Dissolved Oxygen and Primary Aquatic Productivity
Laboratory 12

Introduction

Dissolved oxygen levels are an extremely important factor in determining the quality of an aquatic environment. Dissolved oxygen is necessary for the metabolic processes of almost every organism.

Terrestrial environments hold over 95% more oxygen than aquatic environments. Oxygen levels in aquatic environments are very vulnerable to even the slightest change. Oxygen must be constantly be replenished from the atmosphere and from photosynthesis. There are several factors that effect the dissolved oxygen levels in aquatic environments.

Temperature is inversely proportional to the amount of dissolved oxygen in water. As temperature rises, dissolved oxygen levels decrease.

Wind allows oxygen to be mixed into the water at the surface. Windless nights can cause lethal oxygen depletions in aquatic environments.

Turbulence also increases the mixture of oxygen and water at the surface. This turbulence is caused by obstacles, such as rocks, fallen logs, and water falls, and can cause extreme variations in oxygen levels throughout the course of a stream.

The *Trophic State* is the amount of nutrients in the water. There are two classifications: oligotrophic and eutrophic. Oligotrophic lakes are oxygen rich, but generally nutrient poor. They are clearer and deeper than eutrophic lakes and are younger. Oxygen levels are constant. Eutrophic lakes are more shallow and nutrient rich. The oxygen levels constantly fluctuate from high to low.

Primary production is the energy accumulated by plants since it is the first and basic form of energy storage. The flow of energy through a community begins with photosynthesis. All of the sun's energy that is used is termed gross primary production. The energy remaining after respiration and stored as organic matter is the net primary production, or growth. The equation for photosynthesis is as follows:

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

There are two ways to measure primary production, the oxygen method and the carbon dioxide method. The oxygen method uses a dark and light bottle to compare the amount of oxygen produced in photosynthesis and used in respiration. Respiration rate is determined by subtracting the dark bottle from the initial bottle. The carbon dioxide method places a transparent plastic bag over one sample and a dark plastic bag over the other. Each bottle is set up so that air is drawn through the enclosure and passes over carbon dioxide-absorbent material. The amount of carbon under the dark bag is respiration, while the amount of carbon under the transparent bag is the amount of photosynthesis minus the amount of respiration.

There are three main gases dissolved in aquatic environments: nitrogen, oxygen, and carbon dioxide. Most gases obey Henry's law, which says that at a constant temperature, the amount of gas absorbed by a given volume of liquid is proportional to the pressure in the atmosphere that the gas exerts.

$$c = K \times p$$

c = Concentration of the gas that is absorbed

K = Solubility factor

p = Partial pressure of the gas

Altitude may affect the p value of the equation. Higher altitudes decrease the solubility of gases in water. Temperature also has an affect, as temperature rises, solubility decreases. Salinity, the occurrence of various minerals in solution, also lowers the solubility of gases in water.

The method used to determine the amount of dissolved oxygen in the water is the Winkler titrametric method. It involves a series of chemical reactions which ends with a quantity of free iodine equal to the amount of oxygen in the sample. The iodine is then titrated with thiosulfate to find this quantity.

Hypothesis

The temperature and amount of light an aquatic environment receives greatly affects the dissolved oxygen levels, along with the amount of primary aquatic productivity.

Materials

Measurement of Dissolved Oxygen

This part of the lab required a sample bottle of water from a natural source, a BOD bottle, thermometer, mangonous sulfate, alkaline iodide, thiosulfate, a 2-mL pipette, sulfuric acid, a 20-mL sample cup, a white piece of paper, starch solution, and a nomograph.

Measurement of Primary Productivity

Part B required a sample bottle of water from a natural source, 7 BOD bottles, aluminum foil, 17 cloth screens, rubber bands, a light, thermometer, concavity slides, light microscope, mangonous sulfate, alkaline iodide, thiosulfate, a 2-mL pipette, sulfuric acid, a 20-mL sample cup, a white piece of paper, starch solution, and a nomograph.

