Biogas from Biomass

Objective
Students will describe how biogas is produced and how it is obtained from landfills.

Curriculum Focus
Science

Materials
Copies of "A Methane Generator"
Copies of "Biogas Gravel"

- Gravel
- Dry baby cereal
- Pond water
- Soil
- Grass and leaves
- Raw beef
- Goggles
- 500 ml flasks
- Large beakers
- Hot plate or aquarium heaters
- Thermometers
- Balloons
- Microscope and blank slides
- Eye-dropper with bulbs removed
- Rubber bands
- Fireplace matches or propane lighters

Key Vocabulary
Anaerobic decomposition
Biogas
Digester
Sludge

Next Generation Science Correlations
4-LS1 - 2
4-LS1.D
4-ESS3 - 1
4-ESS3.A
4-ETS1 - 1
4-ETS1.A
5-ETS1 - 1
5-ETS1.A
MS-PS1 - 2
MS-PS1.A
MS-LS1 - 8
MS-LS1.D
MS-LS4 - 1
MS-LS4.A
MS-ESS1 - 4
MS-ESS1.C
MS-ETS1 - 2
MS-ETS1.B

Introduction

This activity investigates the production of biogas from organic material. **Safety in this activity is crucial** as the result can be explosive. Make sure students are aware of the consequences of producing biogas and that adequate safety precautions have been made.

Procedure

1. This activity can be used to investigate parameters associated with a methane generator, such as:
   - Effect of temperature on volume of biogas produced.
   - Effect of liquid-to-solid-waste ratio.
   - Effect of type of biomass used in the generator (poultry, cow waste, etc.).

   These investigations can be carried out if different groups build generators.
2. Students should use their copy of "A Methane Generator" to establish their experiment or design their own generators with readily available materials.

   If sufficient materials are unavailable, this activity can be carried out as a whole class exercise or a teacher demonstration.
3. Five to seven days before conducting experiments, prepare the organic matter mixture as indicated below or have students create their own mixtures to test one of the variables in step 1 of "A Methane Generator."

4. Each student group will need one flask of biomass mixture. Reserve some ingredients to make another flask of biomass mixture identical to the one below for comparison on the day of the experiment.

   Preparation of standard biomass solution:
   a. Line the bottom of the flask with gravel about 2 cm deep.
   b. Add a small amount of beef, pond water, soil, grass, leaves and baby cereal. Use about 200 ml of cereal and 400 ml of water per flask.
   c. Stretch a balloon over the mouth of the flask and secure with a rubber band.
   d. Place in a fume hood or outdoors.

5. Make a stock flask on the morning of the experiment for students to compare to the flasks that have been sitting for a week.

6. Provide students with a copy of "Biogas Gravel" to read.

7. Pass out "A Methane Generator" and have students conduct the experiment. Make sure they wear goggles and thoroughly wash hands when they are finished. Answer and discuss the accompanying questions.

Discussion

Ask students what they think was in the balloon and how it was created. If students conducted their own experiments, compare the amount of gas produced in the different flasks. Ask students to list conditions that are favorable for the production of biogas.

Answers to "A Methane Generator" questions:

1. Anaerobic respiration
2. The balloon inflates
3. Insoluble, or it would have stayed in the water instead of filling up the balloon.
4. Should burn well with a fairly clean flame; smoke is from impurities leading to incomplete combustion.
5. Burn the methane to heat water in a boiler; steam produced turns turbine.
6. Yes, methane from biomass is used on farms and in a few waste-to-electricity power plants.

To Know and Do More

1. Build a larger biogas generator.
2. Take an excursion to a place that produces biogas (for example, sewage treatment plants and landfills).

Careers in Energy

Agricultural Engineer
Biochemist
Alternative Fuels Engineer
Biowaste Technician

Student Sheet: A Methane Generator

Background Information

In the absence of oxygen, bacteria breaks down biomass into methane gas. This gas can be burned to provide heat for cooking, power a generator or modified internal combustion engine or drive farm machinery.

As long as you keep the temperature constant somewhere between 68 and 104 F and feed your digester organic waste mixed with water, you will almost always produce methane. However, thought should be given to temperature, waste-to-liquid ratio, waste type and its carbon-to-nitrogen ratio, presence of oxygen and the form of waste for a quick and efficient digester.

The general rule for temperature is the warmer, the better. A temperature of around 98.6 F is ideal for your digester. At lower temperatures, digestion will take place at a slower rate. Temperatures over 104 F may be difficult for your aquarium heater to reach and will also cause problems with evaporation. Maintaining a constant temperature is very important as a variation in temperature (even a couple of degrees) can kill the bacteria.

