METHANE: THE “OTHER” GREENHOUSE GAS

Overview:
Methane is capable of holding more than 20 times the heat of carbon dioxide but it is often overlooked as an important greenhouse gas because relatively small amounts exist in the atmosphere. Because it degrades in the atmosphere its effects are hard to predict, but methane can exert a powerful influence on temperature.

Objectives:
The student will:
• interpret graphs and charts to determine properties of methane; and
• calculate future methane emissions based on current trends.

Targeted Alaska Performance Measures Tested on the High School Graduation Qualifying Exam

Reading
R4.1 Apply knowledge of syntax, roots, and word origins, and use context clues and reference materials, to determine the meaning of new words and to comprehend text.

Math
M6.3.2 Interpret and analyze information found in newspapers, magazines, and graphical displays.
M6.3.4 Make projections based on available data and evaluate whether or not inferences can be made given the parameters of the data

Targeted Alaska Grade Level Expectations:

Science
[11] SA1.1 The student develops an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.

[11] SC3.2 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by analyzing the potential impacts of changes (e.g., climate change, habitat loss/gain, cataclysms, human activities) within an ecosystem.

Vocabulary

anaerobic – occurring or living in the absence of oxygen
anthropogenic – caused or produced by humans
chlorofluorocarbons – organic compounds that contain carbon, chlorine, and fluorine atoms (CFCs); CFCs are highly effective refrigerants; they are also widely used as aerosol propellants, cleansing agents for electrical and electronic components, and foaming agents in manufacturing of shipping pellets
decomposition – the process of decaying or rotting brought about by the activity of certain bacteria or fungi feeding on it
feedback loop – a circular pathway of cause and effect; related to climate feedback loops, can be positive (adding to the rate of warming) or negative (reducing it)
flux – the amount of something flowing across a given area per unit of time
infrared spectrum – the range of wavelengths of electromagnetic radiation greater than the range of visible red light
methane – chemical compound with the formula CH4; the principal component of natural gas
methanogenesis – the formation of methane by microbes known as methanogens; the production of methane is an important and widespread form of microbial metabolism; in anaerobic environments, it is the final step in the decomposition of biomass
ruminant – a mammal that digests plant-based food by initially softening it within the animal’s first stomach, known as the rumen, then regurgitating the semi-digested mass, now known as cud, and chewing it again; the process of re-chewing the cud to further break down plant matter and stimulate digestion is called ruminating; ruminating mammals include cattle, goats, sheep, giraffes, bison, yaks, water buffalo, deer, camels, alpacas, llamas, wildebeest, and antelope

sediment – a solid material that is not in solution and either is distributed throughout the liquid or has settled out of the liquid

seep – to pass gradually or leak through small openings; become diffused gradually

sink – a natural or manmade reservoir that absorbs and stores chemical compounds (such as carbon or methane) for an indefinite period

talik – a layer of permanently unfrozen ground that lies above permafrost but below the active layer of ground

Whole Picture:

The concentration of methane in the atmosphere is considerably less than that of carbon dioxide. However, it has more capacity to increase temperature, and thus affect climate change. Methane is naturally produced by anaerobic decomposition of biomass in wetlands and animal wastes, and through the aid of anaerobic bacteria in the stomachs of ruminants. It is commonplace to see methane bubbling to the surface of Arctic lakes.

Anthropogenic sources, such as fossil fuel production and agriculture, have begun to contribute significantly to the amount of atmospheric methane. In addition, new studies indicate that fossil methane from below the sea may be finding its way into the atmosphere. Methane’s effects on the atmosphere are not well understood and scientists are unsure of the degree of influence they may have on global temperatures. In this lesson students will read introductory material, work with National Oceanic and Atmospheric Administration graphs to gain insight into the production and effects of methane, and read excerpts from a recent University of Alaska Fairbanks study that may shed new light on methane emissions into the atmosphere.

Materials:

• DIGITAL LECTURE: “Hunting for Methane with Katey Walter Anthony” available on the UNITE US website (uniteusforclimate.org)
• DIGITAL LECTURE: “Methane Bubbles to the Surface of an Arctic Lake” available on the UNITE US website (uniteusforclimate.org)
• VISUAL AID: “Don’t Sleep There”
• VISUAL AID: “Comparing Greenhouse Gases”
• VISUAL AID: “Methane Budget”
• STUDENT INFORMATION SHEET: “Methane: The Other Greenhouse Gas”
• STUDENT WORKSHEET: “Methane Mayhem”
• STUDENT WORKSHEET: “Methane Math”

Activity Preparation:

View the webinar: “Methane Emissions from Thermokarst Lakes” by Dr. Katey Walter Anthony, available on the Alaska Center for Climate Assessment and Policy (ACCAP) website (http://ine.uaf.edu/accap/files/WebinarVideo/2010_5_MethaneLakes_WalterAnthony.mp4). The file is about 30 minutes long.

