Where Land, Air, and Water Meet

Background

The Earth is often compared to a gigantic greenhouse. Energy in the form of sunlight passes through the planet's atmosphere. Some of the energy that strikes the land and water is reflected back into space. Most of the rest is absorbed by the land and water, converted to heat, and radiated back into the atmosphere. This radiated energy is mostly absorbed by carbon dioxide (CO_2) and other atmospheric gases, which act much like the glass in a greenhouse, warming the atmosphere.

Since the middle 1800's, scientists have wondered about the importance of CO_2 as a "greenhouse gas" in the regulation of Earth's climate. According to the "greenhouse effect" theory, increasing levels of CO_2 in the atmosphere will trap more and more heat, raising the planet's overall temperature and affecting regional climates, sea levels, distribution of arable land, animal and human habitats, and more.

The widespread burning of fossil fuels—coal, oil, and natural gas—releases greenhouse gases, including CO_2, into the atmosphere. Concern about the possible climatic effects of increasing atmospheric CO_2 levels was voiced in 1957 by Roger Revelle, then director of the Scripps Institute of Oceanography in La Jolla, California. He wrote, " . . . human beings are now carrying out a large-scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future. Within a few centuries we are returning to the atmosphere and oceans the concentrated organic carbon stored in sedimentary rocks over hundreds of millions of years."

In the late 1950's scientific information on the levels of CO_2 in the atmosphere was sketchy. So Revelle and others commenced an international effort to monitor CO_2 concentrations in the atmosphere from stations in Alaska, Antarctica, and Hawaii, where measurements would not be affected much by nearby sources of greenhouse gases such as factories.

The Mauna Loa, Hawaii, station has been operating since November 1958. The record compiled there over more than 30 years reveals some interesting insights into the global carbon cycle. A chart of changing CO_2 patterns is reproduced on the back of the poster. Notice two patterns: a sawtooth pattern of seasonal variations of CO_2 of about 5 parts per million [ppm] superimposed over a long-term increase of about 1.3 ppm per year.

This long-term increase in CO_2 levels raises new questions. What are the sources of this "new" CO_2? How much comes from burning fossil fuels? How much may be caused by the clearing and burning of forests? What are the "sinks," or storage places, for the "excess" CO_2, and how big are they? Is the increase in atmospheric CO_2 changing the global climate?

Such new tools as computer simulation models and satellite images are used to better estimate the sources and sinks of the carbon cycle. CO_2 dissolves readily in sea water, where it is absorbed by microscopic plants known collectively as phytoplankton. When phytoplankton die, some are incorporated into the ocean bottom sediments, trapping their carbon for millions of years. Sensors borne on satellites can measure electromagnetic energy reflected from the Earth, providing images of the extent and vigor of plant growth. These satellite images are being used to map phytoplankton activity at the ocean's surface and estimate the role of the oceans as a sink for atmospheric carbon.

On land, plants absorb and store CO_2. A large part of the carbon that is fixed in the leaves of plants, as they grow, is released back into the atmosphere when the plants die and decay. During the growing season, plants take in CO_2 and give off oxygen. In the dormant winter months, no CO_2 is taken in. This causes a seasonal oscillation of CO_2 levels in the atmosphere, with maximum concentrations in early spring and minimum ones in the fall. In the longer term, carbon is stored either as wood, as humus in soil, or in certain rocks. Satellite sensors can be used to better delineate the world's forests and grasslands as both sources and sinks for CO_2.

All this information is being integrated into computer models to help scientists simulate how the oceans, the biosphere, and the atmosphere interact in the global carbon cycle. The idea is to learn more about effects of human activity on carbon levels and, thus, on climate.

Activity (Allow 30-45 minutes)

To develop an understanding of parts per million as a concept, teams of students will create successive dilutions of a solution to reach a parts-per-million concentration.

The atmosphere is a mixture of gases. Similarly, the world's oceans and fresh waters contain dissolved chemicals. Many substances dispersed in air or water are measured in parts per million. Some of these substances are colorless, odorless, and tasteless, yet even in small quantities they can be toxic.

Materials

For each group of three students:

- One eyedropper
- Supply of water
- A cylinder with 10-milliliter graduations
- Three 12-ounce clear plastic cups
- Masking tape
- Marking pen
- One bottle of food coloring (darker colors will work best)
- A calculator (optional)
- One box of crayons, pastels, or colored chalk
- A notebook for recording results.

The procedure can be copied and handed out to students.

Procedure

Before beginning the activity, put a piece of masking tape on each cup and label them "Sample 1," "Sample 2," and "Sample 3."