The waste you use should have a ratio of carbon to nitrogen (C:N) that is no more than 30:1. Some typical ratios are cow manure 17:1; grass clippings 12:1; cabbage waste 12:1; wheat straw 180:1. Based on these figures, all the above materials would be suitable with the exception of wheat straw, which would need to be mixed with something with a lower ratio (e.g., cabbage waste). The C:N ratio is generally within acceptable limits with animal waste; however, if you are planning to digest plant material, it could be worth checking. (Source: *nres.usda.gov*, accessed October, 2017)

When producing methane from farm waste, the bacteria on which the process depends are anaerobic (able to live in the absence of oxygen). Therefore, air must be excluded from the organic matter.

Materials

- Gravel
- Dry baby cereal
- Pond water
- Soil
- Grass and leaves
- Raw beef
- Goggles

Per group of students:

- 500 ml flask
- Large beaker
- Hot plate or aquarium heater
- Thermometer
- Balloon
- Microscope and blank slides
- Eye dropper with bulb removed
- Rubber band
- Fireplace match or propane lighter

Procedure

1. You may use a biomass flask prepared by your teacher or make your own using the materials provided or brought from home. You can use manure, grass clippings, potato peelings or other biomass materials. If you use vegetable matter, it should be broken down in a blender.
2. Stir your biomass, adding water until the mixture has a creamy consistency. Place the mixture in a flask (500 ml), leaving sufficient airspace for expansion of the moisture.

3. Place the flask in a water bath maintained at 86 - 95 F (30 - 35 C) (an aquarium heater can be used or perhaps a solar collector that you could design and build).
4. Using a dropper or pipette, place a drop of the solution from your flask on a microscope slide and observe it. Do you see any microorganisms? Bacteria are needed to change the biomass into biogas.
5. Blow up a rubber balloon and stretch its mouth over the top of the flask. Secure it with an elastic band.
6. Wait 7 to 10 days. The first time the balloon inflates, discard the captured gas by squeezing the balloon. This gas will contain mainly air and carbon dioxide. Swirl the flask occasionally to prevent settling.
7. When the balloon has inflated for the second time, squeeze its neck shut and take it off the flask. Without letting the gas escape, insert the large end of a dropper tube or pipette into the balloon and secure it with an elastic band. Test the gas by holding a lighted match at the end of the pipette. Squeeze the balloon gently to maintain a steady flow of gas (you could place a heavy book on it). You will need to adjust the flow rate to light the gas and maintain a steady flame.

Notes

1. Hydrogen sulfide is produced as a byproduct and can be detected by smell. Methane is an odorless gas.
2. All joints should be sealed to minimize obnoxious odors escaping and prevent oxygen from entering the reaction. Oxygen prevents methane production.

Questions

1. What process is happening in the flask?
2. How could you tell that a reaction was taking place in the flask?
3. Is methane gas soluble or insoluble in water? How can you tell?
4. How well does methane gas burn? Does it burn with a smoky or clear flame?
5. How could the methane gas produced be used to generate electricity?
6. Is methane gas currently being used to generate electricity anywhere? If so, how and where?

To Know and Do More

1. How long does the biomass produce methane? Record and graph the volume of gas produced per week.
2. How quickly will methane gas boil a 100 ml beaker of water? Is it as good as liquefied petroleum gas?
3. Determine the ratio of the volume of gas produced to the weight of biomass material. In around 24 hours, one cubic meter of farmyard manure at about 50 F (10 C) will produce around 30 liters of methane.
4. You may want to try to build a larger biogas generator to provide greater amounts of gas.

Student Reading Sheet: Biogas Gravel

Biogas, which is chiefly composed of methane (CH4), is produced from the decomposition of organic matter by bacteria in the absence of oxygen, a process called anaerobic decomposition. Bacteria that can survive without oxygen are called anaerobic bacteria.

