Dissolved Oxygen vs. Temperature

Lesson Focus: Dissolved Oxygen

Learning objective:

- Students will learn the effects of varying temperatures on the dissolved oxygen content of water.
- Students will identify features of an experimental design, and then improve or build upon the design.
- Students will predict and offer suggestions for remediating ecosystems affected by thermal pollution (and subsequent decrease in DO concentrations).

Enduring Understandings for the Lesson:

- Changing water temperatures affect the amount of oxygen dissolved in water and may cause stress on organisms.
- Humans are increasing water temperatures by changing natural vegetation to artificial surfaces.
- Data collected by scientists can be used to better manage natural resources.

Georgia Performance Standards Addressed:

SB4. Students will assess the dependence of all organisms on one another and the flow of energy and matter within their ecosystems.

d. Assess and explain human activities that influence and modify the environment such as global warming, population growth, pesticide use, and water and power consumption.

SCSh1. Students will evaluate the importance of curiosity, honesty, openness, and skepticism in science.

c. Explain that further understanding of scientific problems relies on the design and execution of new experiments which may reinforce or weaken opposing explanations.

SCSh2. Students will use standard safety practices for all classroom laboratory and field investigations.

a. Follow correct procedures for use of scientific apparatus.
b. Demonstrate appropriate technique in all laboratory situations.
c. Follow correct protocol for identifying and reporting safety problems and violations.

SCSh3. Students will identify and investigate problems scientifically.

a. Suggest reasonable hypotheses for identified problems.
b. Develop procedures for solving scientific problems.
c. Collect, organize and record appropriate data.
d. Graphically compare and analyze data points and/or summary statistics.
e. Develop reasonable conclusions based on data collected.

SCSh6. Students will communicate scientific investigations and information clearly.

c. Use data as evidence to support scientific arguments and claims in written or oral presentations.
d. Participate in group discussions of scientific investigation and current scientific issues.

Grade level: 9 – 12th

Materials: **(materials needed for one group)**

- one LaMott Dissolved Oxygen Kit (or similar kit)
- one Celsius thermometer
- one 1000 mL Beaker
- 1000 mL of distilled water
- one aquarium air pump/aerator
- one heating pad
- one wall clock with a second hand
- one wooden or plastic spoon.

Time needed: 90 minutes

Background information:

Free molecular oxygen (O_2) is necessary for most organisms to survive, and thrive. This is demonstrated by the role of oxygen in the process of respiration. Without free oxygen (O_2) nearly all eukaryotic unicellular organisms and all multi-cellular organisms as we know them would not exist.

Water is a requirement for all organisms (unicellular to multi-cellular) on earth. Within each cell, water is the medium in which the ions, compounds, and dissolved gases, including oxygen (O_2) necessary for life are found. The proper regulation of water into and out of cells regardless of habitat – land or water (fresh or salt) is dependent on the cell's ability manage salt concentration. Additionally, life found on land must adapt to potentially desiccating conditions such as aridity, wind, and heat.

Temperature affects how readily solutes dissolve in solvents. Typically, solids dissolve quicker in warmer than cooler solvents. The opposite holds true for most gases. Generally, as the temperature of a solvent increases, the solvent is less able to hold onto its dissolved gases. Mathematicians and scientists describe this as an inverse relationship: as one variable increases, the other decreases. Therefore, warmer water holds less dissolved oxygen than equivalent volumes of cooler water. Since oxygen needs vary by species, varying temperatures will dictate the health of a species, and the types of species present within an ecosystem.

Humans have greatly affected the temperatures of natural water systems. Thermal pollution from power plant discharge, runoff from buildings, and road surfaces has resulted in storm water flowing into streams at significantly increased temperatures, especially in the summer months, than that of the stream. Consequently, as this warmer water enters the stream, the temperature quickly changes, reducing the amount of dissolve oxygen available. This can stress naturally occurring organisms in the ecosystem to the point of eliminating them, and can encourage new and often unwanted species to assume residence in the existing area.

