Lesson 3.1 CO_2: Where does it go?

Introduction

One of the main missions of the CWF Africa to the Americas Expedition has been to collect scientific data during their row. This scientific data will be used for a number of different studies by numerous different scientists. One of the topics that the crew is collection data for is a change in Ocean pH. This is done by measuring dissolved CO_2 and pH but these measurements don't mean much on their own. They need to be analyzed in conjunction with temperature, salinity and DO. This lesson will look at global CO_2 levels and how they are distributed throughout the earth. The students will examine how CO_2 moves between the earth, sea and atmosphere by examining the carbon cycle.

Background

Carbon Cycle on our planet

The carbon cycle is perhaps the most important of Earth's matter cycles. Not only is it vital for life (photosynthesis and respiration), it plays a key role in Earth's global climate because atmospheric carbon dioxide contributes significantly to Earth's greenhouse effect. What is carbon? Carbon is the building block of organic molecules. Carbon is a very important element, as it makes up organic matter, which is a part of all life. Carbon follows a certain route on earth, called the carbon cycle. Through following the carbon cycle we can also study energy flows on earth, because most of the chemical energy needed for life is stored in organic compounds as bonds between carbon atoms and other atoms.

The carbon cycle naturally consists of two parts, the terrestrial and the aquatic carbon cycle. The aquatic carbon cycle is concerned with the movements of carbon through marine ecosystems and the terrestrial carbon cycle is concerned with the movement of carbon through terrestrial ecosystems. The carbon cycle is based on carbon dioxide (CO2), which can be found in air in the gaseous form, and in water in dissolved form. Terrestrial plants use atmospheric carbon dioxide from the atmosphere, to generate oxygen that sustains animal life.

Aquatic plants also generate oxygen, but they use carbon dioxide from water. The process of oxygen generation is called photosynthesis. During photosynthesis, plants and other producers transfer carbon dioxide and water into complex carbohydrates, such as glucose, under the influence of sunlight. Only plants and some bacteria have the ability to conduct this process, because they possess chlorophyll; a pigment molecule in leaves that they can capture solar energy with.

The overall reaction of photosynthesis is:

carbon dioxide + water + solar energy -> glucose + oxygen

$$6\ CO_2 + 6\ H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 + 6\ O_2$$

The oxygen that is produced during photosynthesis will sustain non-producing life forms, such as animals, and most micro organisms. Animals are called consumers, because they use the oxygen that is produced by plants. Carbon dioxide is released back into the atmosphere during respiration of consumers, which breaks down glucose and other complex organic compounds and converts the carbon back to carbon dioxide for reuse by producers. Carbon that is used by producers, consumers and decomposers cycles fairly rapidly through air, water and biota. But carbon can also be stored as biomass in the roots of trees and other organic matter for many decades. This carbon is released back into the atmosphere by decomposition, as was noted before.

Not all organic matter is immediately decomposed. Under certain conditions dead plant matter accumulates faster than it is decomposed within an ecosystem. The remains are locked away in underground deposits. When layers of sediment compress this matter fossil fuels will be formed, after many centuries. Long-term geological processes may expose the carbon in these fuels to air after a long period of time, but usually the carbon within the fossil fuels is released during human combustion processes.

The combustion of fossil fuels has supplied us with energy for as long as we can remember. But the human population of the world has been expanding and so has our demand for energy. That is why fossil fuels are burned very extensively. This is not without consequences, because we are burning fossil fuels much faster than they develop. Because of our actions fossil fuels have become nonrenewable recourses.

Although the combustion of fossil fuels mainly adds carbon dioxide to air, some of it is also released during natural processes, such as volcanic eruptions. In the aquatic ecosystem carbon dioxide can be stored in rocks and sediments. It will take a long time before this carbon dioxide will be released, through weathering of rocks or geologic processes that bring sediment to the surface of water.

Carbon dioxide that is stored in water will be present as either carbonate or bicarbonate ions. These ions are an important part of natural buffers that prevent the water from becoming too acidic or too basic. When the sun warms up the water carbonate and bicarbonate ions will be returned to the atmosphere as carbon dioxide.

Activity

This activity has been adapted, with permission, from a lesson created by Science North (www.sciencenorth.ca). Please visit their site for more information.

In the following activity the students will learn about global climate change through exploring how it is affecting our oceans. They will learn how the carbon cycle works and where in the earth carbon is stored.

Materials

• 15 black balls or balloons to represent carbon
• 1 blue ball
• 1 red ball
• Signs to identify the principal carbon reservoirs: (Atmosphere; Land Biomass; Ocean; Fossil Fuel; Rock)

Procedure

-Discuss why it is important and why the carbon cycle is harder to understand than the water cycle. Reinforce that whenever we examine a cycle of matter, it is useful to investigate the different reservoirs and flow rates.

-Explain that you are representing the amounts of carbon in each reservoir using balloons.

-Assign 5 different lab tables for the different carbon reservoirs. *These should be close enough for visual comparison and to easily move balloons from one reservoir location to another*.
-Place identifying signs in each location, and have a volunteer sit in that location. Place the sign that represents that reservoir there.

