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An Analysis of Dissolved Oxygen Levels as Related to Temperature, Turbulence, and Primary Productivity

ABSTRACT:
The purpose of this investigation was to affirm the existing scientific principles that dissolved oxygen in water varies inversely with temperature and directly with turbulence and primary production. These are principle which are visible in numerous scientific experiments, and help scientists in assessing and monitoring the health of ecosystems. The Winkler method was used to determine oxygen levels in three separate stages. One, to test temperature, involved buckets containing water of different temperatures, but experimental error meant that the results of this experiment were inconclusive. The test was also conducted on containers left in the light and dark respectively to see if primary production, through photosynthesis, increased oxygen levels but again results were mixed. Finally, water from turbulent parts of a stream and from still areas was tested. Here, the results stated that turbulence meant decreased oxygen in opposition to the hypothesis. Error was likely due to incorrect use of the Winkler method and equipment differences, as well as some flaws in the procedure itself. In the end, the procedures need to be revised and more carefully conducted for more useful findings.

Naomi Genuth
Block G

Relationship between Dissolved Oxygen and Turbulence, Primary Productivity, and Temperature

Abstract: *The amount of dissolved oxygen is a significant characteristic of aquatic communities, enabling organisms to perform cellular respiration and revealing the rate of primary production, which is the basis of the trophic structure. Turbulence, primary productivity, and temperature affect the amount of oxygen dissolved in water. The correlation between these three factors and dissolved oxygen was measured by the Winkler method, using samples of turbulent and still water from Bullough's Pond, the Light-Dark Bottle Method, and tap water of various temperatures from Newton North High School. Turbulence was expected to be directly related to the concentration of dissolved oxygen, and the results did show a slightly higher amount of oxygen in turbulent than in still water. The difference was so slight, however, that that experimental errors likely had affected the data. The primary productivity tests also produced erroneous results, with the initial measurements being unexpectedly higher than both the light and dark tanks, instead of there being an increase in the oxygen amounts of the light tank and a decrease in the concentrations of the dark. The hypothesis on the connection between temperature and dissolved oxygen was supported by the data: the calculations showed that they were indeed inversely related, with dissolved oxygen falling as the temperature rose.*

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10/1/08
Block: G

The Effects of Light, Turbulence, and Temperature on Dissolved Oxygen and Primary Productivity in Aquatic Environments

Introduction: The rate of primary production in an ecosystem is the rate at which the ecosystems producers, the organisms at the bottom level of the food chain, turn sunlight and non-organic compounds into organic compounds. Effectively, the rate of primary production is how much life an ecosystem can support with higher levels of production allowing for more life. Naturally, the rate of primary production of ecosystems and life under certain conditions is important for scientists to know as it provides the base for life in the ecosystem. One way that primary productivity can be measured is by testing water samples for the parts per million (ppm) of dissolved oxygen, a byproduct of primary production. An aquatic environment in which there is not much dissolved oxygen indicates that there is not much primary production while more dissolved oxygen would tend to indicate that there is more primary production present in the environment.

There are three main factors that were examined in this experiment that have an effect on the amount of dissolved oxygen present in an aquatic environment. The first factor is the temperature of the water. It is accepted that the colder water is, the more dissolved oxygen it can hold before becoming saturated so the hypothesis was that colder water would have more ppm of dissolved oxygen and the test was simply done to confirm this hypothesis. Another factor that can affect the amount of dissolved oxygen in an aquatic environment is the turbulence of the water. Because more turbulent water, it can be reasoned, traps more pockets of air than still water, the experiment was designed to test the hypothesis that more turbulent water will have a higher will have a higher dissolved oxygen count than its less turbulent counterpart. The third factor that can affect dissolved oxygen in an aquatic environment is light. This is the one factor that does not result from the properties of water itself but rather from primary production, the side effect of which is dissolved oxygen and so, two separate experiments were done. The first test was designed to determine the dissolved oxygen concentrations in Bullough's Pond under different lighting conditions. Because photosynthesis, the cause of primary production, only happens in the light, the second experiment was designed to test the hypothesis that water from the healthy Bullough's pond will have a positive net primary production. It is however, not unusual to have results that do not confirm this hypothesis. Richard C. Dugdale and James T. Wallace preformed a light and dark bottle experiment to determine the primary productivity of two lakes in Alaska at different depths. In their article, "They found that Light and Dark Bottle Experiments in Alaska," they found that their dark sample often had a higher dissolved oxygen count than their light bottle which does not support their hypothesis nor does it support the hypothesis of this experiment.

