# 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 watch a demo of a mini biogas digester, a "burping bottle."

**Explore**

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

**Explain**

Students watch videos and read about the science behind the biogas production process and continue collecting data from their experiments.

**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

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

**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-ESS3-2:** Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

*Oklahoma Academic Standards (Physical Science)*

**EN.ESS2.6 :** Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

*Oklahoma Academic Standards (Physical Science)*

**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.

## Attachments

- Graph-Paper - Spanish.docx
- Graph-Paper - Spanish.pdf
- Graph-Paper.docx
- Graph-Paper.pdf
- Poster-Rubric - Spanish.docx
- Poster-Rubric - Spanish.pdf
- Poster-Rubric.docx
- Poster-Rubric.pdf
- Presentation-Rubric - Spanish.docx
- Presentation-Rubric - Spanish.pdf
- Presentation-Rubric.docx
- Presentation-Rubric.pdf
- Sample-Biogas-Digester-Experiment - Spanish.docx
- Sample-Biogas-Digester-Experiment - Spanish.pdf
- Sample-Biogas-Digester-Experiment.docx
- Sample-Biogas-Digester-Experiment.pdf

## 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

# Engage

### Teacher's Note

The tiny organisms we will focus on in this lesson are methanogens. Methanogens breakdown carbon sources for energy in a process known as anaerobic cellular respiration, which is cellular respiration performed without the use of oxygen. The anaerobic cellular respiration conducted by methanogens is called methanogenisis. Methane gas is a byproduct of this process. In many places, the methane is captured and used for gas cooking stoves, among other things.

### Teacher's Note: Lab Preparation

Follow the directions below to make the demo biogas digester for class. The preparation should be done four to five days before the bottle is opened in front of class as a demo. It's best to have several bottles for each class, so all the students can smell the gas released.

1. Obtain a small, empty water bottle.
2. Mix manure and water together in a separate container and pour the mixture in the empty water bottle (it may be helpful to use a funnel to do this).
3. The mixture should be the consistency of a smoothie—there is no exact quantity of water or manure, just as long as the mixture is the consistency of of a smoothie.
4. After the mixture is placed in the empty water bottle, place shredded or cut-up pieces of paper in the bottle. The paper will serve as the carbon food source for the tiny organisms that are in the manure. Newspaper works well for this as it is digested more easily than copy or notebook paper.
5. Let set for four to five days before starting the Engage part of the lesson.

### Teacher's Note: Caution

Occasionally the bottles burst due to the pressure that builds on the inside. It is a good idea to check the bottles daily, and if you feel the gas pressure is becoming too great, you can "burp" the bottles and release a small portion (NOT ALL) of the gas to relieve the pressure. Be sure to place the bottles in an enclosure or in an area that is easy to clean, in the event the bottle of manure bursts—inside a box or larger Tupperware container, for example.

Once the preparation is complete and the bottles have had four to five days to sit, you can begin the lesson. Show the students a prepared bottle and tell them that you are going to burp the bottle. Tell them to make observations as you burp the bottle. Students will find out later in the lesson that the bottles represent mini-biogas digesters. Hold the bottle out in front of you and gently unscrew the bottle cap. This will release a small amount of methane, which will make a sound similar to a pop bottle being opened; but the odor coming from the bottle will be much different than the order produced when opening a pop bottle. Go around the room "burping" bottles for class.

### Optional Teacher Demonstration

If possible, you should try to capture some of the methane and light it. This will demonstrate the potential energy contained in the gas and show students that the gas released is combustible and may be usable as an energy source. One way you could capture the methane is by holding a beaker upside-down over the bottle as it is burped. Methane is lighter than the ambient air, so it will rise into the beaker above it. Then, using a match or long lighter, ignite the flame. It will burn out very quickly. You may want to dim the lights for this, in case the flame produced is blue.

After you're done burping the bottle and igniting the gas, ask students these questions:

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

### Teacher's Note

Students will probably say that a gas is produced but will not know what kind of gas. The gas, methane, is 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.

After the discussion is over, you can explain to students that you placed manure, water, and paper in the water bottle 4-5 days ago and that you have left it sitting undisturbed for that period of time. 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. Using a strategy such as What Did I Learn Today? have students write down on a piece of paper explaining what they learned from this activity. You can use their responses as an exit ticket.

# Explore

In the explore phase of the lesson, students will build mini-biogas digesters out of small water bottles. Place students into groups with four students in each group. Explain to students that they will be setting up their own burping bottles and that their challenge is to increase the rate at which the burping bottle decomposes material inside and makes gas. Give students a brief review of the materials in the bottle and their correlation to gas production. Tell students they have access to all the materials you used in the demonstration: manure, water, carbon source

**Teacher's Note**

Part of the experiment is to allow students to adjust the amount of materials they utilize in their bottles, but students can also change the type of manure, liquid, and even carbon source they utilize in setting up the experiments. Examples of alternatives to water and paper include but are not limited to: Apple cider instead of water, plastic or oatmeal instead of paper.

Students will have to determine how they will measure decomposition rate and gas production.

**Teacher's Note**

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.

The question driving this experiment is, "Can you increase the rate of decomposition in the burping bottles?" Attached to this lesson is an example of a hypothesis, along with a detailed experimental design which addresses the question. Students can measure rate of decomposition by measuring the weight/mass of the bottles every few days. Students can measure the amount of gas produced by placing a balloon on top of the bottles and measuring the circumference of the balloon (they should not remove the balloons until the experiment is over).