-Explain that one black balloon represents all the carbon in the atmosphere. Elicit what form that carbon is in (carbon dioxide gas). Place one black balloon with the Atmosphere location.

-Have participants estimate how many balloons should be used to represent the carbon in the Land Biomass reservoir. Place 4 black balloons there.

-Discuss the form of the carbon. *cellulose, starch, sugar, protein, etc.*

-Discuss how the carbon got there. *photosynthesis*

-Have participants estimate how many balloons should be used to represent the carbon in the Ocean reservoir *(answer - 50 balloons)*. Place 2 black balloons and one blue balloon there. *State that of course everyone knows the scientific conversion that one blue balloon equals 48 black balloons.*

-Discuss the form of the carbon that is found in the Ocean reservoir. *Bicarbonate salt resulting from the absorption of carbon dioxide from the ocean to form carbonic acid which dissociates to H+ and bicarbonate*

-Have participants estimate how many balloons should be used to represent the carbon in the Fossil Fuel reservoir. Place 7 black balloons there.

-Discuss the form of the carbon found in the Fossil Fuel reservoir. *solid coal, liquid hydrocarbon petroleum, and gas hydrocarbon methan*e.

-Discuss how the carbon got there. *Photosynthesis hundreds of millions of years ago and subsequent burial. Note that fossil fuel carbon is not part of current carbon cycle flows unless people bring it to the surface*.

-Have participants estimate how many balloons should be used to represent the carbon in the Rock reservoir. Place 1 white balloon there. *State that of course everyone knows the scientific conversion that one white balloon equals 66,000 black balloons*.

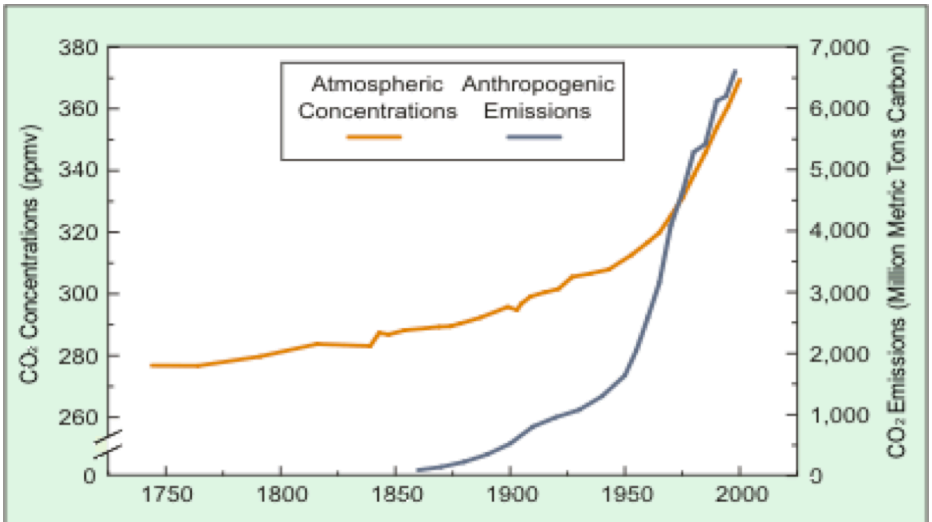
-Discuss the form of the carbon found in the Rock reservoir. *solid carbonate as in limestone - e.g., white cliffs of Dover*

-Now change the focus from the amounts/kinds of carbon to how it flows from one reservoir to another. Take the atmosphere balloon and add it to the Land Biomass reservoir. Say that over the course of seven years, all the carbon in the atmosphere goes into land biomass via the process of photosynthesis. Ask and discuss why we still have carbon dioxide in the atmosphere (*over a seven year period one balloon amount of carbon returns to the atmosphere from land biomass via the process of respiration*).

-Bring a black balloon from the Land Biomass reservoir back to the Atmosphere reservoir. Take a black balloon from the Atmosphere reservoir and add it to the Ocean reservoir. Say that over the course of seven years, all the carbon in the atmosphere dissolves in the ocean. Ask and discuss why we still have carbon dioxide in the atmosphere (*over a seven year period one balloon amount of carbon returns to the atmosphere from the ocean via evaporation of carbon dioxide*).

-Bring a black balloon from the Ocean reservoir back to the Atmosphere reservoir.
Inflate a black balloon by blowing into it and walk over to the Atmosphere volunteer. Discuss how humans have been un-burying fossil fuels and burning them, thereby releasing carbon dioxide into the atmosphere. Show that today's atmosphere has 25% more carbon dioxide than the pre-industrial atmosphere. Illustrate that the amount of carbon dioxide in the atmosphere is projected to double in about fifty years using the graph (see end of lesson for graphs).

Wrap Up
Review the reservoirs of the carbon cycle and how carbon flows into and out of them. Discuss why people care about the increase in carbon dioxide in the atmosphere. Discuss where else an increase in CO_2 can haven an effect.



Source: Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, http://cdiac.esd.ornl.gov/.