Results:

Table 1: Dissolved Oxygen of Still and Turbulent Water

Location of Water Sample	Still or Turbulent	Dissolved Oxygen (ppm)
Shallow water shaded by rushes on main pond	Still	8.6
Deeper water from a sunny area near dam	Still	9.6
Pool of shallow, slightly shadowed water	Still	8.2
Average Dissolved Oxygen Content in Still Samples		**8.8**
Shallow water shaded under a tree in small waterfall	Turbulent	9.1
Fast-moving water partly shaded by a tree	Turbulent	9.0
Below bridge, mostly shaded, manmade waterfall, rock layers in water, plant life on sides	Turbulent	9.8
Past bridge, in middle of stream just before a section of whitewater	Turbulent	7.8
Average Dissolved Oxygen Content in Turbulent Samples		**8.9**

Table 1 shows the dissolved oxygen levels measured by the researchers from F and G Blocks in still and turbulent samples. On average, the dissolved oxygen was 0.1 ppm greater in the turbulent samples than in the still ones.

Table 2:
Calculating Gross Primary Productivity (GPP) and Net Primary Productivity (NPP)

Light Tank		Dark Tank	
Temperature (Celsius)	Dissolved Oxygen (ppm)	Temperature (Celsius)	Dissolved Oxygen (ppm)
21.6	8.8	21	7.0
21	7.4	18	6.9
21	6.5	20	6.5
21	8.1		
21	6.0		
21	7.2		
21	8.8		

Initial Dissolved Oxygen: **9.0 ppm**

Average Dissolved Oxygen of Light Tank: **7.5 ppm**

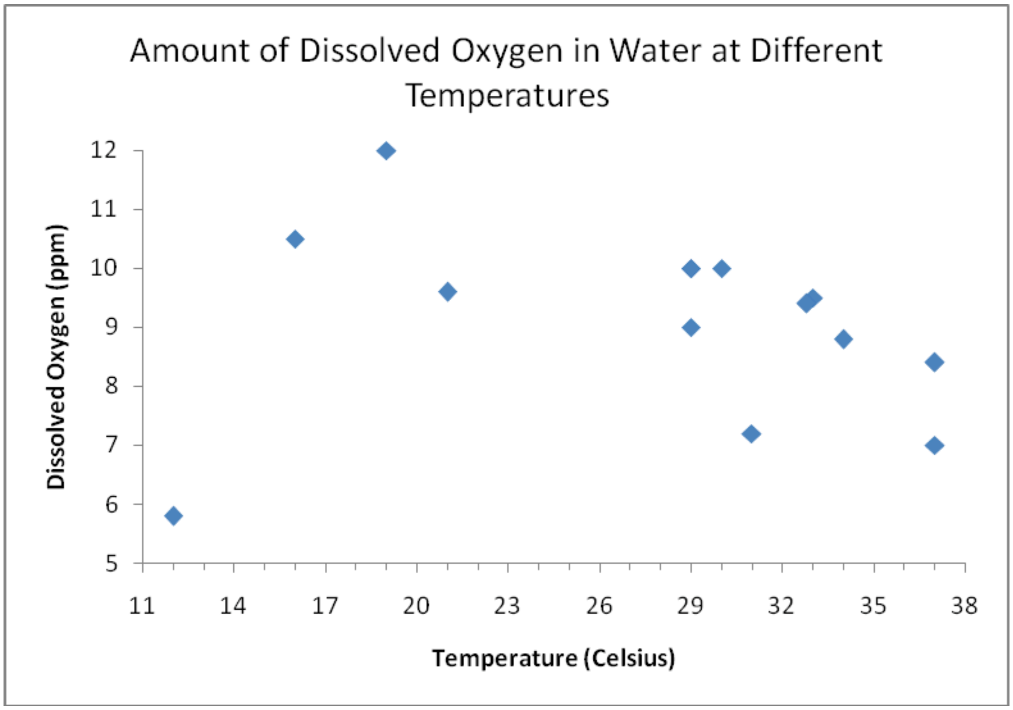
Average Dissolved Oxygen of Dark Tank: **6.8 ppm**

GPP=light DO – dark DO =0.7

NPP=light DO – initial DO = -1.5

In table 2, the tests conducted by F and G Blocks on the light and dark tanks to determine their dissolved oxygen compositions are charted. To the side of the chart are listed the initial measurements and the calculations used to determine primary productivity. The initial amount of dissolved oxygen was the greatest, followed by the light tank and then the dark tank, creating a net primary productivity of -1.5.

Figure 1:



The graph in figure 1 presents the results of the experiments comparing temperature to dissolved oxygen. Each blue diamond represents the results of one test performed by the researchers from F and G blocks. Dissolved oxygen generally appears to decrease with the rising temperature.

