The Effect of Increased Temperatures and Ultraviolet Radiation on Dissolved Oxygen in Ecosystems Primarily Comprised of *Euglena*

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Abstract

The purpose of this study was to determine whether increased levels of UV radiation and temperatures from global warming have a significant impact on dissolved oxygen (DO) output from the alga, *Euglena*, which affects other organisms in the ecosystem. The original hypothesis stated that if temperature was increased along with exposure time to radiation, DO would decrease. The hypothesis that increased temperatures affected DO was supported. However, the minor differences due to radiation were insignificant.

Introduction

People need to be prepared in the event of a climate change to the extent of global warming. This project is centered on three main concepts: global warming, UV radiation, and *Euglena*, which all impact DO. Global warming has become a major issue over the past few years with the release of data suggesting our actions will not only affect our descendants, but the consequences will also manifest in our lifetime. Greenhouse gases are chemical compounds that allow sunlight to pass into the atmosphere and trap heat as it is reradiated (as infrared) back into the atmosphere. The amount of heat absorbed by these gases should keep the global temperature relatively constant, but an augmentation of these gases is known to trap more heat in the atmosphere and result in elevated temperatures (National Energy Information Center, 2004). Greenhouse gases occur naturally, as in animal respiration, or from burning fossil fuels and other industrial processes (National Energy Information Center, 2004), (NASA, ND.) As coal and other fossil fuels are burned for energy, the amount of carbon dioxide, chlorofluorocarbons and other ozone depleting substances (ODS) emitted into the atmosphere rapidly increases. These compounds become unstable and break apart. The resulting new atoms break down the ozone. Therefore an increased amount of these gases in the atmosphere accelerates depletion beyond creation, resulting in less ozone, and increased penetration of harmful UV rays (US EPA 2007b).

Aerosols are solids or liquids suspended in a gas. The higher their density in the atmosphere, the better they reflect sunlight back into space. This keeps sunlight from reaching the earth and results in lower ambient temperatures (NASA, ND). Additionally, aerosols also act like greenhouse gases trapping heat already present in the earth's atmosphere, as the cycle of outward heat radiation back to the sun is blocked (NASA, ND.) It is estimated that 3.2 billion tons of extra carbon dioxide released yearly is unable to be conserved by the carbon cycle, causing a rise in the percentage of greenhouse gases. Aerosol particles can affect weather by changing cloud properties. A high concentration of aerosol particles in a cloud causes water molecules to spread out with increased surface area of the cloud. Additionally, these water molecules decrease in size, and decrease annual precipitation according to NASA. Since greenhouse gases remain in the atmosphere for multiple years, there is uncertainty as to the effects of global warming. However, government agencies such as the Environmental Protection Agency (EPA) affirm that global warming is an imminent threat and they estimate temperatures may rise between 1.1°C and 6.4°C by the end of the century (US EPA, 2007a.)

There are three types of UV radiation: UVA (320-400nm), UVB (280-320nm) and UVC (100-280nm) (NASA, ND); the shorter the wavelength of radiation, the higher the potential for harm (NASA 2001). The effects of UVC on humans are unknown, as UVC has not yet reached the Earth's surface. However, UVB radiation is a known cause

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of skin cancer (US EPA. 2007b). It is possible that UVC radiation may eventually affect humans, as it is currently blocked by the degrading ozone. The radiation used in this study was in the UVC radiation range (254nm), not too far removed from UVB (280-320nm). UVB radiation heavily impacts nutrient cycles, and can accelerate the decomposition of colored dissolved organic matter (CDOM). CDOM ideally protects the aquatic ecosystem by reducing the penetration of short wavelength radiation such as UVB and UVC. However, too much radiation can cause CDOM decomposition rates to increase. This allows harmful UV rays to penetrate deeper into the water, resulting in altered nutrient cycles, death of organisms and a depletion of essential minerals (Zepp, R.G. et al. 2007). If the availability of certain minerals is reduced, organisms do not grow as well and the ecosystem becomes unhealthy. Plants can not conduct photosynthesis normally without needed minerals, which results in a decrease in DO (Zepp, R.G. et al. 2003). Decreased DO exacerbates the bleak situation by causing organisms to run out of oxygen. Eventually, DO levels would drop below 5mg/L, the minimum safe standard for certain fish species, resulting in death (University of Florida, 2003.)

Euglena is a unicellular alga. It grows primarily in fresh water (University of Maryland, 1998). A light sensitive eyespot on its anterior draws it towards light, facilitating photosynthesis (University of Cincinnati, Claremont College, 1997). *Euglena* is a model organism as it reproduces asexually, quickly dividing into two new cells at a time (University of Maryland, 1998). It is for this reason that *Euglena* is often used to study the effects of radiation on eukaryotes. *Euglena* is known to grow in nutrient rich environments, and grow well in warm conditions (Constantopoulos, G. and Bloch, K., 1967), (University of Maryland, 1998). Because *Euglena* photosynthesize, they are a major producer of DO for other aquatic organisms, as terrestrial oxygen must diffuse into the water before it is accessible (Zepp, et al. 2007), (University of Florida, 2007).

