The Greenhouse Effect Analogy

Introduction

Set up a conceptual model of the greenhouse effect with just a few simple items. Demonstrate how increasing atmospheric levels of carbon dioxide (CO_2) and other gases may be raising average temperatures and catalyzing global climate change.

Concepts

- Greenhouse Effect
- Equilibrium

Background

The greenhouse effect, or global warming, is commonly thought of as some sort of abstract process threatening us with coastal flooding, desertification, drought and general global disaster. The greenhouse effect is not a new or an entirely man-made phenomenon. For hundreds of millions of years, the greenhouse effect has been actively regulating the heat balance of the Earth. If it were not for the greenhouse effect and the greenhouse gases in our atmosphere, our planet would be unbearably cold. Scientists estimate that without these gases average surface temperatures would be below freezing! So why is the greenhouse effect being reported as harmful to our planet? The excitement stems from two facts already mentioned: the composition of the atmosphere and the heat balance of the Earth—when one changes it alters the other.

Incoming solar energy, in the form of electromagnetic radiation, reaches the Earth primarily as visible light. Approximately one-third of this energy is immediately reflected by clouds, snow, ice, water and other surfaces. The remaining two-thirds of solar radiation is absorbed by the Earth's surface and various components of the atmosphere. Since the surface temperature doesn't fluctuate widely as day becomes night, this absorbed energy must be re-emitted (energy follows the laws of thermodynamics). The Earth re-emits this energy as heat—also known as infrared radiation. So one hundred percent of the solar energy that reaches the Earth ultimately leaves the Earth; either immediately reflected as visible light or absorbed and re-emitted as infrared radiation. Certain gaseous components of our atmosphere are completely transparent to the incoming solar radiation (the visible light) but are not completely transparent to the infrared radiation (the heat) and they act to trap and delay that heat from escaping the atmosphere. This trapping and delay is known as the greenhouse effect because of its similarity to the function of a greenhouse.

If the amounts of these infrared absorbing components are increased, less heat escapes and the planet will get warmer. The balance of energy is still in effect (i.e., 100% in = 100% out) but the average atmospheric temperature is now higher.

Most important among these infrared absorbing components (termed greenhouse gases) are nitrous oxide, methane, water vapor, chlorofluorocarbons (CFCs) and carbon dioxide. With the exception of CFCs, which are entirely human-generated, all of these gases are naturally present and generated by natural processes. The problems arise due to numerous human-mediated processes that generate ever-increasing quantities of these gases. Eliminating rain forests and burning fossil fuels contribute carbon dioxide; automobiles contribute nitrous oxide; residential and industrial refrigerants contribute CFCs; agriculture, livestock, landfills and natural gas delivery systems contribute methane. Many of these processes are currently under careful scrutiny by regulatory agencies with the goal of finding methods for reducing emissions of greenhouse gases.

Materials (for each student)

Corks, size 00 or 0, 4*
Food coloring/vegetable dye (optional)
Phillips screwdriver, shank diameter of 6–8 mm
Plastic soda bottle, label removed, 2-L
Rubber or plastic tubing (optional)

Safety Precautions

Food coloring will stain skin, clothing, and surfaces. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please consult current Safety Data Sheets for additional safety information. Wash hands thoroughly with soap and water before leaving the laboratory.

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Pre-Lab Preparation

1. Use a Bunsen burner to heat the tip of the screwdriver over the flame. *Caution:* Do not touch the tip of the screwdriver after heating.
2. Once heated, the screwdriver will be capable of melting holes in the plastic bottle.
3. Melt a vertical series of five holes beginning approximately one inch above the support base of the bottle. Each hole should be approximately one inch apart.

Procedure

To demonstrate the greenhouse effect:

1. Place the soda bottle over a sink or catch basin and let a steady stream of water run into it (this may require rubber tubing). A few drops of food coloring will enhance visibility of the water level. The objective is to regulate the water flowing in so that the water level in the bottle remains level with the lowest hole.
2. Plug the lowest hole with one of the corks allowing the water level to rise to the second hole where it will again attain equilibrium.
3. Repeat step two by plugging each successive hole up to the top of the series.

Discussion

In the demonstration the water entering the bottle is analogous to the incoming solar radiation reaching the Earth and the resulting water level is analogous to the average global temperature. Plugging the holes on the bottle simulates increasing the atmospheric concentration of the greenhouse gases. Increased water level represents the increased temperature level of the Earth. With each incremental increase of these "gases" (i.e., as each successive hole is plugged) the average global temperature climbs to a new level. It is important to emphasize that as equilibrium is attained at each level the balance between energy coming in (water entering the bottle) and energy going out (water exiting the bottle) is reestablished.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The resulting solutions may be disposed of by rinsing them down the drain with excess water according to Flinn Suggested Disposal Method #26b.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
MS-ESS3 Earth and Human Activity
ESS3.A: Natural Resources
ESS3.C: Human Impacts on Earth Systems
ESS3.D: Global Climate Change

Disciplinary Core Ideas: High School
HS-ESS3 Earth and Human Activity
ESS3.C: Human Impacts on Earth Systems
ESS3.D: Global Climate Change

Science and Engineering Practices
Asking questions and defining problems
Developing and using models
Constructing explanations and designing solutions
Engaging in argument from evidence

Crosscutting Concepts
Cause and effect
Systems and system models
Structure and function
Stability and change

Acknowledgment

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References

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Global Warming: The Greenhouse Effect, Publication DOE/ER-0411, U.S. Dept. of Energy, Washington, D.C. 20545

Report to the Nation: The Climate System, Winter 1991, VCAR Office for Interdisciplinary Earth Science, Boulder, CO 80307

Global Climate Change, ACS Information Pamphlet, 1990, American Chemical Society, Washington, D.C. 20036

Materials for *The Greenhouse Effect Analogy* are available from Flinn Scientific, Inc.

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AP4315	Cork, Size 00
AP8300	Cork, Size 0

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