Title: Rising Sea Level

Subject: Aquatic Science

Grade Level: 10^{th} – 12^{th}

Rational or Purpose:
This lesson explores students' concepts on the concentration of gases through global warming. In this lesson, students will relate carbon dioxide concentration, sea level, and amounts of melted water from the ice sheets. Students should build up a strong mental relationship between carbon dioxide concentration and sea level. Students will also see how rising sea levels will affect American coastal cities.

Materials: Calculator

Lesson Duration: 90 minutes (45 minutes each week)

TEKS Objectives:
§112.46. Aquatic Science
(c) Knowledge and skills.
(2) Scientific processes. The student uses scientific methods during field and laboratory investigations. The student is expected to:
(A) plan and implement investigative procedures including asking questions, formulating testable hypotheses, and selecting equipment and technology;
(B) collect data and make measurements with precision;
(C) express and manipulate quantities using mathematical procedures such as dimensional analysis, scientific notation, and significant figures;
(D) organize, analyze, evaluate, make inferences, and predict trends from data;
(E) communicate valid conclusions.

(8) Science concepts. The student knows that aquatic environments change. The student is expected to:
(A) predict effects of chemical, organic, physical, and thermal changes on the living and nonliving components of an aquatic ecosystem;
(B) analyze the cumulative impact of natural and human influence on an aquatic system;
(C) identify and describe a local or global issue affecting an aquatic system.

Background Information:
Paleoglaciologists have proven that the concentration of carbon dioxide in the Earth's atmosphere has a substantial effect on sea level. Scientists can trace the ice sample and investigate the concentration of carbon dioxide on a relative time scale (similar to tree-ring investigation). The graph showed below (Fig. 1) illustrates a non-linear relationship between carbon dioxide and sea level.

Although carbon dioxide is not the most influential of the greenhouse gases, it is the largest quantity of gas emitted by humans. Burning of fossil fuels cause a huge amount of carbon dioxide to be released into the atmosphere. Deforestation, on the other hand, inhibits carbon fixation by plants, converting carbon dioxide to sugar. The accumulation of carbon dioxide in the atmosphere will force ice sheets and mountain glaciers to melt. As a result, sea levels will rise.

Most of the world's largest cities are located in coastal areas. Long-term sea level rising will definitely pose a threat to the global economy. Some populated cities will be inundated with water. Hurricane Katrina has taught our society that low-elevation cities are extremely susceptible to flood-related disasters. These disasters will be costly in terms of human lives and economics.

Name: _____ Class Section: _____

Date: _____

Rising Sea Level

Parts per million (ppm) is a unit of concentration. One ppm is mathematically equivalent to one milligram of matter per liter fluid or per kilogram solid. Scientists usually use ppmV (ppm in volume) and ppmM (ppm in mass) to indicate if the values are in mg/L and mg/kg, respectively. ppmV is often used to describe the concentration of a certain substance in air (and water), while ppmM is used mostly in soil and sediments.

Why don't we use molarity? Although molarity is useful to describe concentrations of chemical quantities, it is not convenient to use for small amount sof gas. As you may remember, air molecules are constantly moving in random motions. Unlike the solid or liquid states of matter, the molecules of gases are not closely packed together. Under standard conditions, 1 mole of gas should occupy 22.4 liters of room:

PV = nRT (*Ideal Gas Law*)

P = 1 atm
N = 1 mole
T = 273.15K
R = 8.3145 J/mol K

(1 atm) V = (1 mol) (0.0820574587 L atm/mol K) (273.15K)

V = 22.4 L

Although it is possible to use scientific notation for the representation of gas concentrations, it will make more sense to use the mass of a substance per liter volume to describe concentration (while comparing one gas with another gas in a confined volume, do not use ppmV because the mass does not explicitly quantify the number of molecules. Remember to use mole when comparing two substances).

Fill in the following table for practice.

Mole of CO_2	Milligram of CO_2	ppm of CO_2 (in 2L volume)
	7.50	
3.25×10^{-4}		
		50.0
		175

Look at the following graph:

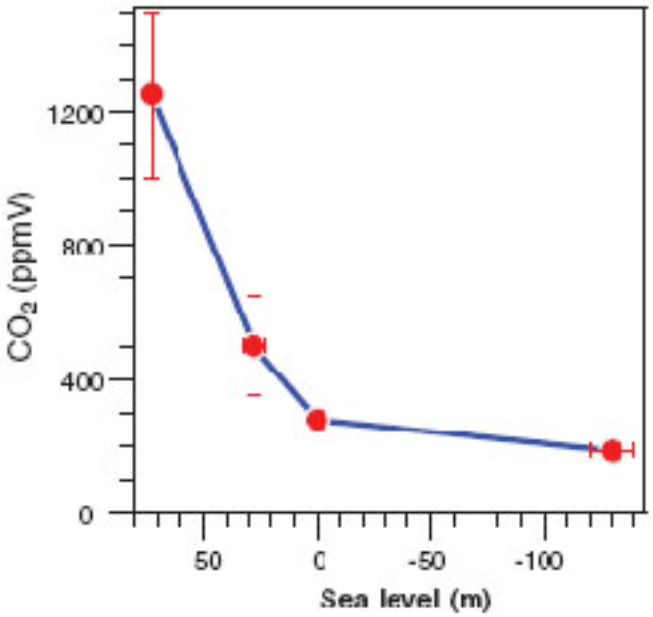

Fig. 1 The rightmost point of the graph, where the sea level is about -130m, shows the sea level and carbon dioxide concentration of the Last Glacial Maximum (peak of last ice age) 21,000 years ago. The point located where sea level is 0m is referring to modern conditions. The absolute maximum of the graph represents the sea level and carbon dioxide concentration of the time when no permanent ice exists on Earth. (Figure by Alley)

This is a graph showing how carbon dioxide would affect sea levels. The source of water is from ice sheets and glaciers. To explain it clearly, it is the carbon dioxide that accumulates in the atmosphere, stores the solar energy in air, and then triggers the melting process of ice sheets and glaciers.

Instruction:
Each group should consist of 4 students. Every group is required to answer the follow questions. PowerPoint presentations are suggested. Presentations must be 8-10 minutes long (for question 3, submit your group choice to your teacher as soon as possible. No groups will discuss the impact on the same city).

Procedure:
Your group will be given a week of time to research and organize information needed to answer the following questions. Only use encyclopedias for factual information. Make good use of library resources and reliable online resources. If you want to quote a scientist's findings in your presentation, you must mention his/her name and the source of findings.

Question 1: What is the relationship between sea level and carbon dioxide concentration? (Linear, quadratic, etc…) Describe how the relationship fits into the graph.

Question 2: Discuss why the slope of sea level between 0m and -100m is so different from 0m and 50m.

Question 3: Pick one of the following cities. Discuss and write up possible scenarios for your city if the sea level were to rise 7m in the future (discussion result should include geographic*, demographic**, and economic information of the city).

New York New Orleans Houston Miami Boston

Question 4: The current carbon dioxide concentration is much lower than the absolute maximum. Does that mean that we should not be too worried about the concentration of carbon dioxide? If not, explain why we should worry about it.

Question 5: What are the consequences of melting ice releasing freshwater into ocean bodies? (Name at least 2) What are the mechanisms that lead to the consequences?

**Geographic information must include the city's elevation. Other specific information that would relate to the impact should be included in the presentation.*

***Demographic information must include current city population.*

Sources:
Alley, R. B., "Ice-Sheet and Sea-Level Changes." *Science* **310,** 456 (2005).