Productivity Simulation

This section required pencil, paper, calculator, and graph paper.

Methods

Measurement of Dissolved Oxygen

The sample bottle was filled completely so that there were no air bubbles in the bottle. The sample bottle was left in the refrigerator until it reached 5° C. A BOD bottle was filled with the sample water until it contained no air bubbles.

Eight drops of mangonous sulfate were added to the bottle. Next, eight drops of alkaline iodide was added and the precipitate manganous hydroxide was formed. The bottle was inverted several times and then allowed to settle until the precipitate was below the shoulders of the bottle. While the solution was settling, a 2mL pipette was filled with thiosulfate. A scoop of sulfuric acid was added, and the bottle was inverted until all of the precipitate dissolved. The sample turned a clear yellow.

20mL of the sample were poured into the sample cup. The cup was placed on a white sheet of paper so that the color changes could be observed. 8 drops of starch solution were added to the sample, making it turn purple. The sample was then titrated with the thiosulfate. One drop of the titrant was added at a time until the color changed to a pale yellow color.

A nomograph was used to determine the percent saturation of dissolved oxygen in the sample.

Measurement of Primary Productivity

A second sample bottle was filled from a natural source making sure there were no air bubbles. Seven BOD bottles were filled completely with the sample with no air bubbles. The first bottle was labeled #1-Initial. The second bottle served as the dark bottle and was labeled #2-Dark. The other five bottles were labeled according to the light intensity: #3-100%, #4-65%, #5-25%, #6-10%, and #7-2%.

Bottle #2 was wrapped completely in aluminum foil so that it received no light. The other five bottles were wrapped in screens to produce the desired light intensity. Bottle #3 had no screens, bottle #4 had 1 screen, bottle #5 had 3 screens, bottle #6 had 5 screens, and bottle #7 had 8 screens. The screens were held in place with rubber bands. Bottles #2-7 were placed under a light source and left overnight.

Bottle #1 was fixed by following the Winkler method. Eight drops of mangonous sulfate were added to the bottle. Next, eight drops of alkaline iodide was added and the precipitate manganous hydroxide was formed. The bottle was inverted several times and then allowed to settle until the precipitate was below the shoulders of the bottle. A scoop of sulfuric acid was added, and the bottle was inverted until all of the precipitate dissolved. The sample turned a clear yellow. It was left at room temperature until the other samples were processed.

A wet mount was observed under a light source, so that the different organisms present could be identified.

The next day, bottles #2-7 were fixed by following the same method used on Bottle #1. The dissolved oxygen levels were determined in each of the seven bottles by titrating. 20mL of the sample were poured into the sample cup. The cup was placed on a white sheet of paper so that the color changes could be observed. 8 drops of starch solution were added to the sample, making it turn purple. The sample was then titrated with the thiosulfate. One drop of the titrant was added at a time until the color changed to a pale yellow color.

Productivity Simulation

The respiration data from Part B was converted to carbon productivity. The data was graphed with comparison to water depths.

Results

A. Measurement of Dissolved Oxygen

Table 1

Dissolved Oxygen Concentration

Temperature	Dissolved Oxygen (mg/l)	% Dissolved Oxygen
5° C	2.0 mg/l	16%
21.5° C	1.28 mg/l	19%

How does temperature affect the solubility of oxygen in water?

As temperature goes up the solubility of oxygen in water goes down. They are inversely proportional.

How does salinity affect the solubility of oxygen in water?

The occurrence of various minerals in solution lowers the solubility of oxygen in water.

Would you expect to find a higher dissolved oxygen content in a body of water in winter or summer?

Oxygen levels would be higher in the winter because the solubility of oxygen in water is higher at lower temperatures.

List and discuss three factors that could influence the dissolved oxygen concentration of a body of water.

Temperature-As temperature goes up solubility goes down.

Pressure- As pressure decreases solubility decreases. Pressure is directly affected by altitude

Salinity-The occurrence of various minerals in solution lowers the solubility of oxygen in water.