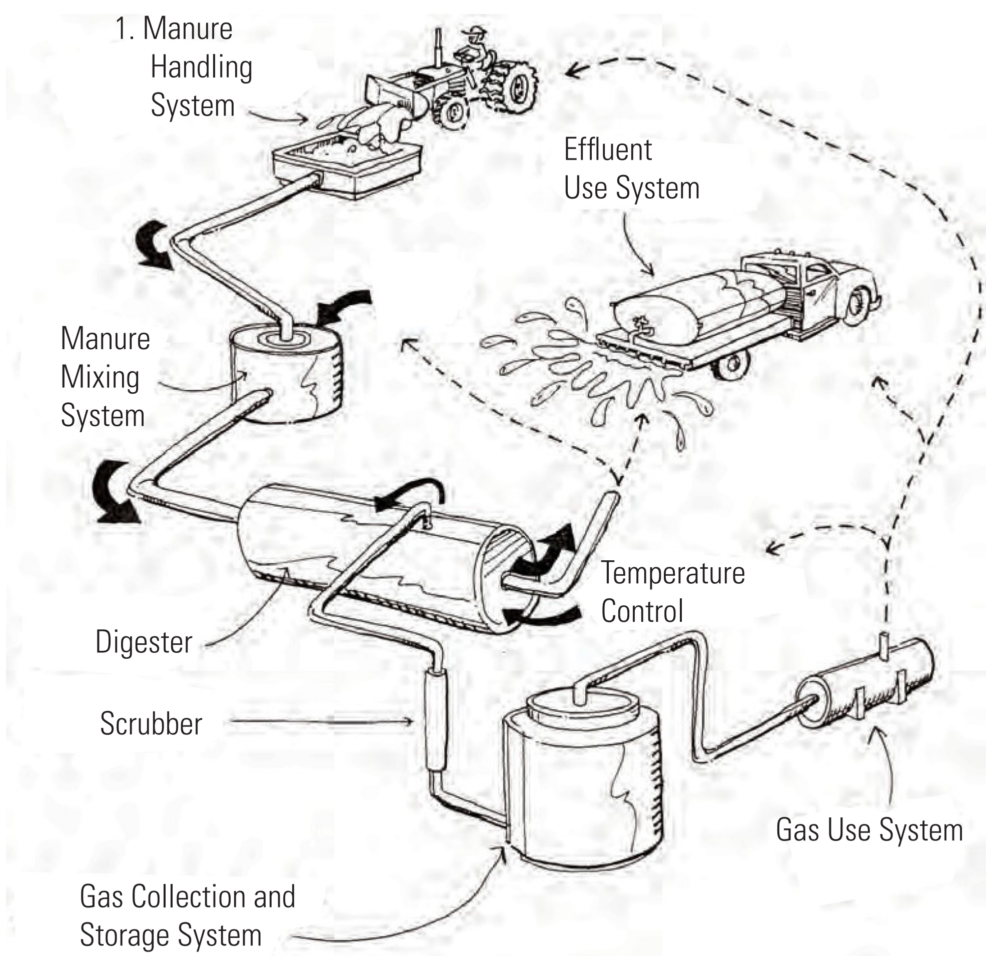
The bacteria are the last link in the food chain. They are the decomposers that break down dead organisms and waste products such as manure. Two different types of bacteria are involved in the process. Acid-forming bacteria break down the volatile solids of organic matter into simple fatty acids and fermentation products (CO_2 and H_2). Methane-forming bacteria convert the fatty acids and fermentation products to methane and carbon dioxide. This mixture is biogas.

If the methane mixture escapes an environment containing oxygen, it is re-oxidized by aerobic bacteria (bacteria that need oxygen to survive). Thus, biogas is a renewable energy source derived from plant, animal, and human waste.

Biogas production from anaerobic decomposition is influenced by temperature, pH, and the nitrogen-to-carbon ratio. For optimal biogas production the pH needs to be neutral (7.0). The more acidic or alkaline, the less biogas produced because fewer bacteria are capable of surviving. The higher the nitrogen-to-carbon ratio, the more biogas produced as nitrogen provides the energy for the process. However, a nitrogen-to-carbon ratio that is too high results in ammonia production, which can be toxic to the bacteria.

To extract the biogas from landfills, wells are drilled into the landfill, and perforated pipe is laid to collect the biogas. The biogas moves through the perforated pipe and out of the well. It then is compressed through an activated carbon filter, removing the contaminants – hydrogen sulfide and ammonia – and passed through a membrane, which separates the methane from carbon dioxide. The methane then is piped directly into a natural gas pipeline.

Biogas also can be extracted from sludge, the remaining solids of sewage treatment. The sludge is placed in airtight tanks called digesters. The digesters are heated to about 96 F (35 C) to encourage and speed up decomposition by anaerobic bacteria. The gas is cleaned so that only the methane is piped into the natural gas pipeline. In large sewage plants, methano-genic bacteria have long been used to produce methane, which can be used as a fuel to generate on-site electricity for use in the sewage plant.



Biogas can be extracted from chicken and cattle manure. The manure is mixed with water, and the resulting slurry is pumped into digesters. The digesters are heated to the desired temperature. The process is similar to extracting biogas from sludge. The diagram on the previous page shows how biogas can be created from manure and the uses of the gas on a farm.

The geological formation of natural gas involves the transformation of kerogen (a solid organic material) by heat and pressure into crude oil. The high temperature is due, in part, to the pressure and generated from the overlying sediments about 7,500 feet (2,300 m) below the surface of the earth. As the temperature increases with depth, the crude oil is transformed into lighter hydrocarbons – natural gas. The conversion of crude oil into natural gas requires a temperature of about 300 F (150 C).

Biogas can be recovered from sewage, landfills, garbage dumps and feedlots. The methane produced, on average, has a lower heating value of natural gas because natural gas often contains other gases that have heat contents higher than that of methane. Biogas generally contains less methane than natural gas.

Biogas production is technically feasible, but economics will influence when, where and how biogas technology becomes commercialized.