Learning Procedure:

1. Divide the students in your class into groups of two or three (equipment dependent). Have each group gather material listed above.
2. Explain to students that they will be conducting an experiment to test the effect of increasing temperature on the concentration of dissolved oxygen found in water. Have students discuss whether warm water or cool water holds more dissolved oxygen. Query them about their beliefs. Ask them if they have they considered the amount of life found in warm seas and cold seas? Be sure students understand the difference between amount of life (as measured by biomass), and number of species. Generally, it is understood that cool, higher latitude seas contain fewer species, but greater biomass than warmer, equatorial seas. Actually, biomass is usually as great in cooler seas, even though they are often very murky, and sometimes opaque!
3. Then, have students create a hypothesis addressing their belief about temperature (of water) and the amount of dissolved oxygen found in the water. A possible hypothesis is: "As the temperature of water is increased, then the amount of dissolved oxygen in the water will _____. (Increase? decrease? Remain the same?)"
4. **SETUP** -Have students place the 1000 mL beaker on top of the heating pad(s). The heating pads should be in the "off" position. Students should fill the beaker with 1000 mL of distilled water, and properly setup an air pump/aerator (turned "on"). Allow one day to permit the surface agitation produced by the air pump/aerator to allow oxygen to dissolve into the distilled water establishing a baseline equilibrium concentration.

5. Begin the experiment. To ensure mixing, gently (but, thoroughly) stir the water with the spoon for one minute. Stirring will disrupt any thermocline (and thermocline-driven DO disparities) that might have occurred. Record the temperature of the water in the beaker at a mid-depth, and centered in the beaker. Then, using the directions accompanying the LaMott's (or other) dissolved oxygen (DO), kit test and record the dissolved oxygen content of the water.
6. Turn on the heating pad(s) for ten minutes. After ten minutes, gently stir the water, and then record the temperature and DO of the water (mid-depth, and laterally centered). Continue to record the temperature and DO content of the water at regular intervals as time permits.
7. Have students create a graph of their results.
8. As a class, discuss the following:
   - What effect could thermal pollution, and subsequent decrease in DO, have on an aquatic ecosystem such as a local stream, lake, pond, etc.?
   - What are some sources of thermal pollution? (runoff from hot asphalt roadways after a storm, power plants, hot roof tops, etc.)
   - What might be some methods or techniques to mitigate or eliminate sources of thermal pollution? (retention ponds in parking lots, using porous pavers for parking lots, selecting light colors for roofs, planting trees, leaving trees in new developments)

Evaluation:

1. Graph – Did they properly complete the graph with temperature measured in degrees Celsius? The temperature will be your independent variable represented on the x-axis, and DO will be dependent variable represented on the y-axis.
2. In paragraph form, have students answer the following questions:
   - Have students evaluate the validity of their hypothesis.
   - Ask students for suggestions to improve the experimental design.
   - Have students suggest additional follow-up experiments.

Extensions:

1. Collect and test (temperature and DO concentration) at a local stream and/or from a variety of runoff sources including roadways, roofs/gutters, lawns, natural vegetation, etc. immediately after a rain event. Testing is best done immediately on site.
2. Challenge students to identify sources of thermal pollution in their communities and develop and implement a program to help others understand the problems

and initiate discussion on how best to mitigate or better yet eliminate the problems

3. Have students develop short radio and/or television reports to disseminate information about the issue for broadcast on local stations.
4. Have students research animals that have been affected by thermal pollution and report back to class through a power-point presentation. (Manatees and American crocodiles in the southeast have become habituated to using warm water runoff from power plants to overwinter in places they normally would not.)

Resources:

- Adopt-A–Stream – www.georgiaadoptastream.org/home.html - for maps, listing of workshops, Educator Guide, and other resources.
- EPA website at www.epa.gov/OWOW/watershed/ - for more information about watersheds and additional lessons and resources.
- Georgia River Network – www.garivers.org - for fact sheets about the 14 major watersheds in Georgia.
- National Oceanic and Atmospheric Administration (NOAA) – http://www.noaa.gov/ - for information of a general nature concerning earth systems, and the environment.
- U.S. Geological Survey (USGS) - http://www.usgs.gov/ -for information about biology, geography, geology, geospatial, water, hazards, as well as other resources.

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This activity is a product of the Rivers to Reef Teacher Workshop sponsored by the Georgia Aquarium and Gray's Reef National Marine Sanctuary that the author participated in. For more information about this workshop, Georgia Aquarium, or NOAA Gray's Reef National Marine Sanctuary, please visit our websites at www.georgiaaquarium.org or http://graysreef.noaa.gov/

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