Dissolved Oxygen Changes with Varying Depth, Temperature, and Salinity

Introduction

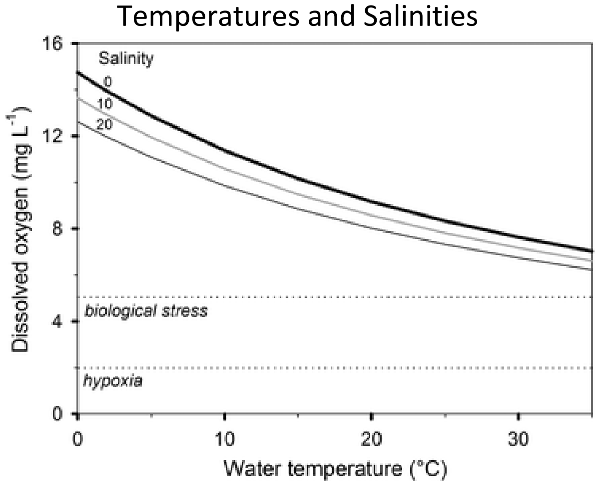
In the aquatic environment, oxygen must be in solution in a free state (O2) before it is available for use by organisms. Its concentration and distribution in the aquatic environment are directly dependent on chemical and physical factors and are greatly affected by biological processes. In the atmosphere there is an abundance of oxygen, with about 200 milliliters of oxygen for every liter of air. Conversely, in the aquatic environment there are only about 5 to 10 milliliters of dissolved oxygen in a liter of water. The concentration of the oxygen in aquatic environments is a very important component of water quality.

At 20°C oxygen diffuses 300,000 times faster in air than in water, making the distribution of oxygen in air relatively uniform. Spatial distribution of oxygen in water, on the other hand, can be highly variable, especially in the absences of mixing by currents, winds, or tides.

Other chemical and physical factors, such as salinity, pH, and especially temperature, can affect the DO concentration and distribution. Salinity, usually expressed in parts per thousand (ppt), is the content of dissolved salts in water. Generally, as temperature and salinity increase, the solubility of oxygen in water decreases.

Figure 1: Solubility of Oxygen in Water

100% Saturation of DO at Different Temperatures and Salinities



The partial pressure of oxygen in the air above the water affects the amount of DO in the water. Less oxygen is present at higher elevations since the air itself is less dense; therefore, water at higher elevations contains less oxygen. At 4,000 meters in elevation (about 13,000 feet), the amount of dissolved oxygen in water is less than two-thirds what it is at sea level. All of these physical factors work together to increase diversity in aquatic habitats with regard to oxygen availability.

Biological processes, such as photosynthesis and respiration, can also significantly affect DO concentration. Photosynthesis usually increases the DO concentration in water. Aerobic respiration requires oxygen and will usually decrease the DO concentration. The measurement of the DO concentration of a body of water is often used to determine whether the biological activities requiring oxygen are occurring; consequently, it is an important indicator of pollution.

Exercise A: Dissolved Oxygen and Temperature

Dissolved oxygen can be measured in parts per million (ppm) using the LaMotte DO test kit. In order to determine the amount of carbon fixed/L, you must follow the conversions listed below.

- ppm O_2 = mg O_2 / L
- mg O_2 / L x 0.698 = mL O_2 / L

From this you will calculate the amount of carbon fixed in photosynthesis as follows:

- mL O_2 / L x 0.536 = **mg carbon fixed /L**

Procedure

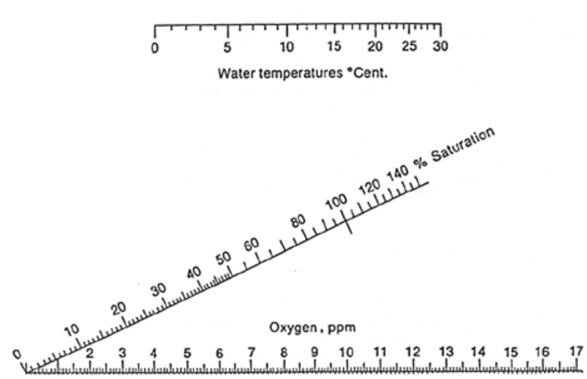
1. Fill 2 of the water sampling bottles with the fresh water samples provided: room temperature and cold temperature.
2. Determine the DO of each sample using the technique given to you. Record these values in Table 1
3. On the nomogram of oxygen saturation (Figure 2), use a straightedge or ruler to estimate the percent saturation of DO in your samples and record this value in Table 1. Line up the edge of a ruler with the temperature of the water on the top scale and the DO on the bottom scale, then read the percent saturation from the middle scale.
4. Record your values on the class document and then enter class means in Table 1