Do you think it would be wise to stock a pond with game fish if it had a dissolved oxygen content of 3ppm? Why or why not?

It would not be wise to stock a pond with an oxygen level of 3ppm with game fish because their optimal levels range from 8 to 15ppm. A concentration of dissolved oxygen less than 4ppm is stressful to most forms of aquatic life.

B. Measurement of Primary Productivity

Respiration Rate = 4.6 ml O_2/l

Table 3

Gross and Net Productivity/ Respiration Rate

Percent Light	Dissolved Oxygen	Gross Productivity	Net Productivity	Gross Productivity (mg C/m^3)
Initial	9.2 ml O_2/l	*NA*	*NA*	*NA*
Dark	4.6 ml O_2/l	*NA*	*NA*	*NA*
100%	6.4 ml O_2/l	1.8 ml O_2/l	-2.8 ml O_2/hr	0.965 mg C/m^3
65%	3.8 ml O_2/l	-0.8 ml O_2/l	-5.4 ml O_2/hr	-0.429 mg C/m^3
25%	4.5 ml O_2/l	-0.1 ml O_2/l	-4.7 ml O_2/hr	-0.054 mg C/m^3
10%	3.7 ml O_2/l	-0.9 ml O_2/l	-5.5 ml O_2/hr	-0.482 mg C/m^3

2%	4.0 ml O_2/l	-0.6 ml O_2/l	-5.2 ml O_2/hr	-0.322 mg C/m^3

Were any of the samples light limited? Why?

Each sample was given a certain amount of light by the use of aluminum foil and screen. Bottle #2 received no light, because it was covered with aluminum foil. Bottles #3-7 had varying numbers of screen ranging from 100% to 2% light intensity.

Productivity Simulation

Based on your analysis, which lake is more productive?

Lake 2 would be more productive because there is more oxygen available in the lower layers than in Lake 1.

What is used as the basis for measuring primary productivity?

Primary productivity is measured by the amount of dissolved oxygen available in the water. This shows the amount of oxygen produced by photosynthesis and the amount used by respiration.

Error Analysis

The Part A experiment was affected mainly by human error and inexperience with the Winkler method. The sample may have been over exposed to the air or the temperature may have changed before the fixing procedure was finished.

The original Part B experiment performed was unsuccessful. There were substantially more decomposing bacteria than photosynthetic organisms in the water sample use. The initial dissolved oxygen level was only 0.84 causing the other samples to have little or no oxygen. The amount of oxygen was so low that it was unable to form the free iodine and could not be titrated. This left no quantifiable data to use in graphs and tables.

Discussion and Conclusion

Temperature is inversely proportional to the solubility of gases in water. As temperature rose the dissolved oxygen levels should have decreased. This was qualified in the data obtained from this experiment, as the 5° C water sample measured 2.0 mg/l and the 21.5° C sample measured 1.28 mg/l. The percent saturation showed that even though the 5° C sample contained more oxygen it was still less saturated than the 21.5° C sample.

Part B of the lab was used to measure dissolved oxygen concentration, gross and net productivity, and respiration rate of the water samples. It also demonstrated the effect of light and nutrients on photosynthesis. In aquatic environments oxygen production and oxygen usage must be balanced to prevent anoxia. In the original experiment this balance was interrupted by the limiting of light by screens and aluminum foil. The amount of respiration in all of the bottles exceeded the amount of photosynthesis occurring. This was due to the types of organisms present in the sample, which was mainly decomposing bacteria and protozoan. The experiment was correct in its methods however the data received was not quantifiable. This absence of sufficient oxygen in the water samples is an indicator of poor water quality, which may require further investigation. Excess pollution or dumping of wastes into the water sample is a suspected cause of the poor water quality.

The data used in this report shows that as more light was limited, there was less dissolved oxygen present in the water. This is caused because photosynthesis cannot occur without sufficient light.