**Sample Student Hypotheses**

Oatmeal will decompose faster than paper in the bottles with manure. Increasing the amount of water added to the manure mixture will increase the rate at which paper decomposes. Increasing the amount of paper in a bottle with manure will increase the rate at which the paper decomposes. Twice as much gas will be produced when twice the amount of manure is used in a biogas digester bottle as compared to a control. Placing the biogas digester under a warm light will increase the rate of decomposition inside the bottle.

There are numerous experiments students can conduct with the mini-biogas digesters. The goal with this section of the lesson is for students to practice experimental design and to see that the mini-biogas digesters will decompose an organic material and produce a gas. Students should individually write a lab report with all of the components listed in the attached example. In the Evaluate phase of this lesson, they will be constructing a poster and sharing the data with their class. If graph paper is needed, it is attached to this lesson.

**Teacher's Note: Activity Timing**

This Explore phase will take a week or two to get decent, measurable results. It is a good idea to wait a week or so before continuing this lesson with the Explain phase. However, students should record observations every day or two from their experiment.

# Explain

**Teacher's Note**

In the resources section, you will find a few options for videos to show the class. You can also provide the video links to students for use in their research.

Begin by showing students one or two video overviews of working biogas digesters. Ask them to use a 3-2-1 strategy while they watch the video. After the video is over, ask 3 or 4 students to share their 3-2-1 with the class.

After the video and the 3-2-1 share out, students will read the article linked here about aerobic and anaerobic respiration (a copy of the URL is in the Resources section at the end of the lesson). There may be some ideas and/or vocabulary that some students are unfamiliar with, so using a close reading strategy (like CUS and Discuss) could be a good idea for this reading.

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

1. What is the gas that is produced from your bottles?
2. What happens to the gas when you release it from the bottle?
3. Is that good for the environment?
4. Can we do anything to prevent the gas from going into the earth's atmosphere?

**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.

# Extend

**Teacher's Note**

The Extend and Evaluate phases of this lesson can take place at the same time. Students are given two tasks for the rest of the lesson: create a poster displaying all their data and results from their experiment, and prepare a persuasive presentation for the class with the goal of implementing and using a biogas digester somewhere in their community to capture and use methane.

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. Using a Jigsaw strategy, 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, the groups should brainstorm ideas for ways that biogas digesters could be used in or around their communities, keeping in mind that they will create a visual presentation for the class based on what they decide. The presentation will be composed using PowerPoint, Prezi, Google Slides, or any other program the teacher choses to use for this assignment.

After the groups have decided on what they are doing, the group will write a Two-Minute Paper responding 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 their responses to this prompt as an exit ticket and tell the students you will read their responses before the next class period and let them know if they can proceed with the presentation or if you have concerns about what they've chosen.

**Teacher's Note**

You can give them more than two minutes. Read the two minute papers before the groups start making their presentations the next day. Tell the class that you have to approve their topics before they get started.

# Evaluate

**Teacher's Note**

This final portion may take three to four days from start to finish. Each group will do 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.

Using butcher paper or bulletin board paper, each group should make a poster displaying all their information from the experiment with the mini biogas digesters. The rubric for this task is in the attachments. After the poster is created, they should be placed around the room and students should do a Gallery Walk. One student from each group should stand by the poster to clarify any questions the other students may have about the experiment.

**Teacher's Note**

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.

After you have approved each group's proposal (the two-minute paper from the Extend phase), they can begin constructing their presentations and doing any necessary research. Give each group a rubric you will use to grade their presentation so they will know what is expected from them. Tell each group to add what they learn from their experiment into their presentations about using a biogas digester in the community. 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--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
- K20 Center. (n.d.). 3-2-1. Strategies. https://learn.k20center.ou.edu/strategy/d9908066f654727934df7bf4f5059a7b
- K20 Center. (n.d.). CUS and discuss. Strategies. https://learn.k20center.ou.edu/strategy/d9908066f654727934df7bf4f5073969
- K20 Center. (n.d.). Gallery Walk / Carousel. Strategies. https://learn.k20center.ou.edu/strategy/d9908066f654727934df7bf4f505a54d
- K20 Center. (n.d.). Jigsaw. Strategies. https://learn.k20center.ou.edu/strategy/d9908066f654727934df7bf4f507c1b8
- K20 Center. (n.d.). Two-Minute Paper. Strategies. https://learn.k20center.ou.edu/strategy/d9908066f654727934df7bf4f506cf73
- K20 Center. (n.d.). What Did I Learn Today? Strategies. https://learn.k20center.ou.edu/strategy/d9908066f654727934df7bf4f5078797
- 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


**RECOMMENDED RESOURCES**

Detailed animation with narration explaining a large biogas plant: (~10 minutes, higher quality)

- BioConstruct. (2008, April 3). How does a biogas plant work? [Video]. https://www.youtube.com/watch?v=3UafRz3QeO8

Video with a man talking about a large home digester (~3 minutes)

- ENERGYWEB. (2013, May 1). Biogas digester - introduction - the little green monster - Wally Weber [Video]. https://www.youtube.com/watch?v=TTdreS_HN2Y

Biogas Animation of complex plant (~4 minutes): madokken. (2003, September 8).

- High rate recovery of biowaste to biogas and biofertilizer [Video]. https://www.youtube.com/watch?v=RGTVrMTAcTU

Biogas Animation with narration of small digester for home use (~3 minutes)

- Thomas H. Culhane. (2009, September 10). Animation of a simple telescoping biogas digester [Video]. https://www.youtube.com/watch?v=BiHDQClpZfI