Table 1: Temperature / DO Data

Temperature	Lab Group DO	Class Mean DO	Lab Group % DO Saturation (from nomogram)	Class Mean % DO Saturation (from nomogram)

5. Graph both the Lab Group and the Class Mean percent saturation as a function of temperature. Be sure to give your graph the appropriate title, label axes with units, equal intervals on axes, correct orientation of axes, and plot data points accurately. For this graph you will need to determine the following:
   a. Independent variable: ______________________________________
   b. Dependent variable : ______________________________________

Figure 2: Nomogram of Oxygen Saturation



Exercise B: Dissolved Oxygen and Salinity

Procedure

1. Fill 2 of the water sampling bottles with the water samples provided by at room temperature: fresh water and 32ppt salt water (similar to ocean water).
2. Determine the DO of each sample using the technique given to you. Record these values in Table 2
3. On the Solubility of Oxygen in Water graph (Figure 1), record the DO amount at 100% saturation for room temperature. Take your DO value and divide it by the 100% saturation value and then multiply by 100. This is the % saturation for your salinity level.
4. Record your values on the class document and then enter class means in Table 2

Table 2: Salinity / DO Data

Salinity	Lab Group DO	Class Mean DO	Lab Group % DO Saturation	Class Mean % DO Saturation

Productivity

The primary productivity of an ecosystem is defined as the rate at which organic materials (carbon-containing compounds) are stored. Only those organisms possessing photosynthetic pigments can utilize sunlight to create new organic compounds from simple inorganic substances. Green plants obtain carbon for carbohydrate synthesis from the carbon dioxide in the water or the air according to the basic equation for photosynthesis:

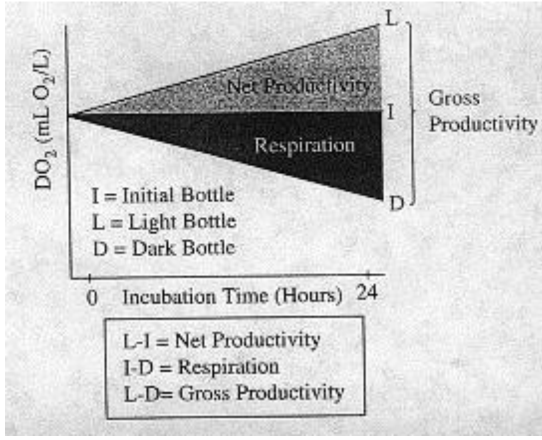
$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

The rate of carbon dioxide utilization, the rate of formation of organic compounds, or the rate of oxygen production can be used as a basis for measuring primary productivity. A measure of oxygen production over time provides a means of calculating the amount of carbon that has been bound in organic compounds over a period of time. For each milliliter of oxygen produced, approximately 0.536 milligrams of carbon has been assimilated.

One method of measuring the rate of oxygen production is the light and dark bottle method. In this method, the DO concentrations of samples of water, are measured and compared before and after incubation in light and darkness. The difference between the measurements of DO in the initial and dark bottles is an indication of the amount of oxygen that is being consumed in respiration by the organisms in the bottle. In the bottles exposed to light, the biological processes of photosynthesis and respiration are occurring; therefore, the change over time in DO concentration from the initial concentrations is a measure of net productivity.