Activity Procedure:

1. Ask students if they have ever seen a pond or lake noticing bubbles rising from the bottom. These are gases escaping from the lakebed. Ask students where the gas is originating? (The decomposition of organic matter releases carbon dioxide and methane. Carbon dioxide can stay in the water (in solution), but methane can’t so it bubbles to the top.) Explain some areas, called seeps, release large quantities of trapped gases. Show students VISUAL AID: “Don’t Sleep There.” Explain people recognized areas with seeps even before the gas was identified.
2. Explain that carbon dioxide is a well-known greenhouse gas released during the decomposition of organic material; methane is another and is the focus of today's lesson. Methane is produced during anaerobic decomposition. Anaerobic means decomposition that occurs without the presence of oxygen. Microbes (decomposers that break down dead plants and animals) metabolize the organic material and release methane as a byproduct.

3. Show the DIGITAL LECTURES: “Methane Bubbles to the Surface of an Arctic Lake,” and “Hunting for Methane with Katey Walter Anthony,” both available on the UNITE US website (uniteusforclimate.org).

4. Show VISUAL AID: “Methane Budget.” Ask students what they think of when they hear the term budget. Budget implies a balance of incoming and outgoing, whether it be as large as running a multi-billion dollar company or as simple as spending your allowance. The term budget is also used in science to discuss Earth processes, like the carbon budget and the methane budget. The pie chart, Methane Sources, shows ways methane is produced, or enters the budget. The pie chart, Methane Sinks, shows the ways methane is removed from the budget. According to this information, obtained from NOAA, six percent of the methane released is not removed and remains in the atmosphere.

5. Hand out STUDENT INFORMATION SHEET: “Methane: The Other Greenhouse Gas.” The pie chart included in the reading is from the U.S. Department of Energy. It breaks down the methane producers a little differently, but the division between natural and anthropogenic is about the same. Katey Walter Anthony, the scientist in the multimedia, gives more credit to natural sources when discussing the methane budget. Walter Anthony says the methane from Arctic lakes is not accounted for in many methane budgets. Read through the material and discuss.

5. Hand out STUDENT WORKSHEET: “Methane Mayhem.” Students will use the information sheet to find answers.

6. Display VISUAL AID: Comparing Greenhouse Gases. Each of the greenhouse gases depicted shows a trend toward greater amounts in the atmosphere. Ask students why the blue lines move up and down (seasonal variability). The red line is the average. Hand out STUDENT WORKSHEET: “Methane Math.” The worksheet has the same methane graph in black and white. Leave the color version on display as students complete the worksheet.

Extension Ideas:

1. If you have access to methane, research experiments that ignite methane bubbles using a soapy solution. Students find this very engaging! Directions can be found on the Internet; video examples are available on YouTube.

2. Ask students to research the viability of capturing methane from seeps to use as a community energy source. Students could complete a design that could harness the methane and pipe it to homes.

Answers:

**STUDENT WORKSHEET: Methane Mayhem**

1. anaerobic
2. B. caused by humans
3. The type and quality of feed given to livestock contributes to the amount of methane released during the animals’ digestion. Increased world population has increased the demand for livestock.
4. The millions of lakes and ponds in the Arctic that release tons of methane every day.
5. Carbon Dioxide = occurs naturally through decomposition, volcanoes, forest fires; also occurs through burning of oil and gas, cement manufacturing and deforestation
   Methane = occurs naturally from anaerobic decomposition and from livestock digestion
   Nitrous Oxide = burning of oil, gas, coal, wood; fertilizers, coal mining; also occurs naturally
6. carbon dioxide
7. methane
8. nitrous oxide
9. more than 10 times more methane than is currently in the atmosphere
10. Methane is released during the decomposition of organic matter. Decomposition is halted in permafrost, but warming temperatures cause permafrost thaw and allows decomposition to continue. Methane is released and enters the atmosphere. Methane is a greenhouse gas and contributes to climate warming, which thaws the permafrost, which releases more methane.

**STUDENT WORKSHEET: Methane Math**

1. Accept answers between 1650 ppb and 1655 ppb.
2. Accept answers between 1795 ppb and 1800 ppb.
3. 8.8%
   
   *Formula for percentage change: ((y2 – y1) / y1)*100 = percent change*
   
   For example, using 1,655 and 1800 as the values, the problem would look like this:
   
   (1,800 – 1,655) / 1,655 * 100 = 8.8%

4. 30,000
   
   (1,800/.06 = 30,000)

5. *Answers will vary depending on graph interpretation. Accept a range of answers between 1,850 and 2,000 as long as explanation justifies answer. For example, using 8.8% (as found in problem 3): 8.8% of 1800 is 158; 1800 + 158 = 1,958 ppb.
   
