

Landfill Gas

Grade: 6

State Standards: Earth Science, 6.0 Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation. Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.

Groups of 2

Preparation Time: 25 minutes

Activity Time: 60 minutes

Key Words: Carbon dioxide, methane, chemical reaction, inorganic, and organic

OBJECTIVE

Students will know environmental and external factors that affect individual and community health. Know ways local, state, federal and international efforts to contain an environmental crisis and prevent recurrence (e.g., solid waste contamination/air pollution). Understand global development and environmental issues. Understand the possible impact that present conditions and patterns of consumption, production and population growth might have on the future spatial organization of Earth.

MATERIALS

- Pencils and paper
- Index cards
- Reference materials: dictionaries, encyclopedias, glossaries, the internet
- Vocabulary handout

BACKGROUND

Approximately 55% of the solid waste produced in the US is disposed of in landfills located across the country. Landfills are a long-term disposal solution that requires that trash to be buried underground. The EPA has identified eight categories of waste that are typically buried in landfills. These categories include: paper, yard trimmings, food scraps, plastics, metals, textiles-rubber- leather, glass and wood.

While decomposition is slowed considerably in landfills due to the lack of light, air and moisture, as the waste slowly breaks down over time it produces a by-product, known as landfill gas (LFG). The composition of this gas varies from one landfill to another based on the type and amounts of waste buried in a specific location, and LFG production usually levels off at somewhere between five to seven years. LFG consists of approximately 40-60% methane, 40-60% carbon dioxide and small amounts of nitrogen, oxygen, sulfides, ammonia, hydrogen, carbon monoxide and any number of contaminants referred to as “non-methane organic compounds” (NMOCs). NMOCs typically account for less than 1% of landfill gas, but should be considered in any plan for managing LFG, as many of them have the potential to recombine into highly toxic compounds under certain circumstances involving combustion.

Once LFG is produced it expands and moves, following the path of least resistance. It typically moves in an upward position, but its escape route can be blocked by tightly compacted waste, causing it to migrate horizontally, until it finds its way beyond the borders of the landfill and into the environment. Instead of allowing LFG emissions to escape most landfills are equipped with a methane collection system that consists of a group of wells and a vacuum system. This type of system captures the LFG, so it can be processed. Once the LFG is collected it can be handled in a variety of ways, including: a) flared, b) used in a boiler, dryer, greenhouse or kiln to make heat, c) used in an internal combustion engine, gas turbine or fuel cell to make electricity, d) used directly to evaporate leachate, or e) separated and converted into methanol (methane) or dry ice (carbon dioxide). There are, of course, pros and cons for each method of handling LFG and each has its advocates and protestors. Municipal solid waste landfills are the second largest source of methane emissions attributed to human actions in the United States.

Many large landfills are already collecting ambient air methane data. Under the 1996 EPA New Source Performance Standards and Emission Guidelines for Municipal Solid Waste Landfills (40 CFR Part 60, Subparts WWW), landfills with the potential to emit more than 50 Mg/year of non-methane volatile organic compounds (NMVOC are typically less than 1% of landfill gas or roughly 2% of methane emissions) must collect and combust the landfill gas. Combusting or flaring of landfill gas reduces odors, safety concerns, and methane emissions. To ensure that the landfill gas collection systems are operating properly, quarterly surface VOC monitoring must be conducted according to EPA regulations (40 CFR 60.755 (c) and (d), and 40 CFR 60, Appendix A, Method 21). These regulations require air monitoring around the perimeter of and within the area of a landfill gas collection system to determine compliance. Readings above 500 ppm require remedial action, and may imply that something is wrong with the gas collection system. http://www.cee.ucf.edu/labs/air_quality/h2s/publications/Research_Paper_03.pdf

PROCEDURE

Before Conducting the Lesson:

- Review the structure of a MSW landfill with students (see Modern Landfill sheet). Introduce the students to the concept of landfill gas and provide them with background information, how landfill gas can be collected and converted for use.

Conducting the Lesson:

1. Divide students into pairs. Provide each pair with a set of blank cards and the vocabulary handout provided at the end of this lesson. Students should be given access to resource materials (dictionaries, encyclopedias, glossaries for environmental science, etc.) and possibly the Internet.
2. Students will work in pairs to locate a definition for each term as it relates to landfill gas, write the term on one side of a card and the definition on the reverse.
3. Once the students have developed their own word bank of terms they will use the cards to sort and classify, creating lists of terms that relate to each of the following questions:
 - What are four components of landfill gas? Landfill gas is approximately forty to sixty

percent methane, with the remainder being mostly carbon dioxide. Landfill gas also contains varying amounts of nitrogen, oxygen, water vapor, sulfur, and other contaminants. Most of these other contaminants are known as "non-methane organic compounds" or NMOCs.

- How is landfill gas produced? Landfill gas production results from chemical reactions and microbes acting upon the waste as the putrescible materials begin to break down in the landfill. The rate of production is affected by waste composition and landfill geometry, which in turn influence the bacterial populations within it, chemical make-up, thermal characteristics, entry of moisture and escape of gas.

- What organisms are present during the decomposition process when the landfill becomes a neutral environment? Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen, used for industrial or domestic purposes to manage waste and/or to release energy. The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide

- What are some of the conditions that affect landfill gas production? Bacteria decompose landfill waste in four phases. The composition of the gas produced changes with each of the four phases of decomposition. Landfills often accept waste over a 20- to 30-year period, so waste in a landfill may be undergoing several phases of decomposition at once. This means that older waste in one area might be in a different phase of decomposition than more recently buried waste in another area.