The difference over time between the DO concentrations in the light bottle and the dark bottle is the total oxygen production and therefore an estimate of gross productivity (see Figure 3)

Figure 3: Light-Dark Bottle Method to Determine Gross Productivity



Exercise C: A Model of Productivity as a Function of Depth in a Lake

Day One Procedure

1. Obtain 7 water sampling bottles (these are also called BOD bottles, for "biological oxygen demand"). Fill all the bottles with the lake water provided. (You may be asked to add a specific weight of aquatic plants to each bottle). Be careful not to leave any air bubbles at the tops of the bottles.
2. Use making tape to label the cap of each bottle. Mark the labels as follows: I (for "initial"), D (for "dark"), 100%, 65%, 25%, 10%, and 2%.
3. Determine the DO for the "Initial" bottle now. Record this DO value in Table 3 and in the class document. Record the class "Initial" mean in Table 3. This is the amount of DO that the water has to start with (a base line). Finally, record the water source name in Table 4.
4. Cover the "Dark" bottle with aluminum foil so that no light can enter.
5. The attenuation of natural light that occurs due to depth in a body of water will be simulated by using black screens. Wrap screen layers around the bottles in the following pattern and be sure to line up the seams of the screens along one side of the bottle:
    a. 100% light – no screen
    b. 65% light – 1 screen
    c. 25% light – 3 screens
    d. 10% light – 5 screens
    e. 2% light – 8 screens

   The bottles will lie on their side under the lights, so remember to cover the bottoms of the bottles to prevent light from entering there. Use rubber bands to keep the screens in place without wrapping them over the main part of the bottle that will be exposed to the light.
6. Place the bottles on their sides under the bank of lights in the classroom. Leave overnight under constant illumination.

Table 3: Respiration

	Lab Group Data	Class Mean Data
Initial DO		
Dark Bottle DO		
Respiration Rate (Initial – Dark)		

Day Two Procedure

7. Determine the DO in all the bottles that have been under the lights. Record the "Dark" bottle DO in Table 3. Calculate the respiration rate using the formula in the table.
8. Record the values for the other bottles in Table 4. Complete the calculations in Table 4 to determine the gross and net productivity in each bottle. The calculations will be based on a time period of 1 day. Enter your respiration rate and gross and net productivities in the data table in the class document. Determine the class means. Enter these means in Table 3 and 5

Table 4: Lab Group Data – Productivity of Screen-Wrapped Samples

Water source: ____________________________

% Light	DO (ppm)	Gross Productivity (Light Bottle – Dark Bottle)	Net Productivity (Light Bottle – Initial Bottle)
100%			
65%			
25%			
10%			
2%			

Table 5: Class Mean Data – Productivity of Screen-Wrapped Samples

% Light	Gross Productivity – DO (ppm)	Net Productivity – DO (ppm)
100%		
65%		
25%		
10%		
2%		

9. Graph both net and gross productivities as a function of light intensity (class means). The two kinds of productivity may be plotted on the same graph. Be sure to give your graph the appropriate title, label axes with units, equal intervals on axes, correct orientation of axes, and plot data points accurately. For this graph you will need to determine the following:
    a. Independent variable: ____________________________________
    b. Dependent variable : _____________________________________

Discussion Questions

1. What are the 3 ways primary productivity can be measured?
2. What is the relationship between oxygen production and assimilation of carbon (what is the conversion unit) and calculate the assimilated amount of carbon from the class mean NPP.
3. From your graph of the temperature data, what is the effect of temperature on the amount of oxygen that water at different temperatures can hold?
4. From your salinity saturation data, what is the effect of salinity on the amount of oxygen that water at different salinities can hold?
5. Refer to your graph of the productivity and light intensity. At what light intensity do you expect there to be: (Hint: look at where the graph becomes negative)
    a. No gross productivity?
    b. No net productivity?
6. A mammal uses only 1 to 2 percent of its energy in ventilation (breathing air in and out) while a fish must spend about 15 percent of its energy to move water over its gills. Explain this difference in their efforts to collect oxygen. (Think about the differences between air and water)
7. Would you expect the DO in water taken from a stream entering a lake to be higher or lower than the DO taken from the lake itself? Explain (Think about the ways oxygen gets into the water from the atmosphere).
8. Would you expect the DO concentration of water samples taken from a lake at 7:00am to be higher or lower than samples taken at 5:00pm? Explain (The temperature variation from morning to evening are not great enough to be a factor)
9. What is eutrophication? Research and explain why allowing nitrogen or phosphorous fertilizers to run into a body of water can negatively affect life in the water.
10. In the following drawings of identical containers with identical fish but with different volumes of water, which one, A or B, would have more oxygen available to the fish **initially** and **then over time**? Explain