Discussion: From an initial look at the data collected, it seems that it does not fit the expected trends. However, knowledge can still be gleaned from the data and in some cases, it suggests more strongly that the hypothesis is correct than would be apparent at first glance. The most apparent theme of the data collected is that it is quite inconsistent, but most of this can be attributed to the short period of time that was available to perform the experiment and the unfamiliarity of the testing equipment to the experimenters.

The table of results for the first test (see table 1) and its corresponding graph (see figure 3) appear to agree with the hypothesis that an area of the pond with more exposure to sunlight will have a higher concentration of dissolved oxygen areas with less exposure to sunlight. The graph of the values represents this upwards trend with the highest concentration of dissolved oxygen present in an area with full exposure to sunlight, and the lowest concentration of dissolved oxygen in the area with the least exposure to sunlight and the medium levels of sunlight exposure have concentrations of dissolved oxygen that are in between. The plot points on the graph though do not correspond exactly with what the hypothesis would suggest of a constant upwards trend. Much of this could be attributed to the fact that the graph does not account for the temperature of the test sites nor does it account for the turbulence of the water although values of water described as being turbulent were not included in an attempt to not have to much variation in the level of turbulence of the water from included data points. Another probable cause of the inconsistencies with the hypothesized result is that the x axis for the graph of the data was measured in descriptions of the light conditions of the testing sites rather than numerical values for the present sunlight and if these values were available, the trend would be based on a more reliable graph. Were the experiment to be preformed again, it the experimenters would calculate the concentration of dissolved oxygen from each location multiple times to make sure that consistent and more precise data is found, but more importantly, all of the water samples would be taken from water of the same temperature or the concentration of dissolved oxygen values would be corrected to take into account temperature such as calculating the percentage of saturation of dissolved oxygen as well as the percentage of sunlight reaching each area would be determined so that the amount of sunlight reaching each test site would be quantifiable.

The results for the second test (see table 2) seem to go directly against the hypothesis that the water in the Bullough's pond aquatic ecosystem has a positive rate of primary production. This could suggest that the hypothesis needs to be rethought and that the rate of net primary production in the pond is in fact negative and that there is therefore no life growing in the pond. However, it would make far more sense given the visible growth and life in the pond that this data was simply the result of a poorly planned experiment. The first apparent error in the data is that the value for initial concentration of dissolved oxygen from the test site that was incubated in the two containers is not only greater than the value for concentration of dissolved oxygen in the dark container, but also greater than that of the light container which figure two would indicate is not an expected result. There are two probable causes for this elevated value of the initial concentration of dissolved oxygen. The first is that the initial value was tested for and gotten for water that was sitting out in the sunlight of the day until the afternoon when it was collected by the experimenters. It is possible that the real sunlight caused more photosynthesis and a higher concentration of dissolved oxygen than the artificial light did even over night. Another factor that probably contributed to the high initial concentration of dissolved oxygen was that the water was carried all the way back from Bullough's pond and then poured into its incubation containers before it was tested for its initial dissolved oxygen. This turbulence probably caused the high initial concentration of dissolved oxygen. To correct for this error in experimental design, the experimenters should have tested the initial concentration of dissolved oxygen at the pond so that the turbulence did not effect the result and this probably would have created and initial value in between the lithe and dark values after incubation. This adjustment to the experiment would have created more trustworthy results and probably would have caused the data to indicate that the initial hypothesis was correct.

In the third experiment, a first look at the table (table 3) and graph (figure 4) does not seem to indicate that any trends are present. However, looking at the plot for all of the values except for the one with a temperature of 12 degrees Celsius, the graph begins to make more sense. It shows a downward trend and that there is in fact and inverse relationship between the temperature of water and the concentration of dissolved oxygen that is also represented in figure 1. All of the data collected in this experiment seems to agree with and support the hypothesis except for this one bit of data that completely skews the results of the experiment. It is probable that this one bit of data that does not fit with the rest came about because of the inexperience of the experimenters in using the Winkler method of testing the concentration of dissolved oxygen. A result of this nature probably is because the experimenter testing this sample of water was impatient when titrating the fixed oxygen and determined that the titration was finished before the solution had become entirely clear resulting in the lower than expected concentration of dissolved oxygen. Especially considering that the rest of the data indicates that the hypothesis is correct, it seems that this one anomaly is the cause of some sort of error in the execution of the Winkler method. To prevent, or at least remedy this sort of problem, the experimenters should in the future test each sample multiple times to determine if the results are consistent or if the results are inaccurate.