During the first phase of decomposition, aerobic bacteria—bacteria that live only in the presence of oxygen—consume oxygen while breaking down the long molecular chains of complex carbohydrates, proteins, and lipids that comprise organic waste. The primary byproduct of this process is carbon dioxide. Nitrogen content is high at the beginning of this phase, but declines as the landfill moves through the four phases. Phase I continues until available oxygen is depleted. Phase I decomposition can last for days or months, depending on how much oxygen is present when the waste is disposed of in the landfill. Oxygen levels will vary according to factors such as how loose or compressed the waste was when it was buried.

Phase II decomposition starts after the oxygen in the landfill has been used up. Using an anaerobic process (a process that does not require oxygen), bacteria convert compounds created by aerobic bacteria into acetic, lactic, and formic acids and alcohols such as methanol and ethanol. The landfill becomes highly acidic. As the acids mix with the moisture present in the land-fill, they cause certain nutrients to dissolve, making nitrogen

and phosphorus available to the increasingly diverse species of bacteria in the landfill. The gaseous byproducts of these processes are carbon dioxide and hydrogen. If the landfill is disturbed or if oxygen is somehow introduced into the landfill, microbial processes will return to Phase I.

Phase III decomposition starts when certain kinds of anaerobic bacteria consume the organic acids produced in Phase II and form acetate, an organic acid. This process causes the landfill to become a more neutral environment in which methane-producing bacteria begin to establish themselves. Methane- and acid-producing bacteria have a symbiotic, or mutually beneficial, relationship. Acid-producing bacteria create compounds for the methanogenic bacteria to consume. Methanogenic bacteria consume the carbon dioxide and acetate, too much of which would be toxic to the acid-producing bacteria.

Phase IV decomposition begins when both the composition and production rates of landfill gas remain relatively constant. Phase IV landfill gas usually contains approximately 45% to 60% methane by volume, 40% to 60% carbon dioxide, and 2% to 9% other gases, such as sulfides. Gas is produced at a stable rate in Phase IV, typically for about 20 years; however, gas will continue to be emitted for 50 or more years after the waste is placed in the landfill (Crawford and Smith 1985). Gas production might last longer, for example, if greater amounts of organics are present in the waste, such as at a landfill receiving higher than average amounts of domestic animal waste.

- How does landfill gas migrate? Gas migrates through the path of least resistance. Gas collection wells are installed throughout a landfill. These wells are made of perforated pipes which give the gas an easy path to move vertically to the surface rather than laterally (outward) toward off-site locations (e.g., buildings). As the gases enter these wells they are either vented into the outdoor air, passed through a flame and broken down by burning, passed through a filter, or used in an energy recovery program. Landfill gas vents need to be kept drained and clear of obstructions such as snow and debris.

For more information: <http://www.atsdr.cdc.gov/hac/landfill/html/ch2.html>

-What are some ways LFG can be handled once it is collected? The general options for dealing with landfill gas (once collected) are as follows:

1. vent it
2. flare it
3. boiler-makes heat
4. internal combustion engine-makes electricity
5. gas turbine-makes electricity
6. fuel cell makes electricity
7. convert the methane to methyl alcohol
8. clean it up enough to pipe it to other industries or into the natural gas lines

For a more comprehensive list of options online at:

<http://www.eia.doe.gov/cneaf/solar.renewables/renewable.energy.annual/chap10.html>

After the Lesson:

- Students will use the word bank to write a description of landfill gas, including: its composition, how it is formed, the conditions that affect its production, how it moves, how it is collected, and how it is handled after collection.
- Students will prepare a statement voicing their opinions on the use of landfills in the US and the world and justify their position based on the evidence and observations collected.

Adaptations:

Students can work independently researching advantages of waste reduction, reuse and recycling to avoid landfilling waste. Some advantage points students should explore:

- Less energy consumption therefore reducing the environmental impact (especially with regard to greenhouse gases)
- Reduction in overall use of materials
- Extends the life of materials
- Cost effective (recycled products can be cheaper than buying a brand new product)

Extensions:

Students can research the pros and cons of converting landfill gas into energy and take a position on the issue of whether or not it should be considered a *green* energy source.

ASSESSMENT

The students will be able to

- Identify and describe the problems and concerns people have about burying trash in landfills and justify their position on the matter.
- Identify and define the pros and cons landfill gas use.
- Write a well-constructed opinion on the use of landfills and justify their position with details from research, observations and data.

HANDOUT

Directions: Use the available resources to locate a working definition related to landfill gas (LFG) for each of the following terms. Write the term on one side of a blank card and the definition on the reverse side. Then sort and classify the cards to help answer the questions that follow.

Anaerobic bacteria	C & D landfill
Chemical reaction	Decomposition
Emissions	Groundwater levels
Hydrocarbons	Methanol
MSW landfills	Natural pathways
Permeability	Solid waste
Water vapor	Gas turbine
Incineration	Methanogenic bacteria
Waste composition	Bacterial decomposition
Carbon dioxide	contaminates
Diffusion	flared
Hazardous waste landfills	Methane
Migrate	NMOC's
Non-hazardous waste	Pressure
Volatilization	Internal combustion engine
Fuel cell	Neutral environment
Age of refuse	Oxygen

- 1. What are four components of landfill gas?**

- 2. How is landfill gas produced?**

- 3. What organisms are present during the decomposition process when the landfill becomes a neutral environment?**

- 4. What are some of the conditions that affect landfill gas production?**

- 5. How does landfill gas migrate?**

- 6. What are some ways LFG can be handled once it is collected?**

A Modern Landfill

