be useful in that location, and how it will be constructed.

Collect the responses as exit tickets. Let students know you will review their ideas before the next class period and confirm whether they may proceed with their presentations or need to revise their proposals.

Evaluate

Teacher's Note: Planning Ahead

This final portion may take three to four days from start to finish. Each group will complete two separate projects. One is a poster explaining their experiment, their hypothesis, and what they were testing. The other project is a computer presentation with the intent of informing and convincing the audience where a biogas digester could fit in their community.

Display **slide 15** and pass out the attached **Poster Rubric** to each group. Tell students that they will be creating a poster with their group and review the requirements with them on the slide. Then, ask them to look at the poster rubric and review it with them. Pass out a piece of poster paper to each group and allow time for students to complete the task.

After the poster is created, ask students to place their posters around the room. Move to **slide 16** and review the Gallery Walk instructional strategy. Ask that one student from each groupstand by the poster to clarify any questions the other students may have about the experiment. The rest of the groups should move around the room to observe and ask questions about other experiments.

Teacher's Note: Expectations

The student standing by the poster fielding questions from other students does not have to present to the class for the final PowerPoint portion of this lesson.

Once you have approved each group's experiment proposal, they can begin constructing their presentations and doing any necessary research.

Display **slide 17** and pass out the attached **Presentation Rubric** to each group. Review the rubric and guidelines on the slide with students. Tell each group to add what they learn from their experiment into their presentations about using a biogas digester in the community. Explain to students that each member of the group should speak for 2 minutes, except for the group member who stood next to the poster during the gallery walk and answered questions, because their presentation requirement for this assignment is complete. However, they still have to contribute to the final project by researching, providing ideas, or helping build the final presentation.

Resources

- Aerobic and Anaerobic Respiration Article: Clark, D. (2010, June 29). Aerobic and anaerobic biodegradation: A look into aerobic and anaerobic biodegradation. Mesa, AZ: ENZO Bottles, LLC. http://grizwater.com/pdf/Aerobic%20Anaerobic%20Biodegradation.pdf
- Biogas Digester: Culhane, T. H. (n.d.). Biogas digester. Tamera. Retrieved from https://www.tamera.org/fileadmin/PDF/biogas_digester.pdf
- Chapter 7 - Biogas Digesters: Clean Energy Resource Teams. (n.d.). Chapter 7: Biogas digesters. Clean Energy Resource Teams Manual. Retrieved from http://www.cleanenergyresourceteams.org/files/CERTsManualCh7.pdf
- Powered by Pigs Article: Houghton, D. (2013, September 9). Manure digester means Nebraska farm is powered by pigs. National Hog Farmer. Retrieved from http://nationalhogfarmer.com/environmental-stewardship-winners-2013/manure-digester-means-nebraska-farm-powered-pigs
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- K20 Center. (n.d.). What Did I Learn Today? Strategies. https://learn.k20center.ou.edu/strategy/169
- Human Poop-Powered Rocket Article: Lee, R. (2014, November 28). Human poop-powered rocket may fly man to the moon in the future. Tech Times. http://www.techtimes.com/articles/21099/20141128/human-poop-powered-rocket-may-fly-man-to-the-moon-in-the-future.htm
- BioConstruct. (2008, April 3). How does a biogas plant work? [Video]. https://www.youtube.com/watch?v=3UafRz3QeO8
- ENERGYWEB. (2013, May 1). Biogas digester - introduction - the little green monster - Wally Weber [Video]. https://www.youtube.com/watch?v=TTdreS_HN2Y
- High rate recovery of biowaste to biogas and biofertilizer [Video]. https://www.youtube.com/watch?v=RGTVrMTAcTU
- Thomas H. Culhane. (2009, September 10). Animation of a simple telescoping biogas digester [Video]. https://www.youtube.com/watch?v=BiHDQClpZfI