   *If you just look at the difference between 2000 and 2010 there is approximately a 20ppb increase over those 10 years, or 2ppb per year. If you extrapolate that out 25 more years that would be an increase of 50ppb, or 1850 ppb by 2035. If you look at the current trend over the past 10 years, versus the last 24 years you get very different answers. If you looked at the increase from 2006 to 2010 that would give a different answer as well. In looking at the graph you can see that it is not a straight-line increase; it is flattening out in more recent years (current trend).*

6. Answers should reflect an understanding of the methane budget: Currently 96 percent of methane is removed through chemical reaction, leaving six percent in the atmosphere. If ten times more methane is released, not only would that lead to ten times more methane in the budget (and the atmosphere), it is possible that chemical reaction may not continue to absorb 96 percent. The current six percent may grow to a greater percentage. The parts per billion would be far greater. As a greenhouse gas methane has the potential to significantly impact the global climate.
METHANE BUDGET

Methane Sources

- **Anthropogenic Sources**
  - Fossil Fuel Related: 20%
  - Landfills: 6%
  - Animal Waste: 5%
  - Domestic Sewage: 5%
  - Ruminant Animals: 15%
  - Biomass Burn: 8%
  - Rice Paddies: 12%

- **Natural Sources**
  - Wetlands: 22%
  - Termites: 4%
  - Ocean/Fresh Water: 3%

Chemical Reactions: 88%

- Oxidation by Bacteria in Soils: 6%
- Unclaimed: 6%

Graphs are based on information obtained from the National Oceanic and Atmospheric Administration (NOAA).
COMPARING GREENHOUSE GASES

Carbon Dioxide
- Parts per million (ppm)

Methane
- Parts per billion (ppb)

Nitrous Oxide
- Parts per billion (ppb)

CFC-12
- Parts per trillion (ppt)

CFC-11
- Parts per trillion (ppt)
Don’t Sleep There

Scientists studying landscape processes in Alaska’s Arctic Coastal Plain interviewed many Inupiat Elders and hunters. Many pointed to a site where people were warned not to spend the night. They warned them, “If you go to sleep there, you will never wake up.”

Several Elders and hunters told them that these sites, “are often places where shamans are buried or where spirits dwell.” Inupiaq culture bearer Ron Brower, Sr. suggested that these areas are places where methane or carbon dioxide escapes, called seeps. They are dangerous when there is no wind.
METHANE: THE “OTHER” GREENHOUSE GAS

Carbon dioxide tends to dominate the greenhouse gas spotlight, but methane is a formidable competitor.

Dr. Katey Walter Anthony, assistant professor at the University of Alaska Fairbanks calls methane a very potent greenhouse gas. “A molecule of methane is 25 times stronger than carbon dioxide,” she said. In other words, it has the ability to hold 25 times more heat and re-radiate it back to Earth.

Methane is a naturally occurring by product of anaerobic decomposition. Methane, or CH4, is a principal component in natural gas – a highly sought-after fossil fuel and a critical component in the world’s energy supply.

NOTE: Ruminants, mostly livestock, are included in human-caused methane production. The type and quality of feed given to livestock contributes to the amount of methane released during the animals’ digestion. A bacteria in the animals’ gut is responsible for methane production. The methane is released primarily through belching. Increased world population has increased the demand for livestock.

This U.S. Department of Energy Technology Laboratory chart depicts sources of methane worldwide.

Walter Anthony says such charts may not give enough credit to an important source of methane: the millions of lakes and ponds in the Arctic that release tons of it every day. In fact the methane bubbling to the surface of Arctic lakes could match the amount released by wetlands.

Methane Budgets and Feedback Loops

As the process of decomposition occurs, methane is continually released from millions of seeps across Alaska, and thawing permafrost is a major contributor. As the climate of the Arctic trends toward increasing temperatures, Katey Walter Anthony speculates that increased temperature might thaw more permafrost, which will release more methane, which could contribute to warmer temperatures. This self-feeding cycle is called a positive feedback loop.

Vocabulary

anaerobic – occurring or living in the absence of oxygen
anthropogenic – caused or produced by humans
decomposition – the process of decaying or rotting brought about by the activity of certain bacteria feeding on it
greenhouse gas – any of the atmospheric gases that contribute to the greenhouse effect, trapping the sun’s radiation in Earth’s atmosphere; greenhouse gases help regulate Earth’s climate
ruminant – a mammal that digests food by softening it within the first stomach then regurgitating the semi-digested mass and chewing it again, called ruminating
METHANE: THE “OTHER” GREENHOUSE GAS

Methane Budget

Methane enters the atmosphere in many ways but it is also removed through a variety of natural processes. This cycle of in and out is called a budget. Chemical reaction in the atmosphere converts about 88 percent of methane into water and CH3, a methyl radical. Bacteria in soil take up methane and account for six percent of methane uptake. That leaves another six percent still in the atmosphere.