Sample 1.

1. Put 99 drops of water in the graduated cylinder. Record the volume of this amount of water in the notebook. (You will need this measurement later to avoid having to measure another 99 drops.) Pour the water from the 99 drops into the cup marked "Sample 1."

2. Add one drop of food coloring to sample 1. Stir the water. Record the color in your notebook using crayons, pastels, or chalk.

3. Answer the questions in the question section. You can use a calculator. Write the answers on the sheet or copy the information into your notebook.

Sample 2.

1. Pour an amount of water equal to 99 drops into the graduated cylinder. Pour this into the cup marked "Sample 2."

2. Add one drop of sample 1 to sample 2.

3. Stir and record the resulting color.

4. Answer the questions in the question section.

Sample 3.

1. Pour an amount of water equal to 99 drops into the graduated cylinder. Pour this into the cup marked "Sample 3."

2. Add one drop of sample 2 to sample 3. Stir and record the color of the solution.

3. Answer the questions in the question section.

Questions

What is the concentration of food coloring in sample 1?________________________________

Can you see the food coloring in sample 1? ________________________________

Suppose the food coloring was a harmful substance, how would you "clean" the water?________________

____

What happened to the color of the water in sample 2? Describe and explain.________________________

____

What is the concentration of food coloring in sample 2?________________________________

What is the concentration of food coloring in sample 3?________________________________

Can you see the food coloring in sample 3? __________Explain why or why not. ________________

____

How could a parts-per-billion solution be made?________________________________

____

Extensions

Once the students are familiar with the procedure required to create a parts-per-million solution of a pollutant, have a selection of substances available for them to dilute and observe. Encourage the students to create experimental tests for determining if other substances are observable in the part-per-million concentration. Some suggested substances to experiment with are detergent and acid (vinegar). You can ask:

Are the new substances observable in any way? (Do they form a film, or foam, or is there discoloration?)

Has there been a change in a Ph test for the acid or base? (Use litmus paper to test the solutions.)

Answers will vary.

Discussion note—is a diluted substance "gone" just because it is no longer visible? How can these ideas be transferred from a liquid to a gas like CO_2?

For the Teacher

Answers to questions: Sample 1: Because you have added *one drop of food coloring to 99 drops of water*, the concentration is one part per hundred, which can also be expressed as 1/100 or 1 percent. A calculator can be used to visualize the answer. Divide 1 by 100. The answer is 0.01. The color should be visible.

Students might answer that filtering the water through a substance like sand or through paper might "clean" it, but filtering will not remove a chemical solution. The teacher might use this question as an opportunity to discuss the removal of CO_2 from the atmosphere. Just as no such simple process as filtering the water will remove food coloring, no simple process will remove excess CO_2 from the atmosphere. Reducing the amount of CO_2 emitted by human activity reduces the need to remove it later.

Sample 2: To 99 drops of new water, you add a drop of the solution from sample 1, which consists of .99 parts water and .01 part food coloring. Because you have now diluted the .01 drop of food coloring in a total of 100 drops of solution, divide .01 by 100 on the calculator. Your answer is .0001. This means you now have 1 part food coloring in ten thousand, or 1/10,000. Depending on the color used, the food coloring in sample 2 should be faintly visible.

Sample 3: Again you have 99 drops of new water and one drop from the solution in sample 2. The one drop is .9999 parts water and .0001 parts food coloring. To calculate the concentration of food coloring in sample 3 divide .0001 by 100 (the total number of drops in the solution). The answer is 0.000001 or one part food coloring in one million (1/1,000,000). The food coloring will not be visible at this concentration.

Making a parts-per-billion sample: Continue the procedures described above. Begin with 99 new drops of water. Use one drop of the parts-per-million solution. You will get 0.00000001 parts food coloring or one part food coloring in one-hundred million (1/100,000,000). For the final step, take nine new drops of water and add to it one drop of the previous solution. This yields 0.000000001 or one part per billion.

Classroom Resources

Hocking, C., Sneider, C., Erickson, J., and Golden, R., 1990, Global warming—The greenhouse effect: Berkeley, California, Lawrence Hall of Science, 171 p.

Johnson, R. L., 1980, The greenhouse effect—Life on a warmer planet: Minneapolis, Minn., Lerner Publications, 112 p.

Morrison, Philip, and Morrison, Phylis, 1982, Powers of ten: Redding, Conn., Scientific American Library, 150 p.

Schwartz, David M., 1985, How much is a million?: New York, Lothrop Lee and Shepard, 40 p.