DO is an important indicator of water quality in ecosystems because all organisms take part in either its production or its consumption (State of Kentucky, 2007). DO is produced from two main sources, photosynthesis of aquatic plants and oxygen diffusing into the water from the atmosphere. Most DO is produced from photosynthesis. It is known, that as temperatures increase, DO decreases. At higher temperatures photosynthesis increases in plants. However, organisms are also more active, and need more oxygen than normal, which is not available to them. The solubility of oxygen in water decreases as water temperatures rise (Senese 2007). It is also known that DO changes during the day, peaking at dusk and decreasing until dawn (University of Florida, 2003). DO in a healthy ecosystem should constantly remain above 5mg/L; any amount less and the ecosystem becomes stressed. If readings remain below 5mg/L for an extended period of time, large scale fish kills are possible. Conversely, too much DO is harmful, causing oxygen related diseases among fish in waters with concentrations above 100-110 % (State of Kentucky, 2007).

Because UV radiation and greenhouse gases can alter nutrient cycles that are directly involved in photosynthesis, it is probable that exposure to UV radiation will impact DO as a result of interrupted photosynthesis (Zepp, et al. 2007). But, how big will the impact be?

Materials and Methods

Six 400mL beakers were filled with 400ml of spring water. As water evaporated from the beakers and dropped below 300mL, all beakers were refilled in order to keep water levels at comparable ranges between groups. The *Euglena* was then separated equally into the beakers. Samples were separated into two temperature groups; one at 23°C and the other incubated at 28°C (the predicted temperature difference over the next century (US EPA. 2007a)). One sample from each temperature functioned as the control, and was not exposed to radiation. The remaining two beakers were exposed to UVC radiation at an intensity of 0.6W/m? once a week via an UV radiation lamp. A low dose radiation group was exposed for 24 minutes and 20 seconds, while a high dose radiation group was exposed for 48 minutes and 40 seconds. DO readings (mg/L) were recorded daily using a HACH Sension 156 portable multi-parameter water meter post radiation. *Euglena* was exposed (weekly) to UVC radiation (254nm) a total of four times.

Results and Conclusions

All statistical tests were performed on DO data collected after Day 11, as a fluke DO reading generated a statistical outlier before Day 11 (Figure 1).

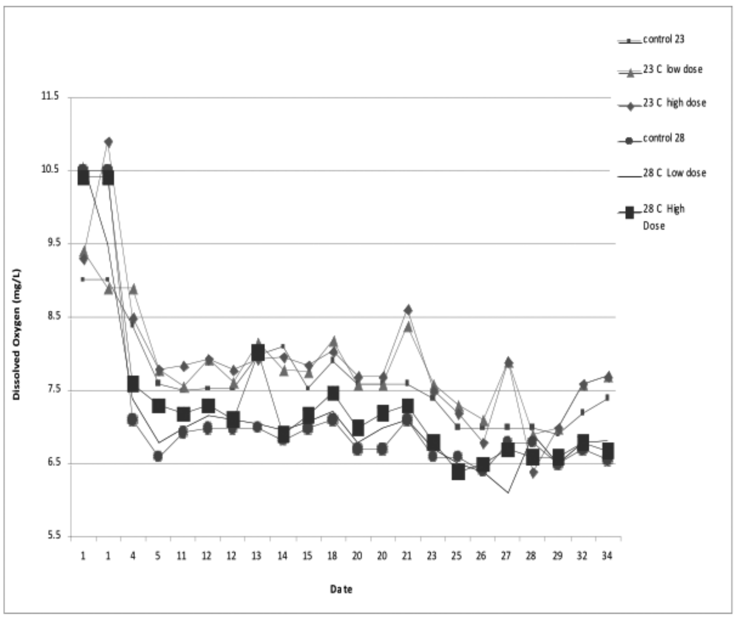

Figure 1. Dissolved oxygen levels per day in aquatic ecosystems containing *Euglena*.

A two sample t-test compared the means of DO data collected from groups grown at 23°C and 28°C, regardless of dosage. A significant difference between *Euglena* grown at these two temperatures ($p \approx 5.20E\text{-}16$. $\alpha = 0.05$) was shown.

Two, one way ANOVAs were performed to compare the difference between the DO from the radiation at each temperature. At 23°C there was not a significant difference observed between the means of DO from *Euglena* exposed to radiation at any dosage ($p \approx 0.23$ $\alpha = 0.05$.) At 28°C the same was true ($p \approx 0.17$, $\alpha = 0.05$).

The original hypothesis stated that if temperature and exposure to UV radiation dosage was increased, then DO production by *Euglena* would decrease significantly. The results of this experiment support that temperature has a significant effect on DO levels produced, while increased radiation dosage does not. The results of this experiment agree with University of Florida findings which show, that as temperature increases, DO decreases (University of Florida. 2003)(Senese 2007). Unexpectedly, increased radiation dosage did not have an effect on the CDOM which should have limited the nutrients available for photosynthesis (Zepp, Erickson, Paul, and Shulzberger, 2007). Preliminary (unpublished) studies by researchers in this field show that decomposition of *Euglena* does not result from UVC radiation. However, if another green algae was present then UVC radiation could have possibly had an effect on resultant DO.

In the future, other types of alga or plankton should be studied to see what the effects of UV radiation are on an aquatic environment especially with regard to humanity's increased concerns associated with global warming.

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