Comparing Greenhouse Gases (GHGs)

Just as different types of blankets keep in different amounts of heat, different greenhouse gases work differently. Some keep in more heat than others. If you think of one volume of carbon dioxide as being one blanket, then the same volume of methane would equal 25 blankets and nitrous oxide would equal 296 blankets.

Without greenhouse gases, Earth would be a much colder planet, dropping at least 33º Celsius (59º Fahrenheit) colder than current temperatures. Too many greenhouse gases could overheat the planet.

<table>
<thead>
<tr>
<th>GHG</th>
<th>How long does it stay in the atmosphere?</th>
<th>Warming potential</th>
<th>Percent of total atmosphere</th>
<th>Where does it come from?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>50 - 200 years</td>
<td>1</td>
<td>0.039%</td>
<td>Naturally occurring through respiration, volcanic activity, and forest fires; a byproduct of burning fossil fuel, of cement manufacturing, deforestation and other land uses</td>
</tr>
<tr>
<td>Methane</td>
<td>12 years</td>
<td>25</td>
<td>0.000179%</td>
<td>A natural byproduct of anaerobic decomposition and from livestock digestion; a byproduct of oil and gas production, coal mining, rice paddies, dams and landfills</td>
</tr>
<tr>
<td>Nitrous Oxide</td>
<td>120 years</td>
<td>296</td>
<td>0.00003%</td>
<td>A byproduct of burning fossil fuels; a byproduct of fertilizer manufacturing and coal mining; also occurs naturally</td>
</tr>
</tbody>
</table>

About 99 percent of Earth’s atmosphere is made up of nitrogen and oxygen. The remaining are trace gases. Greenhouse gases are among the trace gases.
NAME: __________________________

METHANE MAYHEM

**Directions:** Use STUDENT INFORMATION SHEET: “The Gas Line” to complete the following questions.

1. Circle one. Methane is produced by the anaerobic / aerobic decomposition of organic matter.

2. Anthropogenic means:
   - A. genetic anthropology
   - B. caused by humans
   - C. caused by ruminants

3. Give two reasons the contribution of methane by ruminants is considered anthropogenic.
   ___________________________________________________________
   ___________________________________________________________

4. The U.S. Department of Energy Technology Laboratory graph, Methane Sources, may not give enough credit to what major methane contributor? __________________________________________________________

5. Match the greenhouse gas with its source.
   - **Carbon Dioxide** occurs naturally from anaerobic decomposition and from livestock digestion
   - **Methane** burning of oil, gas, coal, wood; fertilizers, coal mining; also occurs naturally
   - **Nitrous Oxide** occurs naturally through decomposition, volcanoes, forest fires; also occurs through burning of oil and gas, cement manufacturing, and deforestation

6. Once in the atmosphere, which greenhouse gas can stay up to 200 years? ____________________________

7. Once in the atmosphere, which greenhouse gas lasts about 12 years? ____________________________

8. Which greenhouse gas has the highest warming potential? ____________________________

9. According to Katey Walter Anthony, if Arctic permafrost was to thaw, how much more methane would be put into the atmosphere? ____________________________

10. Describe the positive feedback loop created by methane released from thawing permafrost.
    ___________________________________________________________
    ___________________________________________________________
    ___________________________________________________________
NAME: __________________________

METHANE MATH

The National Oceanic and Atmospheric Administration graph at right shows the atmospheric methane levels between 1978 and 2010. The dark line shows recorded methane levels with seasonal variability. The light line is the annual average.

1. In 1986 methane was present in approximately what amount? (Use the line showing average.)
   ___________ ppb

2. In 2010 methane was present in approximately what amount?
   ___________ ppb

3. What is the percentage change between 1986 and 2010? Round your answer. __________________________
   Use the following formula: \((\frac{y_2 - y_1}{y_1}) \times 100 = \text{percent change}\)

4. Determine the total emission of methane in 2010.
   Scientists know that 94% of methane is removed by chemical reaction. The graph shows the 6% that remains. Using the amount noted in problem 2, determine the total emission of methane in 2010 before chemical reaction.
   ppb 2010 _______________________/ .06 = ________________________ ppb total methane emission 2010

5. If current trends continue, what will the atmospheric methane level be in the year 2035? ________________
   Explain how you determined your answer.
   ____________________________________________________________________________________________
   ____________________________________________________________________________________________
   ____________________________________________________________________________________________

6. According to Katey Walter Anthony of the University of Alaska Fairbanks, if permafrost were to melt, 10 times the amount of methane would be released into the atmosphere. How do you think this would affect the methane budget?
   ____________________________________________________________________________________________
   ____________________________________________________________________________________________
   ____________________________________________________________________________________________
   ____________________________________________________________________________________________